# CHAPTER 2

## WATERSHED DESCRIPTION

### 2.1 Location and Setting

Bear Creek watershed lies on the east side of the North Coast Range at the interface with the west side of the Sacramento River Valley, in northern California. The watershed encompasses 102.9 square miles (266.4 $km^2$) between 38º 55' 35" N and 39º 15' 43" N latitude and between 122º 19' 1" W and 122º 35' 42" W longitude. It is elongated 23 miles in a NNW to SSE direction, parallel to the regional orientation of the Coast Range and major geological faults in the area. At its widest point, the watershed extends 9.5 miles east to west.

***Geopolitical Setting***

The watershed lies entirely within Colusa County and comprises the southwest corner of Colusa County at its border with Lake County. By area, it occupies 8.9 percent of the County. Colusa County has a dominant rural character and is not part of a metropolitan or micropolitan statistical area as defined by the Federal Office of Management and Budget (OMB) (US Census Bureau 2009).

The City of Colusa, the county seat of Colusa County, is 23 air miles east of the watershed. The City of Williams along Interstate Highway 5 in Colusa County is 15 air miles east, and the City of Clearlake, in Lake County to the west, is also 15 air miles away. The postal zip code for Williams (95987) covers residents' street addresses in Bear Creek watershed.

The closest large urban areas are Yuba City (Sutter County), 40 air miles to the east, and Sacramento (Sacramento County), 56 air miles to the southeast. Clearlake (Lake County), a Federal OMB micropolitan area 25 miles west, is the closest small-scale urban area to Bear Creek watershed.

The watershed is part of California District 2 in the U.S. House of Representatives. Assembly District 2 and Senate District 4 cover the watershed area in the California state legislature. At the county level, County Supervisor District IV includes the entire watershed.

Figure 2.1 shows the watershed location in relation to Colusa, Lake, and Yolo counties.

***Watershed Location***

Bear Creek watershed is part of the California Water Resource Region, defined as the drainage area that ultimately discharges into the Pacific Ocean through the State of

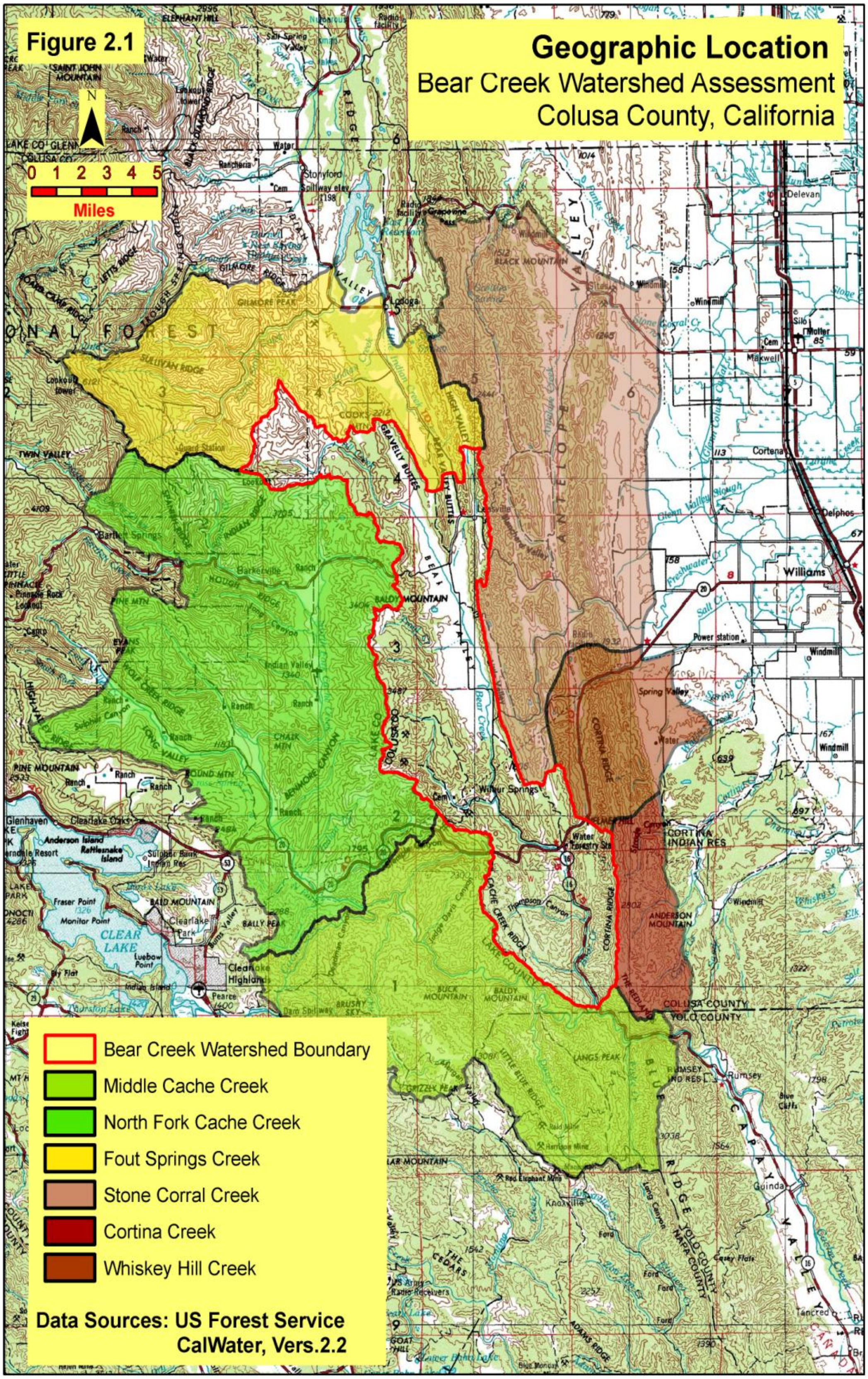


Figure 2.1
Geographic Location
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3 4 5
Miles
Bear Creek Watershed Boundary
Middle Cache Creek
North Fork Cache Creek
Fout Springs Creek
Stone Corral Creek
Cortina Creek
Whiskey Hill Creek
Data Sources: US Forest Service
CalWater, Vers.2.2

California. It is one of the 88 watersheds that lie within the Sacramento River Hydrologic Region as defined by the California Department of Water Resources for the California Water Plan (California Department of Water Resources 2005).

Water originating from Bear Creek watershed flows to the Pacific Ocean, passing through Cache Creek, the Sacramento River, the Sacramento-San Joaquin Delta, and San Francisco Bay. Although its drainage area into the Delta and the Bay is comparatively small (Figure 2.2), water from Bear Creek contains high amounts of mercury that significantly impact water quality and biological integrity of the Delta and Bay ecosystems.

Table 2.1 - Hierarchical context of Bear Creek watershed

| DWR Administrative Unit | Unit Name | Area (square miles) |
|---|---|---|
| Hydrologic Area | Bear Creek Watershed | 103 |
| Hydologic Basin | Upper Cache Creek Basin + Lower Cache Creek | 1,666 |
| Hydrologic Subregion | Sacramento River | 27,245 |
| -- | Sacramento / San Joaquin Delta Drainage | 42,509 |
| -- | San Francisco Bay Drainage | 47,032 |
| Water Resource Region | California | 256,931 |

Sources: Seaber et al. (1987), Interagency, CalWater, Version 2.2.1 (2004), USDA Natural Resource Conservation Service (2008)

Table 2.2 – Watersheds and basins in the vicinity of Bear Creek watershed

| Watershed (Hydrologic Area) | Basin (Hydrologic Unit) |
|---|---|
| Bear Creek | Cache Creek |
| Middle Cache Creek | |
| North Fork Cache Creek | |
| Cortina Creek | Cortina Creek |
| Whisky Hill | |
| Stone Corral Creek | |
| Fouts Springs | Stony Creek |

Six other watersheds surround Bear Creek watershed, all of which also drain to the Sacramento River Hydrological Region. Two of these watersheds are part of the Cache Creek Hydrologic Unit: Middle Cache Creek to the south and North Fork Cache Creek directly west of the watershed. Bear Creek flows into Middle Cache Creek near the point where the boundaries of Colusa, Lake, and Yolo counties meet.

***Ecological Setting***

The USDA Forest Service has divided California into ecological subsections based on similarities of climate, geology, topography, soils, vegetation, and wildlife (Miles and

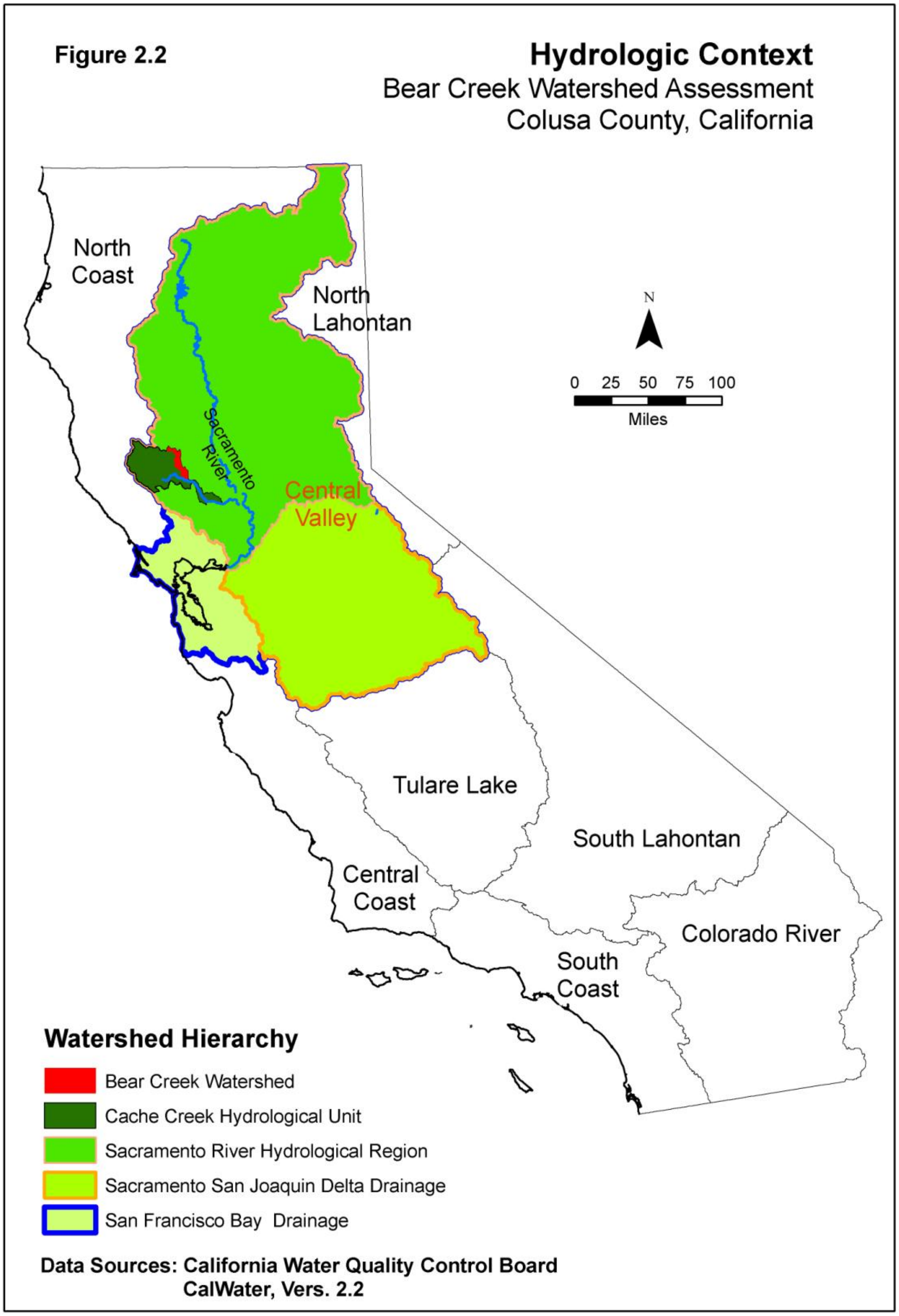


Figure 2.2
Hydrologic Context
Bear Creek Watershed Assessment
Colusa County, California
North Coast
North Lahontan
Sacramento River
Central Valley
Tulare Lake
South Lahontan
Central Coast
Colorado River
South Coast
N
0 25 50 75 100
Miles
Watershed Hierarchy
Bear Creek Watershed
Cache Creek Hydrological Unit
Sacramento River Hydrological Region
Sacramento San Joaquin Delta Drainage
San Francisco Bay Drainage
Data Sources: California Water Quality Control Board
CalWater, Vers. 2.2

Goudey 1997). Three subsections occur in the watershed and contribute to a landscape of notable diversity over the watershed area. Following are brief descriptions of the subsections, and Figure 2.3 displays the distribution of subsections in the watershed.

*Eastern Franciscan (Subsection M261Ba)*

The Eastern Franciscan Subsection comprises the smallest area of the three ecological subsections in the watershed, occupying only the highest elevations of the western and northwestern edges of the watershed, which are also the coolest and wettest areas. The terrain consists mostly of mountains bisected by narrow canyons. Landslides and stream erosion are common due to the unstable geology formations. Mixed conifer forests predominate and contrast distinctly with the chaparral vegetation to the east and south.

*Stony Creek Serpentine (Subsection M261Bc)*

Regionally, the Stony Creek Serpentine Subsection forms a narrow ecoregion typically underlain by ultramafic (high magnesium and iron) rock types. Stony Creek Serpentine lies between the Coast Range Thrust on the west and the Stony Creek Fault on the east, forming the eastern edge of the North Coast Range. Landslides and stream erosion are widespread because of the unstable terrain. Compared to the Eastern Franciscan Subsection, the climate is hotter and drier. Vegetation consists of conifers and evergreen shrubs tolerant of ultramafic soils or chaparral dominated by chamise (*Adenostoma fasciculatum*) on sites with non-ultramafic soils. The vegetation of Bear Valley, the lowest-elevation part of the Stony Creek Serpentine subsection, includes predominantly herbaceous wet meadow and prairie species, with mixtures of non-native and native grasses, annual and perennial forbs.

*Western Foothills (Subsection M261Ca)*

Watershed lands east of the Stony Creek fault belong to the Western Foothill subsection. They are notable for their contrast in topography, geology, soils, and vegetation from the Stony Creek Serpentine portions of the watershed. Soils are sedimentary in origin. The steep Western Foothills environments at the east margin of Bear Valley run roughly parallel to the Sacramento River Valley. Fluvial erosion occurs frequently. Blue oak (*Quercus douglasii*) woodlands predominate in this ecological subsection, with smaller areas of mixed-species and chamise chaparral.

The Stony Creek and Western Foothills are dominant in Bear Creek watershed, and the watershed constitutes a part of a NNW-to-SSE trending band 150 miles long by 17 miles wide spanning northwest Solano County to southeast Shasta County (Figure 2.4).

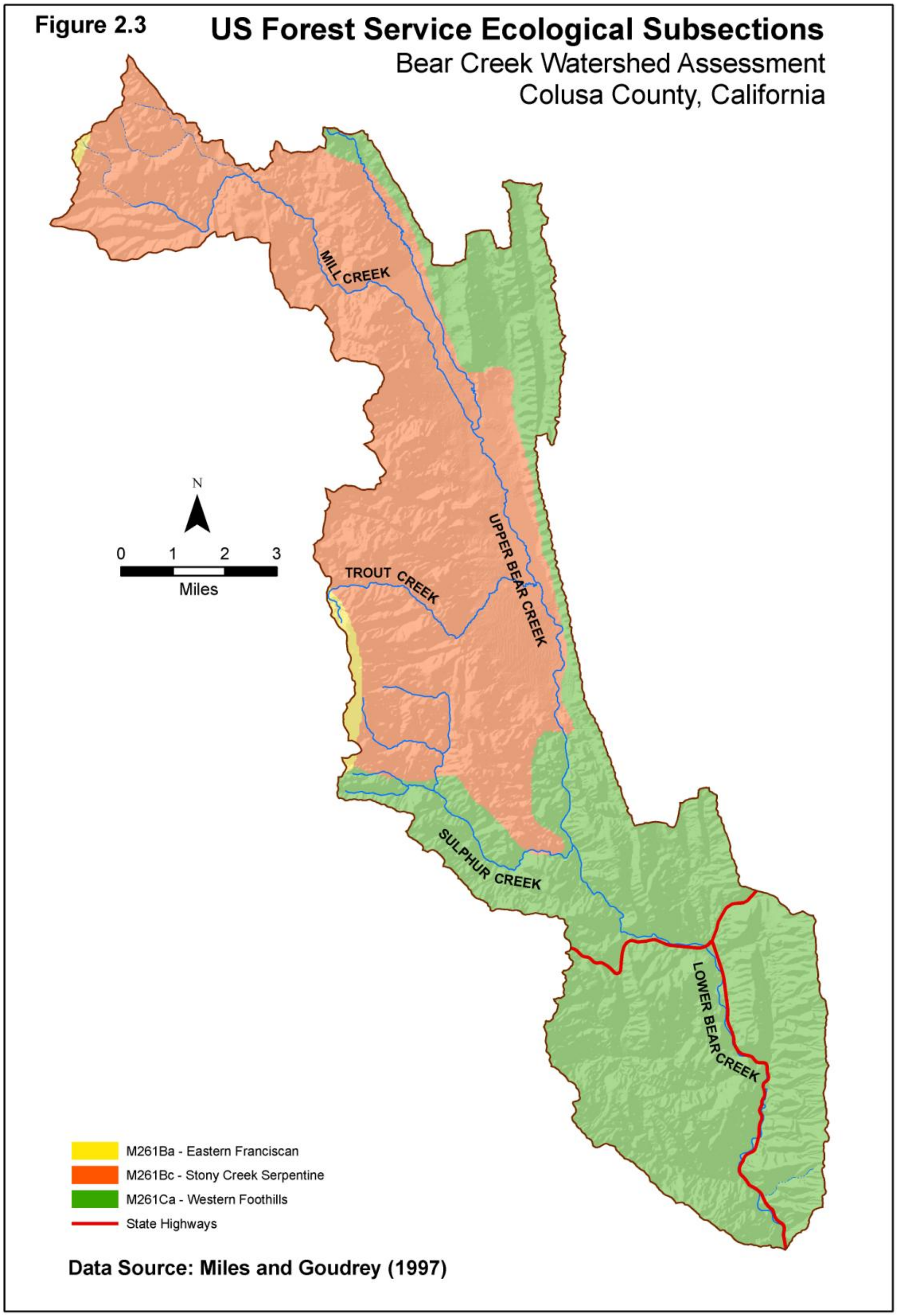


Figure 2.3
US Forest Service Ecological Subsections
Bear Creek Watershed Assessment
Colusa County, California
MILL CREEK
UPPER BEAR CREEK
TROUT CREEK
SULPHUR CREEK
LOWER BEAR CREEK
N
0 1 2 3
Miles
M261Ba - Eastern Franciscan
M261Bc - Stony Creek Serpentine
M261Ca - Western Foothills
State Highways
Data Source: Miles and Goudrey (1997)

## 2.2 Watershed Boundaries

Bear Creek watershed consists of the topographic area that drains surface water to Bear Creek. The watershed boundary delineation (Figure 2.1) comes from CalWater, Version 2.2.1 (2004).

The northwest and west boundaries of the watershed consist of a series of ridgelines from south to north: Cache Creek Ridge, County Line Ridge, Walker Ridge, Red Ridge, and Love Lady Ridge. These ridges separate Bear Valley from the main stem of Cache Creek on the southwest and Little Indian Valley (North Fork Cache Creek) to the west. The southern tip of the watershed is the confluence of Bear Creek with Middle Cache Creek. Cortina Ridge marks the southeastern boundary of the watershed. Cortina Ridge, Blue Ridge, and other unnamed ridges northward at the east boundary of Bear Valley constitute the westernmost edge in a series of north-south foothill chains extending to the Sacramento River Valley floor. In the north-central and northeast portions of the watershed, Gravelly Buttes, Bear Valley Buttes, and low rolling hills separate Bear Creek watershed from Fout Springs Creek watershed.

### *Subwatersheds of Bear Creek Watershed*

Subwatershed delineations are useful for planning watershed improvements as they are logical management units for evaluating ecological conditions and water quality issues. Table 2.3 gives acreages and geographic descriptions for each subwatershed delineated by Jack Alderson, USDA Natural Resource Conservation Service (NRCS). Chapter 7 expands on the watershed issues present in each subwatershed.

## 2.3 Topography

Love Lady Ridge, at the northwest watershed boundary, contains the highest elevations in the watershed. East of Walker Ridge and Love Lady Ridge on the west boundary, the otherwise steep terrain gives way to several bench terraces, including Davis Flat, Robbers Flat, Deadshot Flat, and Malaney Flat, before sloping steeply again to the floor of Bear Valley. From Sulphur Creek subwatershed south, mid-elevation bench terraces are absent and a highly dissected canyon landscape characterizes the watershed west of Bear Creek.

In the southeast, low-elevation but steep canyons roughly perpendicular to Cortina Ridge and Blue Ridge open into lower Bear Creek. The series of uniform low and rounded foothills at the eastern boundary makes a striking visual contrast to the steep westside slopes. Leesville Gap in the northeast breaks the chain of eastern hills to permit drainage from Long Valley westward into Bear Valley.

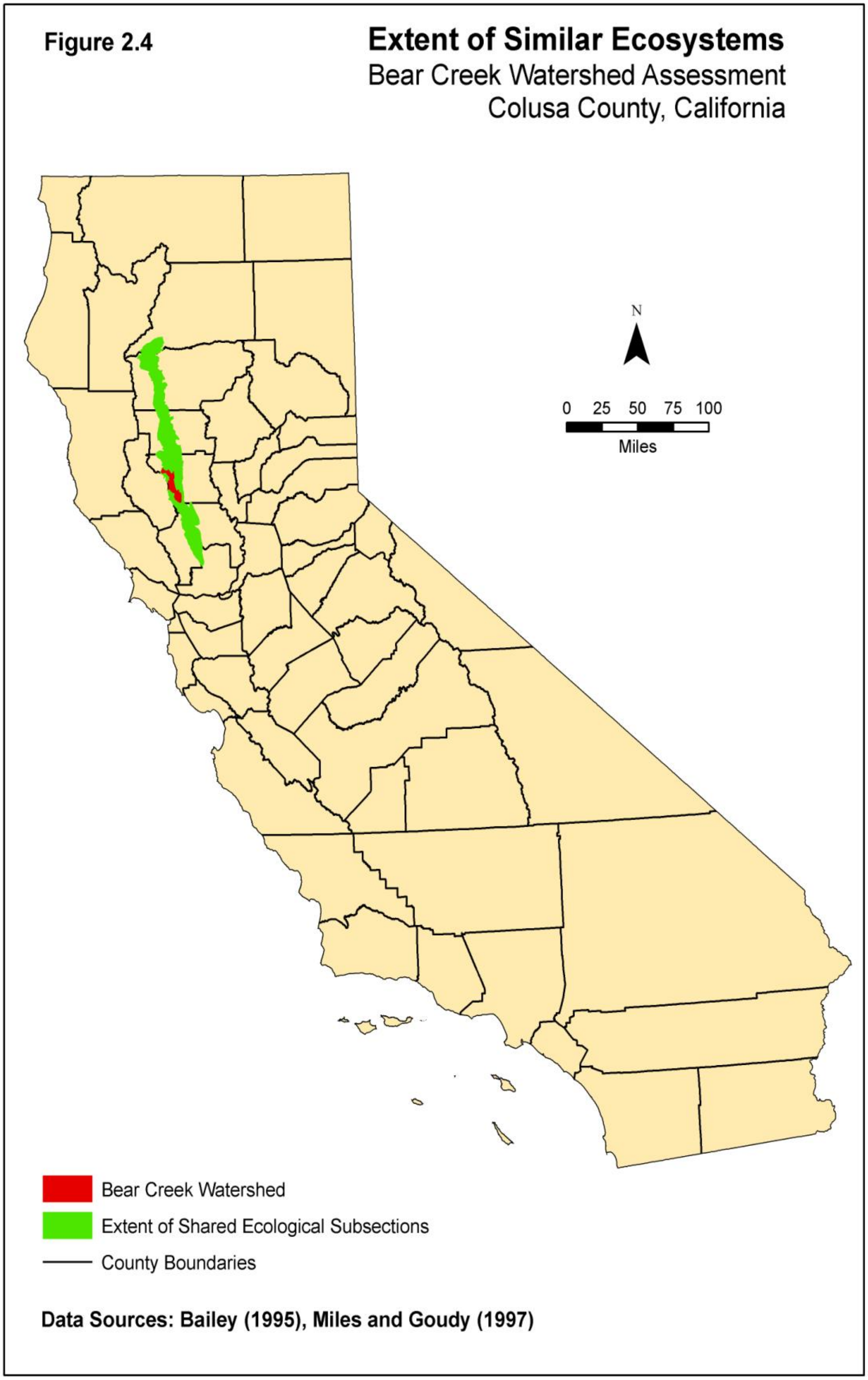


Figure 2.4
Extent of Similar Ecosystems
Bear Creek Watershed Assessment
Colusa County, California
N
0 25 50 75 100
Miles
Bear Creek Watershed
Extent of Shared Ecological Subsections
County Boundaries
Data Sources: Bailey (1995), Miles and Goudy (1997)

Table 2.3 – Subwatersheds of Bear Creek watershed

| Subwatershed | Acres | Description |
|---|---|---|
| **Upper Bear Creek** | | |
| Bear Creek Upper Stem | 14,526 | Overland flow drainage area directly to the main stem of Bear Creek north of the south end of Bear Valley |
| Deadshot Canyon | 684 | Drainage east from Walker Ridge through Deadshot Canyon to Bear Valley |
| Doyle Canyon | 946 | Drainage east from north end of Walker Ridge and Grapevine Flat to Bear Valley |
| Gaither Canyon | 1,676 | Drainage directly south from Doyle Canyon, flowing east to Bear Valley |
| Leesville | 1,997 | NE corner of the watershed flowing north and then west into Bear Valley |
| Mill Creek | 10,646 | NW corner of the watershed flowing SE to Bear Valley |
| Robbers Flat | 824 | Drainage east to Bear Valley |
| Stinchfield Canyon | 461 | Drainage south of Robbers Flat east into Bear Valley |
| Trout Creek | 2,342 | Drainage from Walker Ridge and Cold Spring Mountain east to Bear Valley |
| **Lower Bear Creek** | | |
| Bear Creek Lower Stem | 8,627 | Drainage area directly to the main stem of Bear Creek south of the south end of Bear Valley |
| Brophy Canyon | 2,168 | Most southerly subwatershed on west side of Bear Creek |
| Craig Canyon | 737 | SE flowing drainage just north of Thompson Canyon |
| Eula Canyon | 254 | SE flowing just north of and parallel to Craig Canyon |
| Hamilton | 2,932 | SW drainage to Bear Creek |
| Hamilton Canyon | 799 | Drainage NW from Blue Ridge into Bear Creek east of Coyote Peak |
| Holsten Canyon | 409 | Small west-flowing drainage from Cortina Ridge |
| Holsten Chimney Canyon | 323 | Small west-flowing drainage from Cortina Ridge |
| Jackson Canyon | 1,112 | Small west-flowing drainage from Cortina Ridge |
| Lawson Canyon | 210 | Small west-flowing drainage from Cortina Ridge |
| Lynch Canyon | 480 | North flowing drainage to Bear Creek |
| Olgert Canyon | 457 | Most southerly subwatershed on east side of Bear Creek |
| Shale Spring Flat | 295 | Small west-flowing drainage from Cortina Ridge |
| South Jackson Canyon | 1,219 | Small west-flowing drainage from Cortina Ridge |
| Sulphur Creek | 6,525 | Drainage SE from County Line and Walker ridges to Bear Creek |
| Thompson Canyon | 3,999 | Largest drainage below Sulphur Creek, flowing east to Bear Creek |
| Warnick Canyon | 278 | Small south-flowing drainage to Bear Creek from Blue Ridge |

Source: Jack Alderson, USDA Natural Resource Conservation Service, Colusa, CA, 2008

At the north edge of the watershed, large boulder outcrops form the Bear Valley and Gravelly buttes that reflect the abrupt contrasts with geology in the landscape at the interface between the North Coast Range and the Central Valley. At the southern end of Bear Valley Buttes, two smaller valley forks converge to create Bear Valley. At its widest extent, Bear Valley is slightly more than two miles wide. The gentle Bear Valley terrain comprises the heart of the upper watershed and provides the largest drainage area for Bear Creek. Canyons on the west side of Bear Valley empty into prominent alluvial fans on the Valley floor.

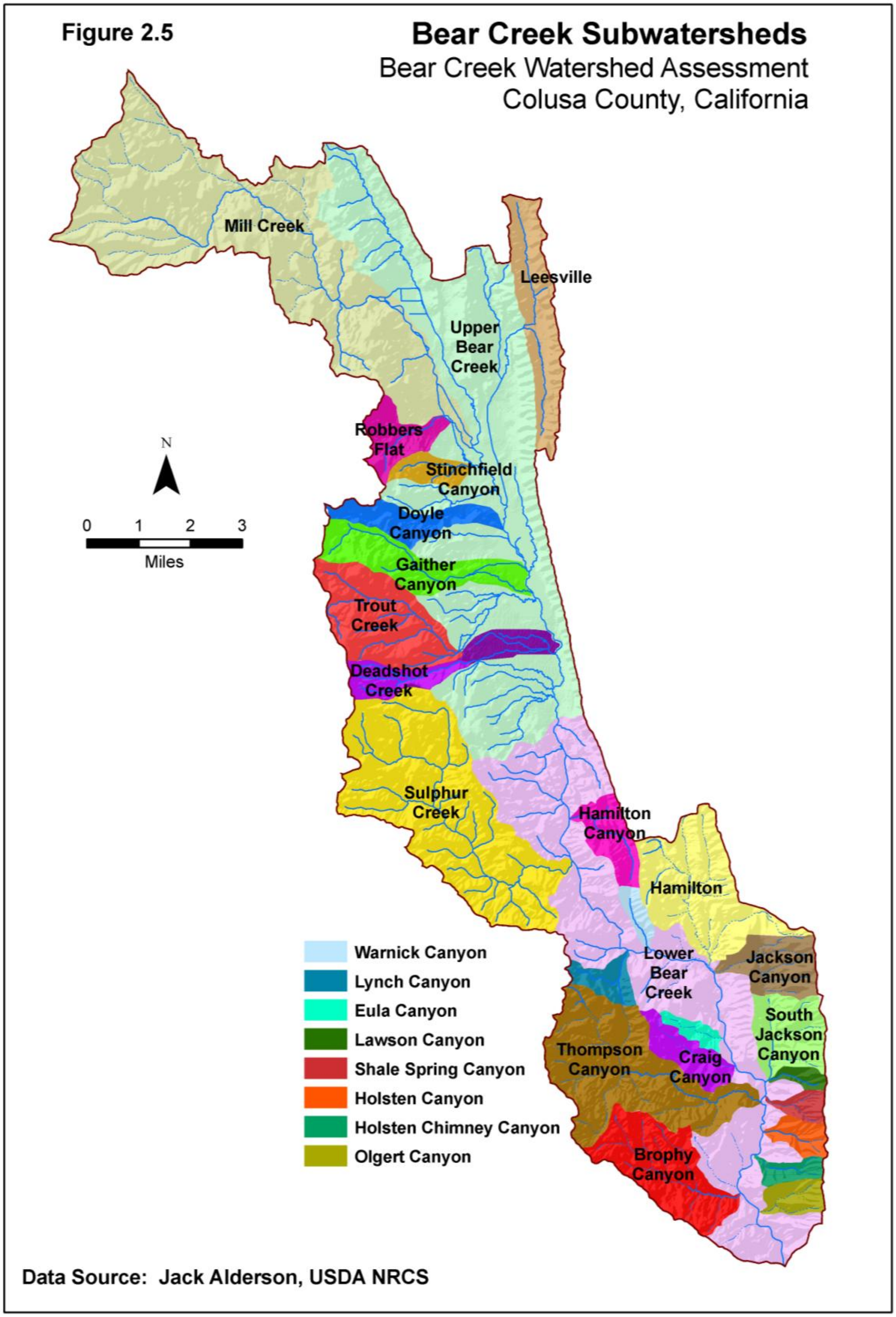


Figure 2.5
Bear Creek Subwatersheds
Bear Creek Watershed Assessment
Colusa County, California
Mill Creek
Leesville
Upper Bear Creek
Robbers Flat
Stinchfield Canyon
Doyle Canyon
Gaither Canyon
Trout Creek
Deadshot Creek
Sulphur Creek
Hamilton Canyon
Hamilton
Lower Bear Creek
Jackson Canyon
South Jackson Canyon
Thompson Canyon
Craig Canyon
Brophy Canyon
N
0 1 2 3
Miles
Warnick Canyon
Lynch Canyon
Eula Canyon
Lawson Canyon
Shale Spring Canyon
Holsten Canyon
Holsten Chimney Canyon
Olgert Canyon
Data Source: Jack Alderson, USDA NRCS

Below Bear Valley, narrow canyons extend about five miles. Then, below the intersection with Sulphur Creek Valley, a broad 2.5-mile long flood plain opens. The flood plain closes and Bear Creek courses through the complex hill and canyon landscape along Highway 16 before Bear Creek empties into the main stem of Cache Creek at the Colusa / Yolo county line.

### *Elevation*

Elevation above mean sea level within the watershed ranges from 635 ft at the confluence of Bear Creek with Cache Creek (39° 55’ 34.90”N, 122° 20’ 00.00”W) to 3,862 ft on Love Lady Ridge (39° 12’ 50.84”N, 122 35’ 50.90”N) at the westernmost point in the watershed. The steepest elevation changes are in Mill Creek subwatershed, extending from Love Lady Ridge. In the shortest distance (six miles) between the Ridge and valley floor opposite Gravelly Buttes, Mill Creek drops in elevation 2,017 feet or about 330 feet per straight-line mile. In contrast, from the foot of Bear Valley Buttes to the southern end of Bear Valley, a distance of 6.45 miles, the change in elevation is 67 feet, or about ten feet per mile. This wide range of elevation changes over similar distances changes the speed at which water moves through the watershed. The meandering pattern of Bear Creek in Bear Valley indicates an overall slower current than for Mill Creek. Figure 2.6 displays elevation contours in Bear Creek watershed.

### *Aspect*

Aspect determines how much solar energy (light and heat) reaches a piece of ground. The predominant aspect across the watershed is SSE. Areas with northern aspect tend to be wetter and cooler in comparison to drier, hotter sites having a southern aspect. Figure 2.7 shows the distribution of terrain aspect throughout the watershed.

### *Slope*

The watershed has a broad range of slopes (Figure 2.8). The sedimentary rock surfaces on the east side of the watershed are generally less steep due to faster rates of erosion than on igneous and metamorphosed igneous rocks on the west side of the watershed.

## 2.4 Climate

The watershed has a Mediterranean climate, characterized by cool, wet winters and hot, dry summers. Different microclimates occur due to the wide range of elevations, slopes, and aspects, often varying within short distances.

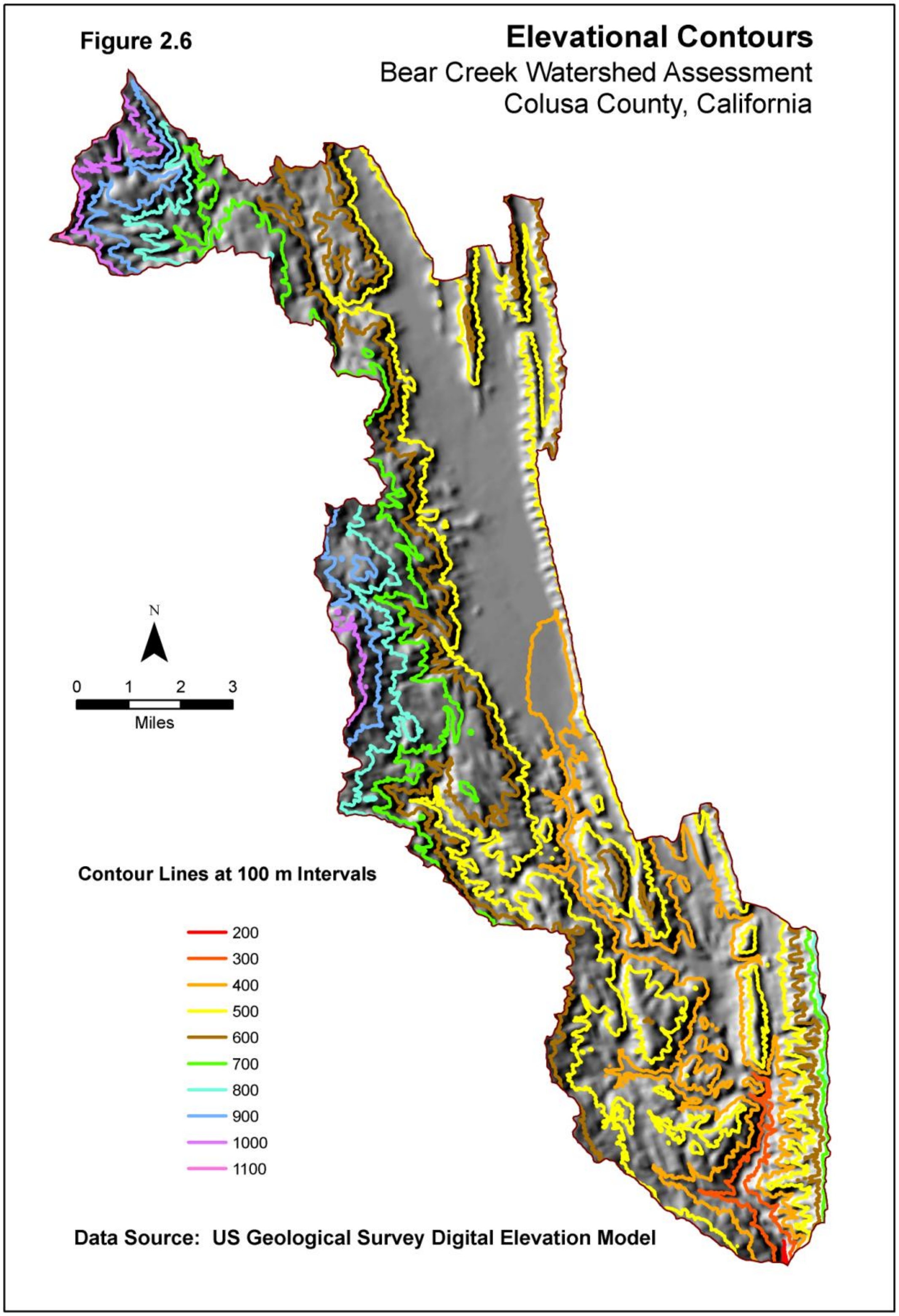


Figure 2.6
Elevational Contours
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Contour Lines at 100 m Intervals
200
300
400
500
600
700
800
900
1000
1100
Data Source: US Geological Survey Digital Elevation Model

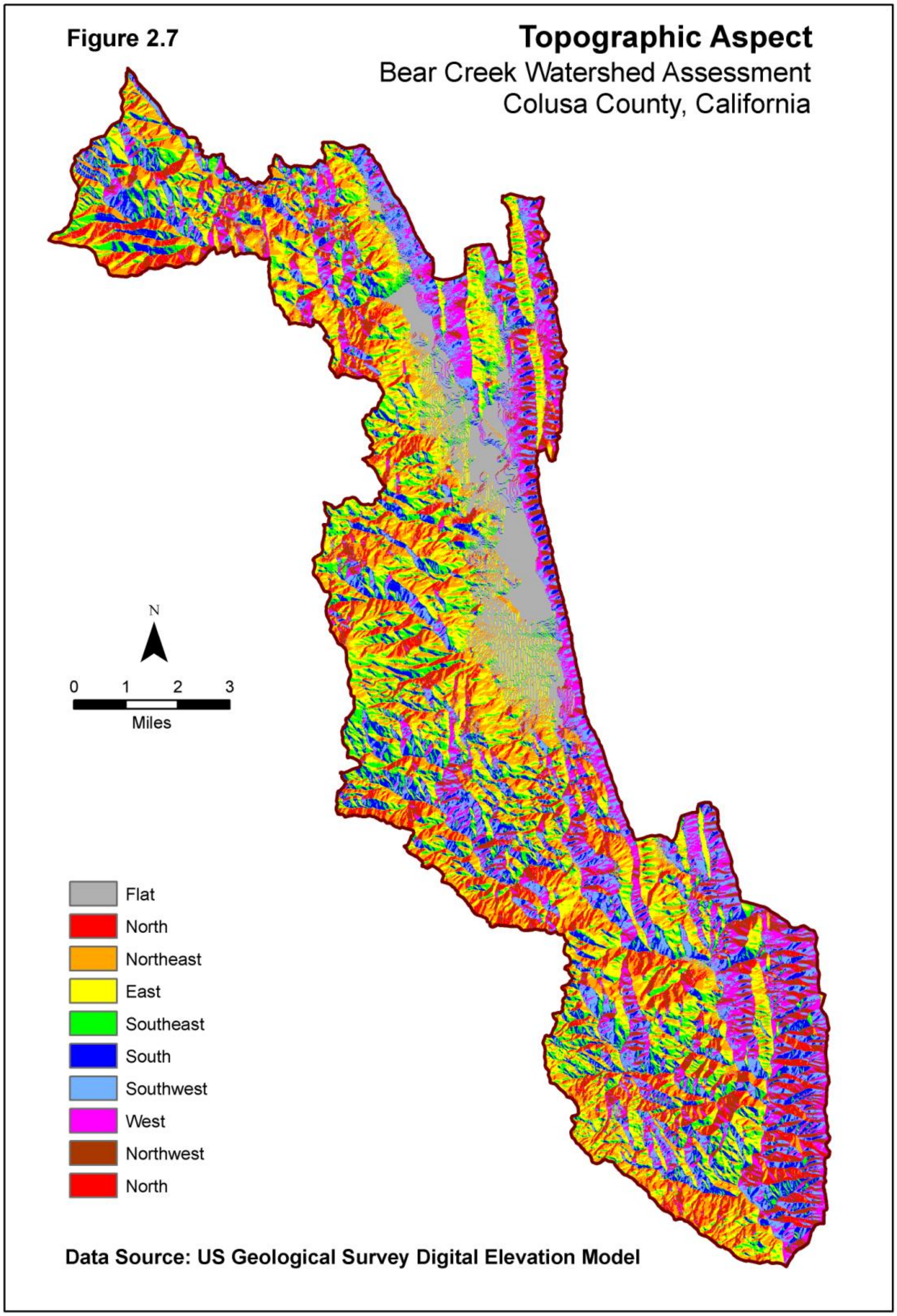


Figure 2.7
Topographic Aspect
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Flat
North
Northeast
East
Southeast
South
Southwest
West
Northwest
North
Data Source: US Geological Survey Digital Elevation Model

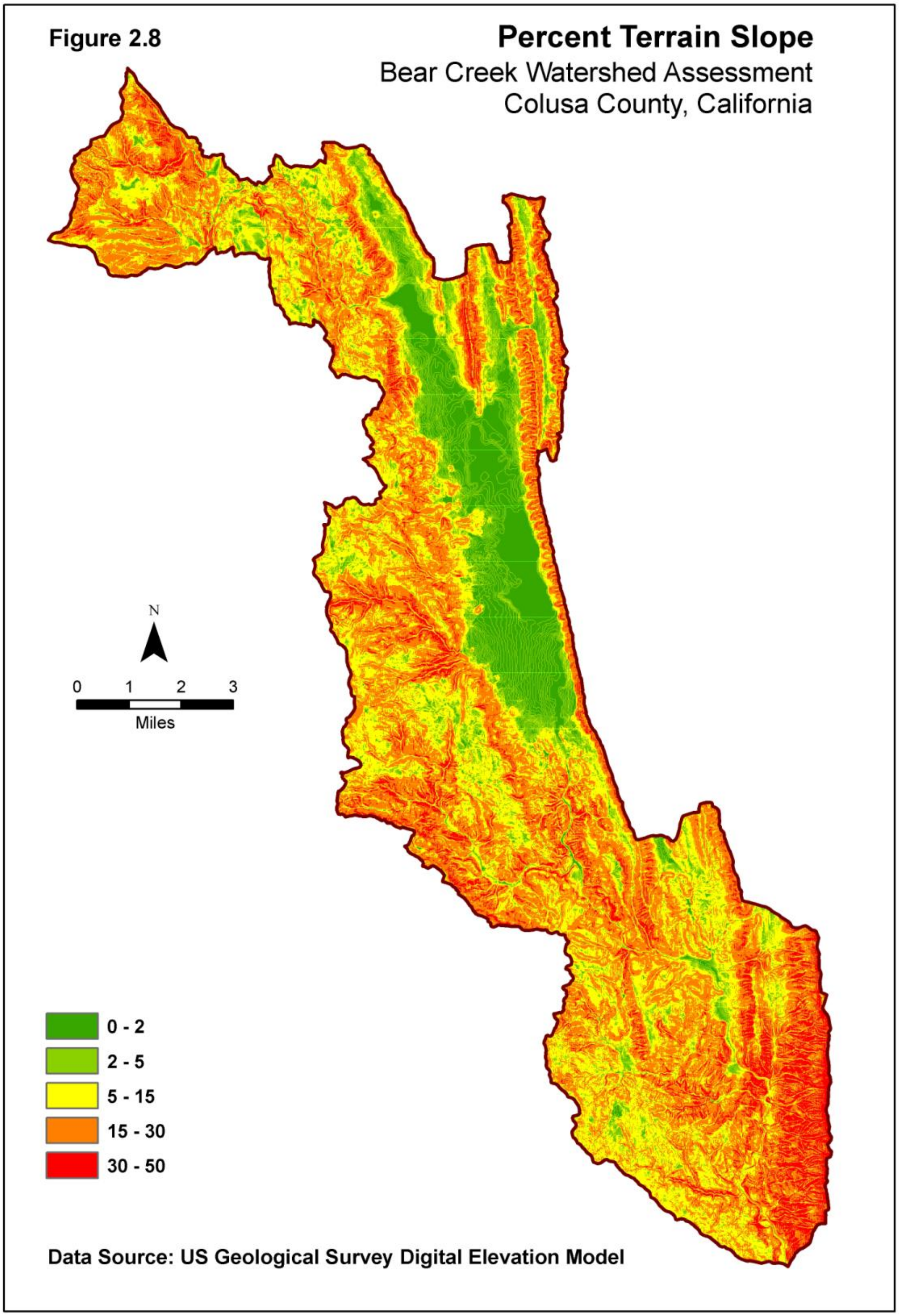


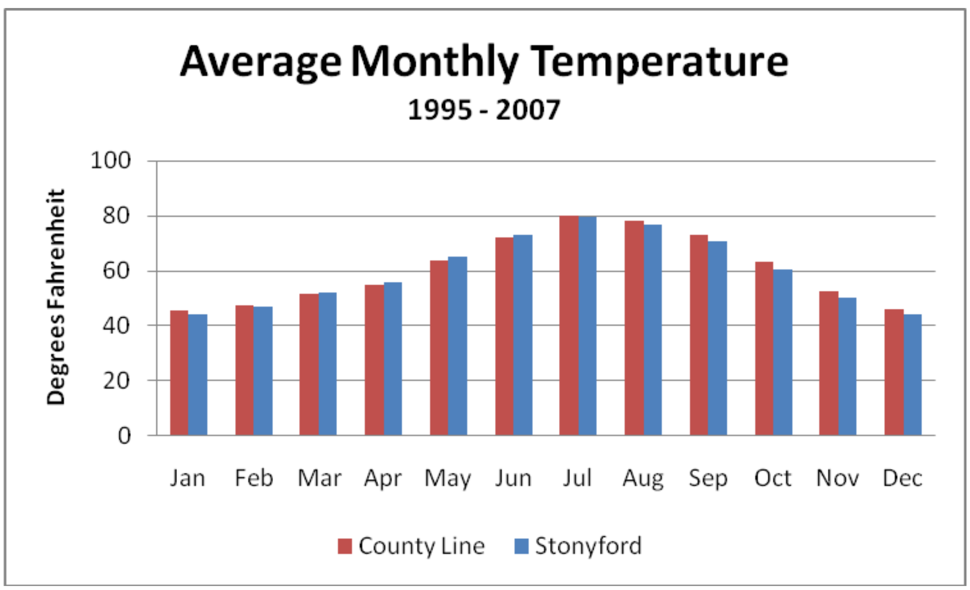
Figure 2.8
Percent Terrain Slope
Bear Creek Watershed Assessment
Colusa County, California
N
0
1
2
3
Miles
0 - 2
2 - 5
5 - 15
15 - 30
30 - 50
Data Source: US Geological Survey Digital Elevation Model

Climate conditions set limits to agricultural production in Bear Creek watershed. Additionally, data for temperature, rainfall, wind speed, temperature, solar radiation, and evapotranspiration are all necessary to develop a watershed model for Bear Creek that simulates hydrologic functioning in the watershed, including surface runoff and water yields.

Available data describing the climate of Bear Creek watershed come principally from the two remote automated weather stations (RAWS) located just outside the boundaries of the watershed: County Line station, in Lake County just a few feet west of the county line with Colusa County, and Stonyford station in Colusa Couty, seven miles north of the northeast end of Love Lady Ridge. Other data come from the Leesville Keegan Ranch station which operated between 1959 and 1977.

***Temperature***

Average monthly temperatures for the two RAWS stations are nearly identical. Daily midwinter temperatures average 45° F. Temperatures peak in July with daily average temperatures near 80° F.

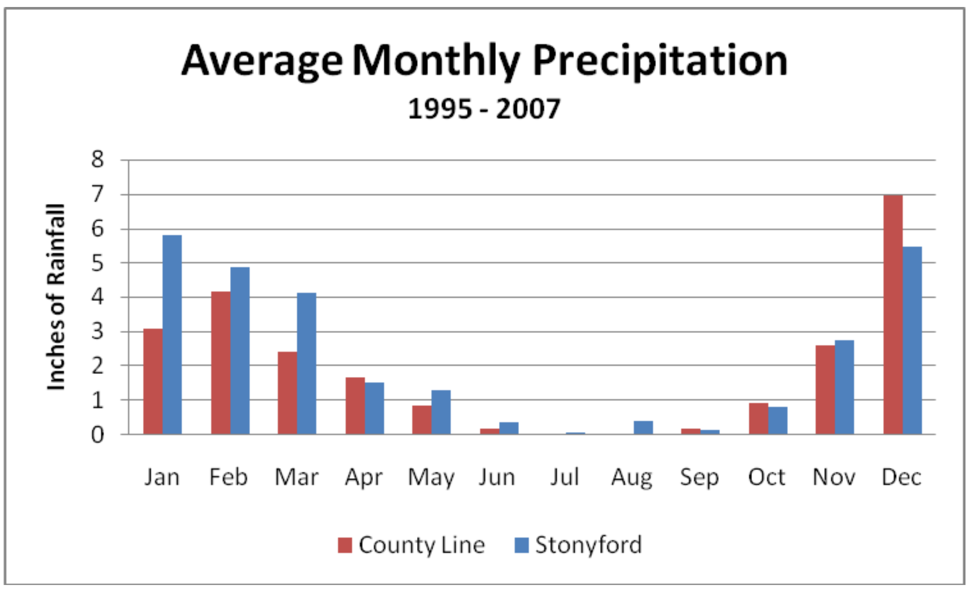



***Precipitation***

Rainfall timing and amounts in Bear Creek watershed, however, vary greatly from year to year, a pattern typical of regions with Mediterranean climates (Gasith and Resh 1999, Domagalski et al. 2004b). The maximum values of annual rainfall in the watershed are approximately double the annual mean (Lustig and Busch 1967). For example, abnormally high rainfall in 1998-1999 exceeded 40 inches. During the severe drought in 1976, only 5.41 inches of rain fell at the Leesville Keegan Ranch weather station (Western Water Research Institute archive data).

Fluctuations in annual precipitation result from weather patterns generated by the El Niño/Southern Oscillation in the southern Pacific Ocean. Strong El Niño conditions bring high rainfall as in 1998, while strong La Niña conditions bring drought. When surface water warms more than 0.5ºC in the southern Pacific Ocean, the resulting decrease in air pressure in the eastern Pacific Ocean causes the number of winter storms reaching California to increase. Conversely, cooling of surface water causes the number of winter storms to drop and may lead to drought in California. An important consequence of the El Niño rainfall pattern in the California Coast Ranges is that soil erosion increases as the number of storm events increases.

The second feature of precipitation in Bear Creek watershed is its seasonality, also a trait of Mediterranean climates (Gasith and Resh 1999). Precipitation mostly falls during winter-season storms. Regionally, 85 percent of rainfall occurs between November 1 and March 31 (Lustig and Busch 1967).




The number of days of significant measurable precipitation also characterizes the distribution and impact of precipitation. During the rainy season, precipitation falls principally during major storm events rather than as a moderate and steady input throughout the season. The most frequent rainfall and most intense storms occur during December through February. The one-day maximum precipitation recorded was 4.1 inches at Leesville Keegan Ranch on January 21, 1967.

Most precipitation in Bear Creek watershed falls as rain. Duration and volume of precipitation affect how much water evaporates back to the atmosphere, percolates into the soil, runs overland, and exits the watershed via Bear Creek. Snowfall occurs infrequently in winter on the floor of Bear Valley but often accumulates for weeks at a time at the highest elevations. The amount of time that snow remains on the ground, however, is too brief to accumulate a snowpack that then releases melting water downstream outside of the rainy season. The one-day maximum snowfall recorded at the Leesville Keegan Ranch station of 12 inches occurred on January 4, 1974. On October 17, 1874, an extraordinary foot of snow fell in the Bear Valley area (Rogers 1891, page 142).

### *Solar Radiation*

RAWS station data provide daily readings of actual solar radiation, the total amount of energy from the sun that reaches the ground. The presence of cloud cover and decreased day length create conditions of reduced solar radiation in winter months. December and January have about one-quarter of the solar radiation available in June and July.

### *Wind*

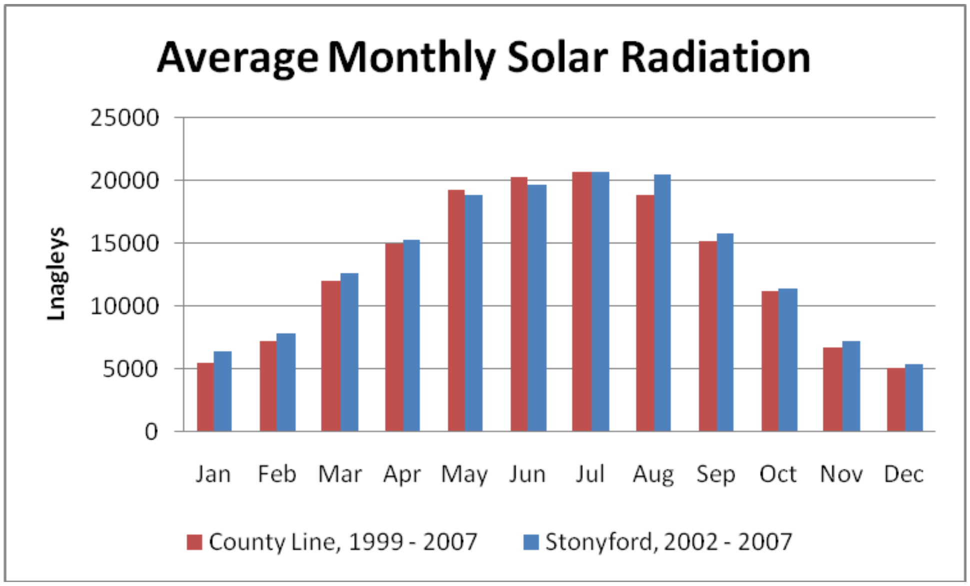
Throughout the year, winds come predominantly from the west and WSW directions. Wind speed varies across Bear Creek watershed, with higher elevations being more exposed and windier. Wind speeds from County Line RAWS station average up to three times faster than those concurrently recorded from Stonyford RAWS station, situated at a lower, more sheltered elevation.

A renewable energy company has been collecting information on wind speeds at selected sites on Walker Ridge (Figure 3.10). Information from those wind stations is not public information at present.

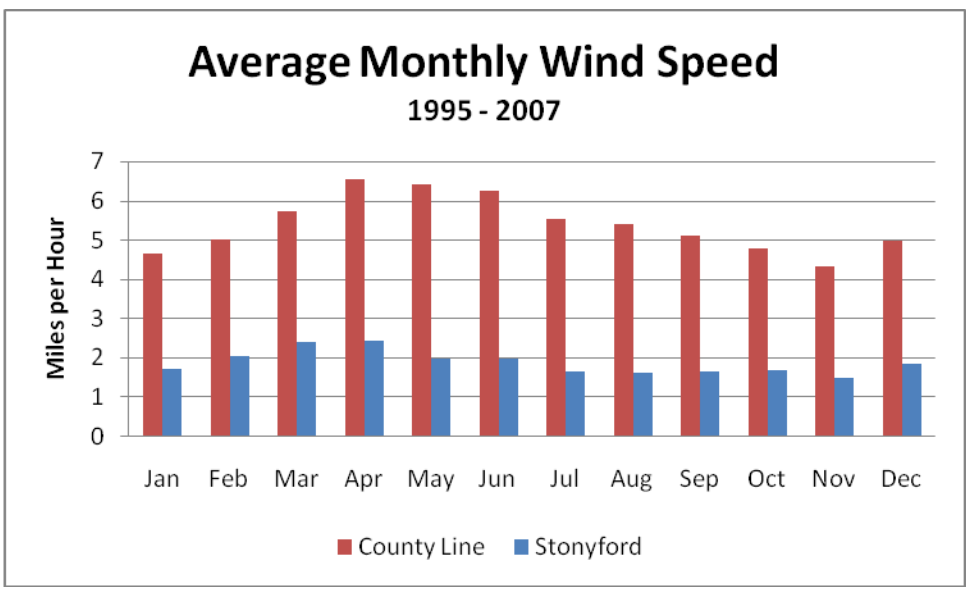
### *Evapotranspiration*

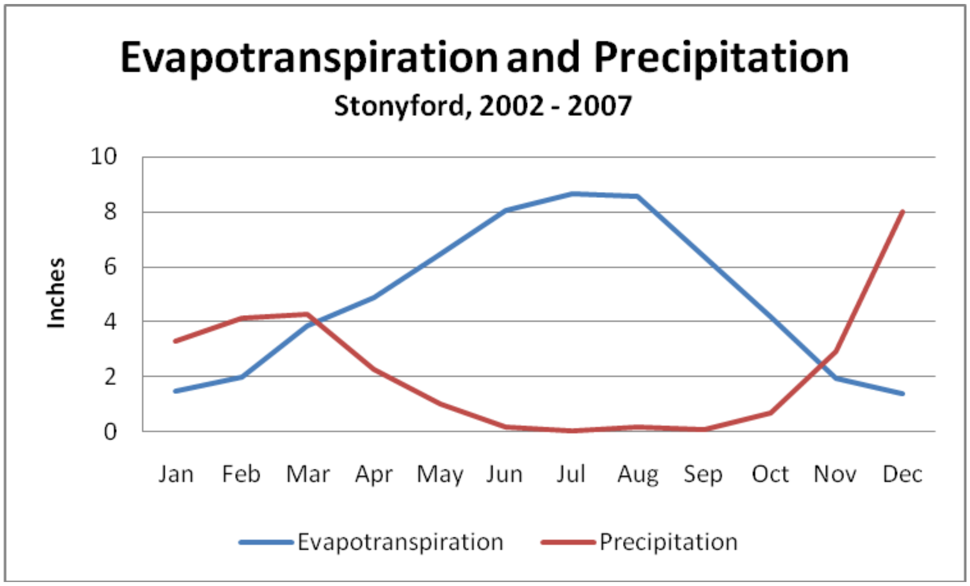
Evapotranspiration is the sum of water lost from the soil through direct evaporation plus the amount of water lost to the air from plants through transpiration. A soil moisture deficit occurs in summer and early autumn months in Bear Creek watershed because precipitation is usually absent and fails to recharge soils with moisture. At the same time, low humidity and high temperatures cause soils and plants to lose moisture faster through evapotranspiration. Drought occurs when evapotranspiration exceeds precipitation (see below). Plants continue to transpire more water until they wilt for lack of soil water to take up through their roots.

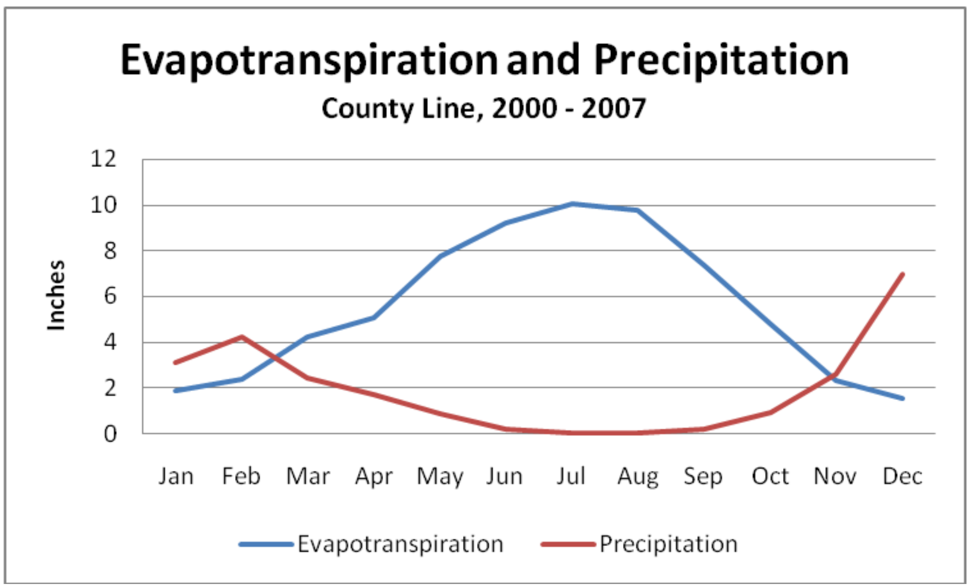
The natural drought curtails plant growth between March and November at the County Line RAWS station and between April and October at the Stonyford RAWS station. The differences in the length of growing season between the two sites result from differences in site inputs from the physical environmental factors such as wind speed, air temperature, humidity, and soil moisture. These differing microclimate conditions can affect biomass acccumulation in vegetation and agricultural crop productivity. For summer-season crops that require non-drought conditions in the soil, farming in Bear Creek watershed requires irrigation. Attention to specific microclimate conditions is also important to successful revegetation with native plants.




**Note:** A langley is a unit of solar radiation equal to one gram-calorie per square centimeter. A gram-calorie is the amount of heat required to raise the temperature of one gram of water one degree Celsius.






***Information Gaps***

A larger set of RAWS and SCAN stations, including resumption of station readings for Bear Valley, would provide landowners and land managers with more localized records of weather conditions at areas of greatest concern.

## 2.5 Hydrology

The interaction among water, geology, topography, soils, geology, vegetation, and the atmosphere is the hydrologic cycle, an ecological process that helps to shape the unique character of Bear Creek watershed. This section discusses water sources, water supply, water storage, and water flow in the watershed.

***Water Sources***

Water supplies in the watershed have two principal sources. The more abundant source is meteoric water, or water on the surface, in the ground, and in the atmosphere that originates from rainfall. The other source of water is geologic water, which has remained embedded in below-ground strata for thousands or even millions of years. This water source is critical to hydrology in the watershed because over time geologic water has come to contain unusually high amounts of dissolved chemical elements and ions originating in rock underlying the watershed.

Most geologic water in Bear Creek watershed is connate water. Connate water was once seawater that subsequently became trapped in sedimentary rocks as they formed under pressure from sediments deposited on the ocean floor of what is now the Central Valley (Goff et al. 1993). Over eons, the pressure on connate water has built up so that the water bursts through sedimentary rocks at weak points along geologic faults and forms artesian springs that push the ancient water aboveground (Davisson et al. 1994). Another source of geologic water results from subterranean formation of metamorphic and volcanic rocks. No data are available about the amounts of geologic water presently stored underground in the watershed.

***Overland Flow (Surface Runoff)***

Yates (1989) has estimated that annual runoff per unit area in Bear Creek watershed averages five inches (12.7 cm). Diverse topography, soils, vegetation, and runoff amounts vary across the watershed.

The timing of overland surface flows follows the pattern of rainfall closely, with flow rate responding with less lag time than stream flow does. The volume, speed, and energy with which precipitation becomes overland flow depend on the amount, duration, and intensity of precipitation plus the capacity of the ground surface to absorb water into the soil. Actual measures of overland flow from specific sites, however, are not available for the watershed.

A major issue for the watershed (refer to Section 6.2) is the impact of soil erosion and transport of mine waste sediments overland. In particular, the force of overland flows during and after winter storms erodes soils and mine sediments known to have high mercury content, and transports these sediments into Bear Creek and its tributaries (Cooke and Stanish 2007). The assessment sections that follow consider the effects of the amounts of sediment, organic matter, and solutes transported by overland flow and in-stream water as well as the implications for their delivery downstream.

### *Hydrography*

The dendritic (branch-like) network of streams in Bear Creek watershed constitutes the watershed hydrography (Figure 2.5). The National Hydrography Dataset managed by the US Geological Survey is the national mapping standard for the Bear Creek stream network. Of the total 277 miles of streams in Bear Creek watershed, 80 miles (or 29 percent of the total length) are intermittent streams. Intermittent streams, where water flows only seasonally, predominate in the southern third and in the northwest corner of the watershed.

Bear Creek originates midway along the northern perimeter of the watershed on gentle terrain, just west of Gravelly Buttes. It runs north to south through the east side of Bear Valley and then through the dissected canyon landscape of the southern third of the watershed to the confluence with the mid-reach of Cache Creek. Most tributaries to Bear Creek in Bear Valley arise from steep ridges at the west perimeter of the watershed.

Mill Creek, the largest tributary to Bear Creek, begins in the northwest corner of the watershed from three branches draining Love Lady Ridge and flowing southeast to Bear Valley. Steep canyons constrict the channels of Mill Creek branches. At its confluence with Bear Creek in northwest Bear Valley south of Brim Road, Mill Creek often has a greater flow volume than Bear Creek. Because Mill Creek subwatershed is difficult to access, hydrologists have not studied the creek, and little information about Mill Creek exists.

The second largest tributary to Bear Creek is Sulphur Creek which drains southeast from the southern third of Walker Ridge. Because of the economic importance of mining, mercury issues, and the unusual chemistry of its water sources, Sulphur Creek, has been the most studied tributary in the watershed. Trout Creek is the other major stream descending from Walker Ridge, flowing belowground where the coarse gravelly texture of its creek bed allows water to rapidly infiltrate.

Tributaries on the east side of Bear Valley are mostly small channels in swales, flowing at low volumes after rain storms. Streams from Leesville and Hamilton Canyon subwatersheds are the major streams flowing west into Bear Valley and Bear Creek. In the southern third of the watershed, Brophy Canyon, Lynch Canyon, and Thomson Canyon subwatersheds on the west side of Bear Creek and Holsten Canyon, Lawson Canyon, and South Jackson Canyon on the east have the only permanent tributaries.

### *Stream Flows*

Water arrives in Bear Creek and its tributaries from several sources: overland flow, groundwater moving laterally into the streams, and springs and seeps. Flow in watershed streams displays distinct seasonality within a year and considerable variability in total flow from year to year. The main stem of Bear Creek flows continuously except in the most extreme drought years. Data on stream flows, measured as the cubic feet of water flow per second (cfs), comes from four gage stations maintained by the US Geological Survey. Apart from stations on Sulphur Creek, no flow data are available for other tributaries of Bear Creek. Figure 2.9 depicts flow amount at USGS gage stations.

Table 2.4 – Gage stations on Bear Creek and Sulphur Creek

| USGS Gage No. | Gage Name | Drainage Area (square miles) | Period of Record | | Flow Variables Tracked |
|---|---|---|---|---|---|
| | | | Start Date | End Date | |
| 11451690 | Sulphur Creek at Wilbur Springs | 9.87 | 1999 10 29 | 2004 09 30 | discharge, water quality*, real time flow |
| 11451700 | Sulphur Creek tributary near Wilbur Springs | 4.49 | 1961 10 01 | 1963 09 30 | discharge |
| 11451715 | Bear Creek (main stem) above Holsten Chimney Canyon, near Rumsey | 94.90 | 1997 11 20 | current | discharge, river stage, water quality*, turbidity* |
| 11451720 | Bear Creek (main stem), near Rumsey | 100.00 | 1958 10 01 | 1998 01 04 | discharge (mean) |

*this variable tracked for only a part of the period of record

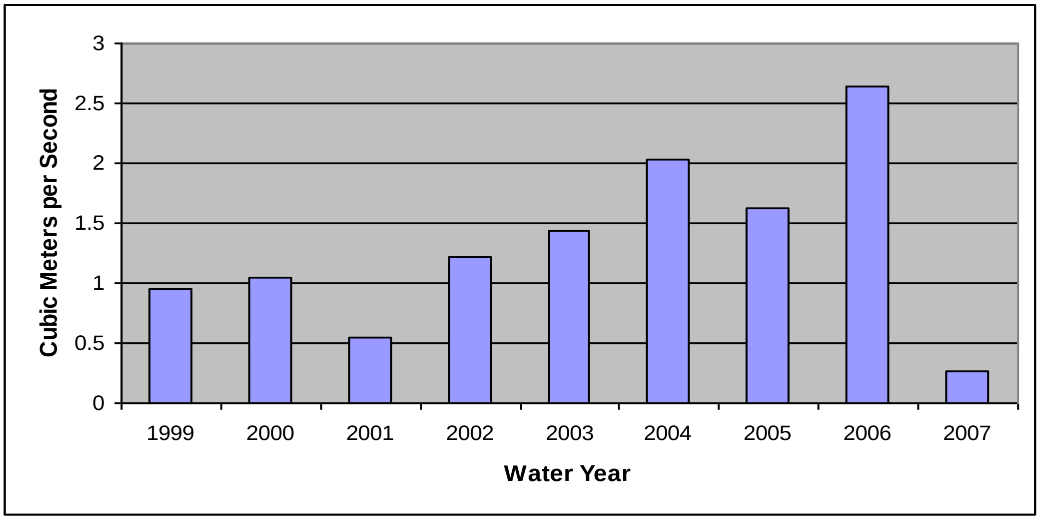
Flow volume from USGS monitoring station 11451715, located on Bear Creek three miles upstream from its confluence with Cache Creek and 7.5 miles northwest of Rumsey, CA, best approximates the volume contribution of Bear Creek to the total water budget of the Cache Creek basin.

*Annual Flows*

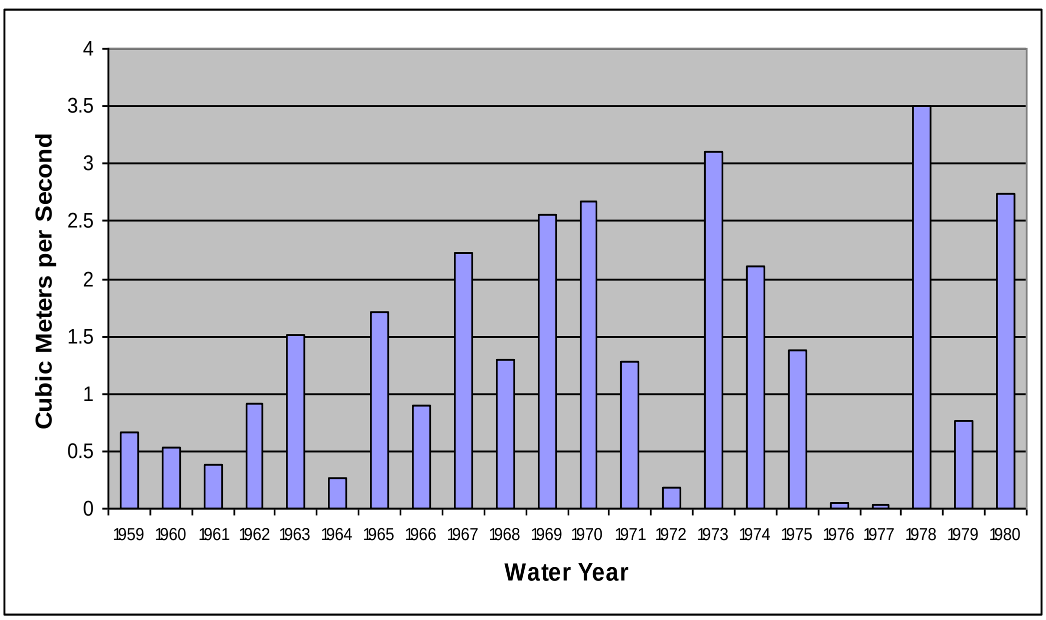
Data in Figure 2.9 are expressed in cubic meters per second rather than cubic feet per second to give the graph a smaller scale (1 cubic meter = 35.3147 cubic feet). The annual water volume from Bear Creek flowing into Cache Creek averaged 1.455 billion cubic feet during the nine-year period between 1999 and 2007. Changes year to year in water flow volumes have varied widely. For example, the water flow for the 2007 water year was ten percent of the flow recorded for the 2006 water year. A look back at data from the USGS station that operated nearby from 1959 to1980, shows both higher and lower annual flows than seen in recent years. Water flow from Bear Creek into Cache Creek averaged 1.566 billion cubic feet annually for that 21-year period. The larger average flow volume (+7%) may be a function of the larger (+5%) drainage area included for station 11451720 rather than evidence of a lower flow during the period 1999 to 2007 for station 11451715. Although there is widespread concern about the possibility of long-term declines to water supplies on account of climate change, data from Bear Creek are insufficient to draw any conclusions about trends.

Figure 2.9 – Average Annual Stream flow Rate in Bear Creek at USGS Stations

Station 11451715, 1999 - 2007




Station 11451720, 1959 - 1980




Sulphur Creek is the other drainage for which stream flow data exist, but the data series for Sulphur Creek covers two brief time intervals, 1962-1963 and 2001-2004 (Table 2.5).

Table 2.5 – Average annual stream flow (volume per second) for USGS monitoring gages on Sulphur Creek

| Water Year | Station No. | Basin Area (square miles) | Flow (cfs) |
|---|---|---|---|
| 1962 | 11451700 | 4.49 | 0.49 |
| 1963 | | | 1.39 |
| 2001 | 11451690 | 9.97 | 1.99 |
| 2002 | | | 3.95 |
| 2003 | | | 4.73 |
| 2004 | | | 6.56 |

*Monthly Stream Flows*

Monthly stream flows in Bear Creek are variable, with flow lowest in the late summer and early autumn months just before the rainy season (Figure 2.10).

For water years 2001 through 2004, Sulphur Creek subwatershed contributed nearly ten percent of the total water flow in lower Bear Creek (Figure 2.10, Table 2.6). The months with the greatest percentage of contribution to Bear Creek from Sulphur Creek are in September and October – months when total Bear Creek stream flow is lowest. This pattern likely results from discharge of geologic water from springs in Sulphur Creek subwatershed. Flow from deep (geologic) spring sources is more evenly distributed throughout the year than rainfall-dependent (meteoric) stream flow and proportionally provides a greater share of total flow in the driest rainless months. By contrast, Bear Creek stream flow derives largely from meteoric water sources.

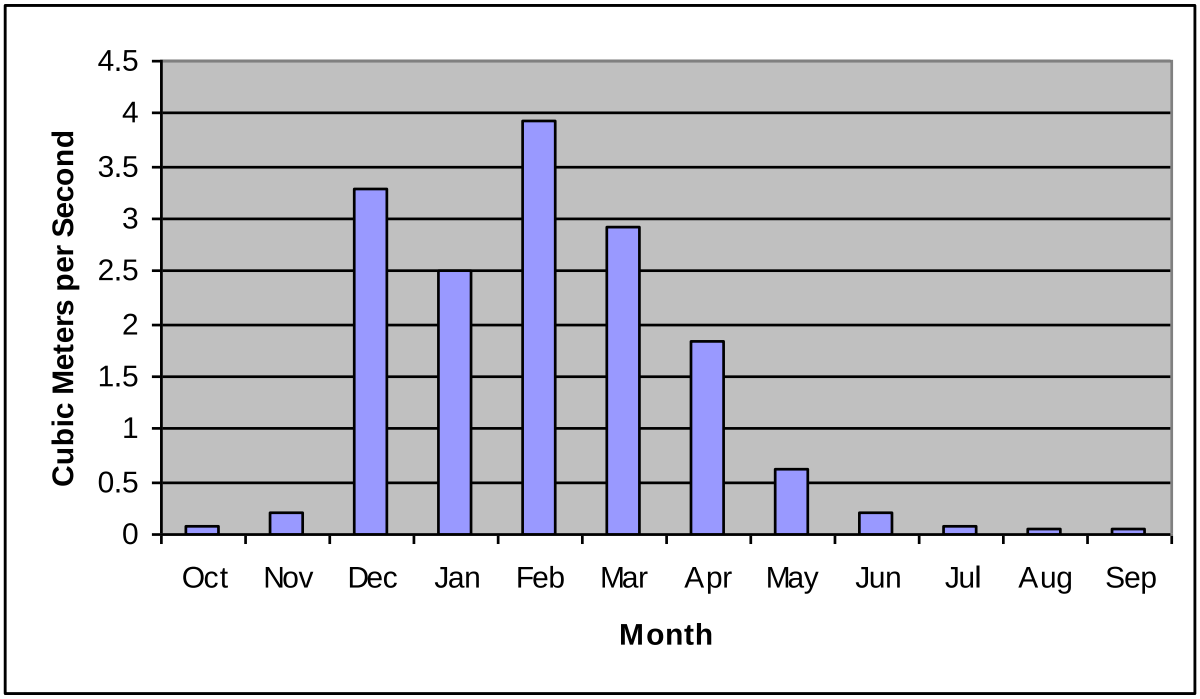
***Low Flows***

Inadequate groundwater recharge has caused Bear Creek to run dry during the summer in only three years over the period of water flow records. From 1961 through 2007, days with no flow in Bear Creek have amounted to 2.4 percent of all days of record. The severe drought in 1976 and 1977 was the cause of the most days with no flow in Bear Creek. Intervals longer than seven days of no flow in Bear Creek occurred for the following dates:

| | |
|---|---|
| July 3, 1972 to September 12, 1972 | 71 days |
| June 27, 1976 to July 4, 1976 | 8 days |
| July 7, 1976 to August 7, 1976 | 32 days |
| June 4, 1977 to November 11, 1977 | 159 days |

Figure 2.10 – Average Monthly Stream flow Rate in Bear Creek at USGS Stations

Station 11451715, 1999 - 2007




Station 11451720, 1959 - 1980

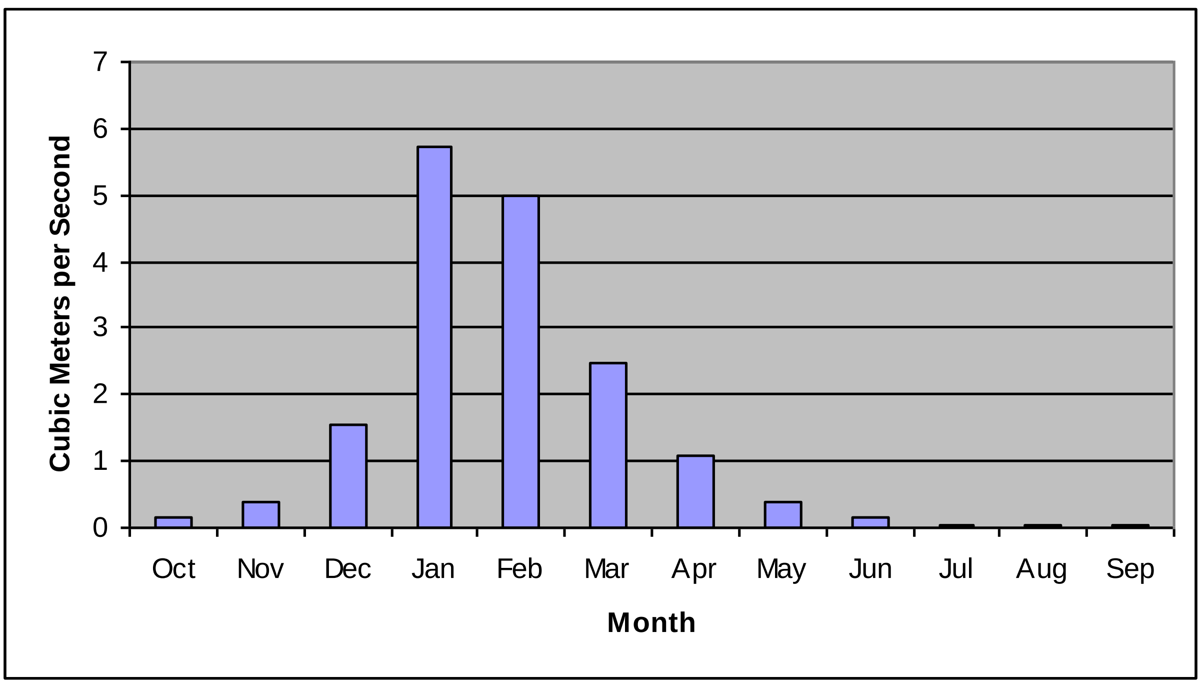


Table 2.6 – Average monthly stream flows for Sulphur Creek and Bear Creek, water years 2001 - 2004

| Month | Stream flow (cfs) | | Sulphur Creek Percent of Bear Creek Total |
|---|---|---|---|
| | Sulphur Creek Gage 11451700 | Bear Creek Gage 11451715 | |
| Oct | 0.272 | 2.090 | 12.9 |
| Nov | 1.031 | 8.984 | 11.5 |
| Dec | 16.009 | 165.638 | 9.7 |
| Jan | 10.075 | 109.303 | 9.2 |
| Feb | 12.846 | 140.568 | 9.1 |
| Mar | 6.926 | 79.591 | 8.7 |
| Apr | 2.390 | 23.990 | 10.0 |
| May | 1.317 | 15.115 | 8.7 |
| Jun | 0.420 | 4.787 | 8.8 |
| Jul | 0.184 | 2.333 | 7.8 |
| Aug | 0.148 | 1.589 | 9.4 |
| Sep | 0.208 | 1.656 | 12.5 |
| Annual Total | 4.285 | 45.928 | 9.6 |

When flow stops in Bear Creek, considerable lag time passes before enough groundwater and runoff accumulate to recharge creek flow. Apart from the exceptional five-month period of no flow in 1977, days of no flow in lower Bear Creek have occurred from the last days of June through August. The 1999 to 2007 record of water years had no days without flow in Bear Creek.

### *Ponds and Lakes*

No natural ponds or lakes are present in Bear Creek watershed. Section 3.4 Water Delivery presents information on man-made ponds and dams in the watershed.

### *Groundwater*

*Bear Valley Groundwater Basin*

Bear Valley Groundwater Basin (Basin 5-64) lies entirely within Bear Creek watershed and extends an estimated 9,100 acres. The Bear Valley Groundwater Basin drains to the south, roughly following the course of Bear Creek. No estimate of the water volume in the groundwater basin is available, but the volume is relatively small and much less economically important in comparison to the Central Valley Groundwater Basin to the east, which produces about nine million acre-feet of water annually (Ferriz 2001). The Colusa County Groundwater Management Plan (2008) does not cover the Bear Valley Groundwater Basin as the Basin does not contribute to the supply of water for agriculture in the Central Valley.

The California Department of Water Resources has no information about water-bearing formations, groundwater flow rates, infiltration rates, and trends in groundwater levels, or groundwater quality in the Basin. The Groundwater Basin consists mostly of meteoric water, but geologic water contributes to the groundwater supply through many deep rock fissures associated with the Stony Creek fault complex that bisects the watershed through Bear Valley.

*Capay Valley Groundwater Basin*

Bear Creek recharges water downstream south into the Capay Valley Groundwater Basin (Basin 5-21.68). This recharge is critical because the water quality of Bear Creek could affect the groundwater quality of the Capay Valley, an important agricultural region in Yolo County. Bear Creek is a major source of boron and other high concentrations of minerals flowing into Cache Creek and the Capay Valley Groundwater Basin (Swartz and Hauge 2003). The assessment addresses chemical elements, their loads, and downstream impacts in Chapter 5 Contaminants.

*Sulphur Creek Geothermal Reservoir*

The precise origin of the mineral-rich geothermal waters beneath Sulphur Creek subwatershed is unclear. Water from the deepest parts of the reservoir are thought to reach 180°C (Thompson 1993), far hotter than the spring waters at the surface where they flow into Sulphur Creek and other Bear Creek tributaries.

McLaughlin et al. (1989) proposed that geologic water has intruded through faults and other rock fractures deep below the surface and has become encased in mostly impermeable ultramafic rocks. Subsequently escaping the pressurized surroundings of these rocks, mineral-rich geologic waters of volcanic origin have mixed with connate waters found in the overlying sedimentary bedrock. Further mixture with percolating meteoric water produces waters with unique chemical properties found in springs of the watershed. The Sulphur Creek geothermal reservoir has not been a commercial source of energy generation (Goff et al. 1993).

***Springs and Seeps***

Springs and seeps furnish vents for subsurface water sources to aboveground water flow throughout Bear Creek watershed. Currently, locations for more than 80 springs and seeps are known, and new sources are being discovered by geologists (Slowey and Rytuba 2008) and botanists (J. Alderson, pers. comm.) working in the watershed. Figure 2.11 displays locations of described springs and seeps in the watershed. Forty-five percent of all springs known to date are in Sulphur Creek subwatershed, known internationally for its mineral hot springs. Eaton Springs and Malaney Flat on Walker Ridge are particularly noteworthy for supplying water to wetlands found on ultramafic hydric soils.

Information about water temperatures and flows from springs is fragmentary. Table 2.7 provides water temperatures and flow rates for selected springs in Sulphur Creek subwatershed. Section 5.4 Sources of Water Contaminants characterizes the chemical elements in waters from individual springs. Geologists have calculated proportions of geologic and meteoric waters in spring waters originating from Sulphur Creek subwatershed based on proportions of isotopes of key elements dissolved in spring waters (Goff et al. 2001).

Table 2.7 – Flows and temperatures of selected hot spring waters from Sulphur Creek subwatershed

| Spring | Temperature at Spring Source °C | Estimated Subsurface Reservoir Temperature °C† | Flow (liters $min^{-1}$) |
|---|---|---|---|
| Blanck Hot Spring | 36 - 44 | >121 | 1 - 14 |
| Elbow Hot Spring | 70 - 74 | >88 | 0.5 |
| Elgin Hot Spring (Main) | 67 - 70 | >133 | 20 - 26 |
| Jones Fountain of Life* | 53 - 62 | >101 | 0 - 95 |
| Unnamed Spring | 52 | >76 | ≤ 0.5 |
| Wilbur Spring (Don White) | 54 - 57 | >151 | 5 |
| Wilbur Spring (Main) | 55 - 57 | >161 | 20 |

*Geyser properties of this spring account for the wide range reported
† Based on chalcedony as a geothermometer
Sources: Goff et al. (2001), Suchanek et al. (2004)

At present, no data describe flows from cold spring waters that occur in subwatersheds other than Sulphur Creek subwatershed. The few data on temperatures recorded from wells and cold springs range from 14.5 to 24.5°C, based on just four readings (Barnes et al. 1973a, Thompson et al. 1978, White et al. 1973).

*Depth to the Water Table*

The Colusa County Soil Survey (Reed 2006) provides a wet and a dry season model of the distribution of the depth to the water table for Bear Creek watershed. The average depth to the water table changes seasonally in Bear Creek watershed, but in 95 percent of the watershed, the depth to the water table exceeds two meters (78 inches) year round. Other small areas with shallow water tables (< 2 meters depth) consist of wet Venado clay soils associated with alluvial fans at the base of Walker Ridge. Historic accounts of Bear Valley imply that the depth to the water table was formerly much shallower year-round in the Valley. The causes for the drop in water table are not precisely known. A combination of natural causes, land use changes, and intentional or inadvertent alterations to stream channels is likely (J. Alderson, pers. comm.).

***Information Gaps***

Gaps in knowledge about the hydrology of Bear Creek watershed are significant. They include:

- water flow information for Mill Creek, the largest tributary of Bear Creek and for Bear Creek above the confluence with Sulphur Creek
- information about the Bear Valley groundwater basin
- continuous, long-term flow data for the lower main stem of Bear Creek and in Sulphur Creek from existing stations; existing data, while informative, has been intermittent and provides only a short-term view of changes to stream flow.
- volumes and trends in seasonal and inter-annual spring flows as well as their associated mineral contents.

The CALFED program has proposed a performance measure (Performance Objective 3, Performance Measure 3) to ascertain with greater certainty the deliveries of water to the Sacramento-San Joaquin Delta for each water year (Performance Measures Subcommittee 2007). Closer monitoring and evaluation of water flow in the Bear Creek watershed are important to water managers' understanding of all water flows from watersheds supplying the Delta. Multiple gage stations strategically placed across the watershed would provide better monitoring data on water flows.

## 2.6 Geology

The earth subsurface controls the movement of water deep in the earth up to the soil surface, shapes current watershed flow through geomorphology, impacts water quality through the mineral content of rocks and soils, and strongly contributes to vegetation patterns in the watershed. Also, Bear Creek watershed geology both facilitates and limits economic production of natural resources in Bear Creek watershed, including industrial minerals, geothermal and fossil energy resources, and water quality.

The most detailed geological information comes from Sulphur Creek subwatershed, a historically important mining area and the core of the Sulphur Creek Mining District.

*The Great Valley Geomorphic Province*

Rocks from the Great Valley Geomorphic Province are sedimentary rocks (developed from eroded sediments) and metamorphosed sedimentary rocks (chemically altered) from sediment that eroded from the Sierra Nevada (Dickinson and Rich 1972) into the Sacramento Valley when the Valley was an ocean floor. Pressure transformed these deep

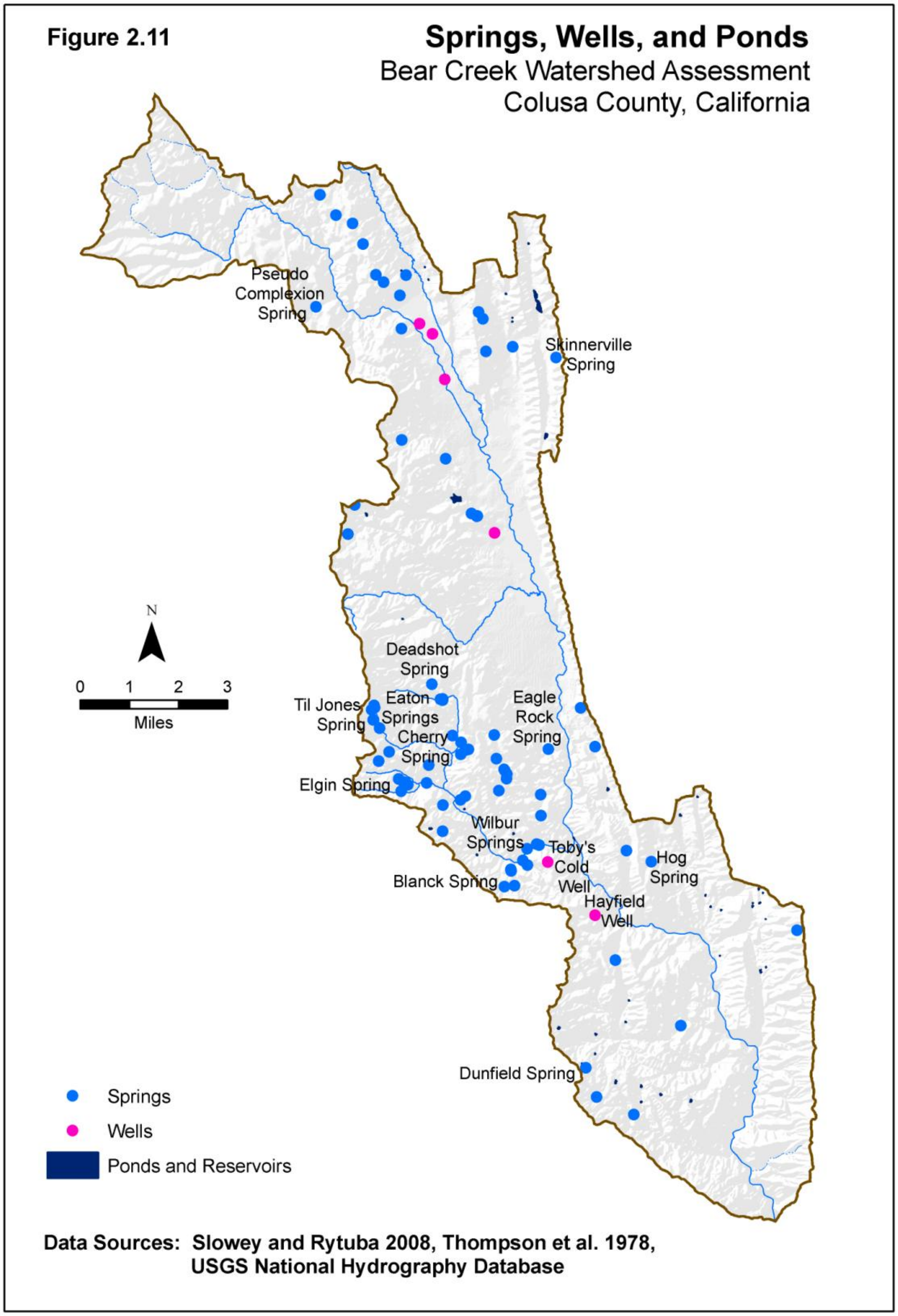


Figure 2.11
Springs, Wells, and Ponds
Bear Creek Watershed Assessment
Colusa County, California
Pseudo Complexion Spring
Skinnerville Spring
N
0 1 2 3
Miles
Deadshot Spring
Til Jones Spring
Eaton Springs
Eagle Rock Spring
Cherry Spring
Elgin Spring
Wilbur Springs
Toby's Cold Well
Hog Spring
Blanck Spring
Hayfield Well
Dunfield Spring
Springs
Wells
Ponds and Reservoirs
Data Sources: Slowey and Rytuba 2008, Thompson et al. 1978, USGS National Hydrography Database

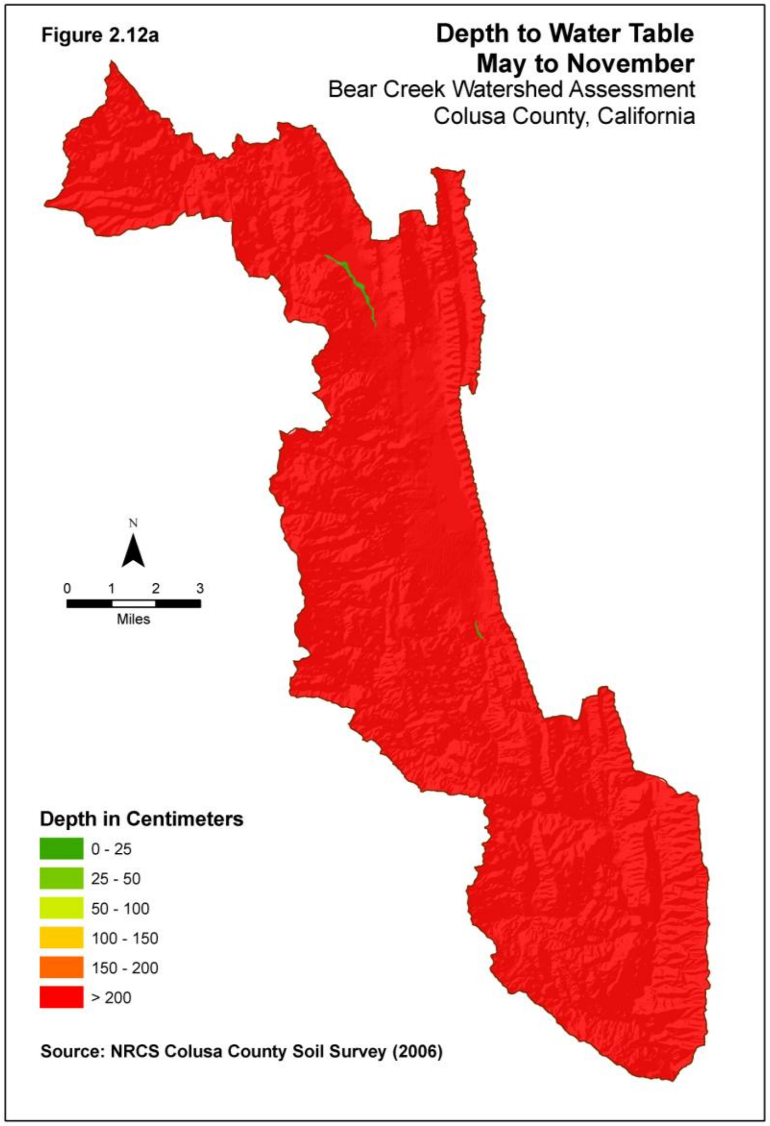


Figure 2.12a
Depth to Water Table
May to November
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Depth in Centimeters
0 - 25
25 - 50
50 - 100
100 - 150
150 - 200
> 200
Source: NRCS Colusa County Soil Survey (2006)

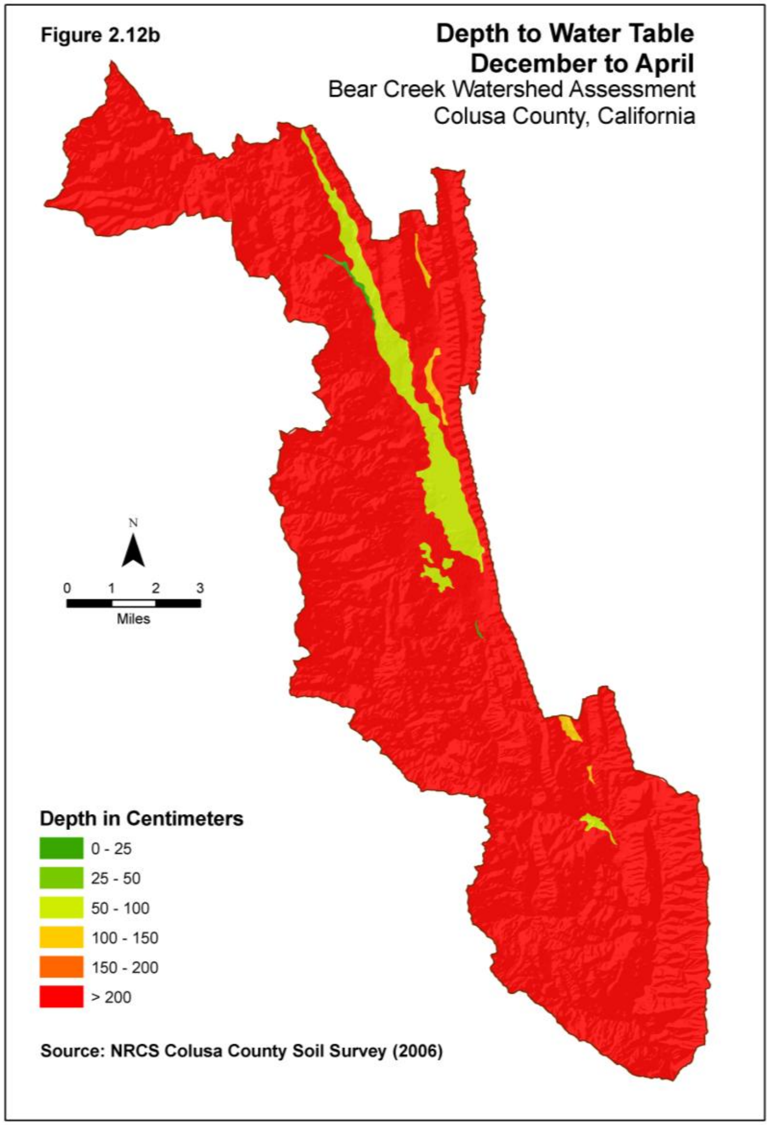


Figure 2.12b
Depth to Water Table
December to April
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Depth in Centimeters
0 - 25
25 - 50
50 - 100
100 - 150
150 - 200
> 200
Source: NRCS Colusa County Soil Survey (2006)

sediments into sedimentary rocks 169 to 65 million years ago. Sedimentary rocks now underlie the eastern half and southern third of the watershed.

*Coast Range Geomorphic Province*

The Coast Range Geomorphic Province is the source for three bedrock types on the west side of Bear Creek watershed. Frequent and complex earth movements from the San Andreas Fault and associated faults along the coast of California have deformed and jumbled the rock layers of different origins into three different bedrock mixes: (1) the mafic and ultramafic igneous (formed from magma) rocks formed in ancient mid-Pacific Ocean earth mantle and crust; (2) metasedimentary rocks from sediments that accumulated over the mid-Pacific Ocean; and (3) complex mixtures of volcanic, metavolcanic, and metasedimentary rock types known as “Franciscan Assemblages”.

When the Pacific Plate and associated plates pushed against the continental North American Plate 175 to 150 million years ago, igneous rocks in the plate crust and mantle of the Coast Range Geomorphic Province thrust themselves upward and overtopped Great Valley sedimentary rocks. Overthrust volcanic and metavolcanic bedrock occupies a smaller area in the NW part of Bear Creek watershed. These rocks originated from volcanic activity around Clear Lake, Lake County.

***Major Bedrock Types in Bear Creek Watershed***

Table 2.8 provides information on the total area and proportion of area in the watershed occupied by each bedrock unit in Bear Creek watershed, and Figure 2.14 shows the distribution of underlying rock formations in the watershed.

Table 2.8 – Principal bedrock types in Bear Creek watershed*

| **Bedrock Unit** | **Total Watershed Acres** | **Percent of Watershed Area** |
|---|---|---|
| **Bear Valley Alluvial and Terrace Sedimentary** | **8,736** | **13.2** |
| **Great Valley Geomorphic Province Subtotal** | **34,781** | **52.6** |
| Cortina Sedimentary | 5,370 | 8.1 |
| Lodoga Sedimentary | 20,432 | 30.9 |
| Stony Creek Sedimentary | 8,979 | 13.6 |
| **Coast Ranges Geomorphic Province Subtotal** | **22,548** | **34.2** |
| Franciscan Metasedimentary | 782 | 1.2 |
| Franciscan Volcanic and Metavolcanic | 2,149 | 3.3 |
| Tehama-Colusa Serpentinite Mélange | 19,617 | 29.7 |
| **Total** | **66,065** | **100.0** |

*arranged by geomorphic province of origin and in reverse chronology of formation

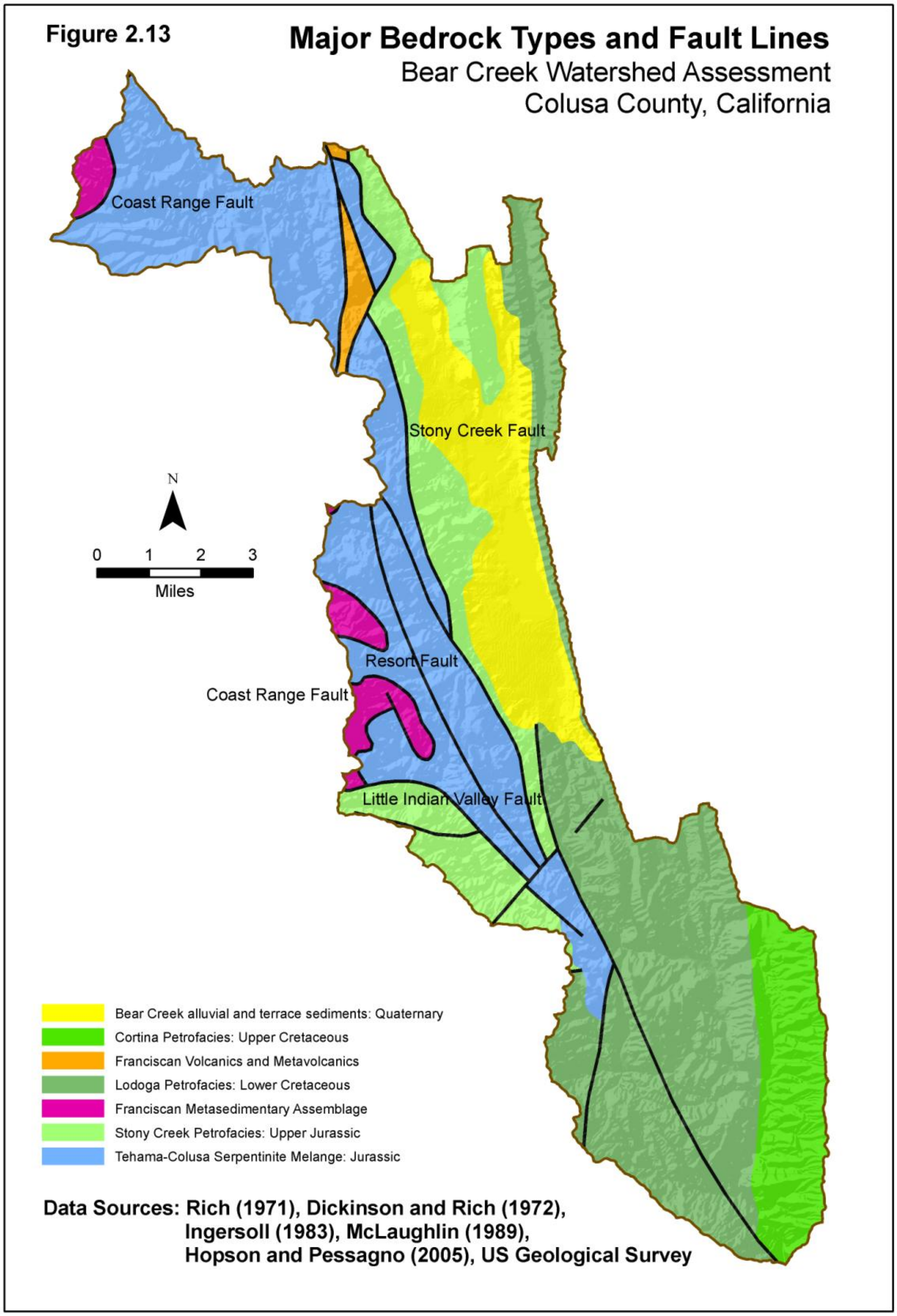


Figure 2.13
Major Bedrock Types and Fault Lines
Bear Creek Watershed Assessment
Colusa County, California
Coast Range Fault
Stony Creek Fault
Resort Fault
Coast Range Fault
Little Indian Valley Fault
N
0 1 2 3
Miles
Bear Creek alluvial and terrace sediments: Quaternary
Cortina Petrofacies: Upper Cretaceous
Franciscan Volcanics and Metavolcanics
Lodoga Petrofacies: Lower Cretaceous
Franciscan Metasedimentary Assemblage
Stony Creek Petrofacies: Upper Jurassic
Tehama-Colusa Serpentinite Melange: Jurassic
Data Sources: Rich (1971), Dickinson and Rich (1972),
Ingersoll (1983), McLaughlin (1989),
Hopson and Pessagno (2005), US Geological Survey

*Great Valley Sequence Sedimentary Bedrock Units*

Great Valley Sequence bedrocks arose in the ocean-filled Sacramento Valley when submarine avalanches occurred after earthquakes along the tectonic plates underlying the watershed. Sediments sorted vertically in the aftermath of submarine avalanches, with the densest sediments settling first and lowest thus creating a columnar structure of sediment layers with relatively uniform sediment textures. The resulting sedimentary rocks often contain gold deposits and pockets of fossil fuels, the latter a legacy of biomass from ancient marine organisms. Over millions of years changes in sediment deposition took place, sedimentary rock layers tilted due to upthrusts and lateral shifts at fault lines, and pressure metamorphosed sedimentary rock layers (Dickinson and Rich 1972). These processes created different kinds of sedimentary rocks termed "petrofacies" (Dickinson and Rich 1972, Ingersoll 1983). The three petrofacies found in Bear Creek watershed are, in chronological order of formation: Stony Creek, Lodoga, and Cortina. Differences are based on relative proportions of plagioclase feldspar, polycrystalline quartz in total quartz-derived sediments, and total lithic pieces (gravel, pebbles, and cobbles).

*Major Coast Ranges Bedrock Units*

Unlike the Great Valley bedrock units, the bedrock units from the Coast Ranges Geomorphic Province sources in Bear Creek watershed are significantly different from one another, originating as marine igneous rocks, sedimentary rocks, and volcanic igneous rocks.

<u>Tehama-Colusa Serpentinite Mélange</u>

The Tehama-Colusa Serpentinite Mélange (TCSM) originated 160 million years ago from ultramafic igneous rocks, extending in a narrow north-to-south band up to four miles wide and 56 miles long from western Tehama County through Glenn County to just south of Highway 20. The TCSM constitutes the easternmost element of the Coast Ranges Geomorphic Province in the watershed. These rocks were part of the Pacific Plate and upthrust after contact with the North American Plate. They consist mostly of serpentinite, a metamorphosed igneous rock type with greater than 90 percent mafic minerals (rich in iron and magnesium minerals). The high percentage of mafic minerals and less than 45 percent silica, potassium, and calcium content qualify the bedrock type as "ultramafic", as defined by the International Union of Geological Sciences. These rocks have formed unique outcrops and several ultramafic barrens, largely devoid of vegetation, in Bear Creek watershed.

The TCSM arose from an "ophiolite" column of igneous rock layers formed from magma beneath the mid-Pacific Ocean (Hopson and Pessagno 2005). Mafic rocks such as basalt formed the submarine crust layer of the ophiolite. In the upper mantle below the crust, heavier ultramafic rocks predominated. Ultramafic peridotite, the basal rock portion of the ophiolite, metamorphosed gradually to serpentinite. As the ophiolite structure became jumbled by plate shifts and uplifts, the ophiolite structure disassembled into a mix (or mélange) of serpentinite rocks with blocks of basalt, chert, and slate intermixed. As the TCSM bedrock tilted to the east over millenia, the formation came to uplift and expose less weathered peridotite rock on the west side of the TCSM. Thus, greater serpentinite on the east side of Walker Ridge contrasts with more prevalent peridotite on the crest of Walker Ridge at the west watershed boundary.

Franciscan Metasedimentary Assemblage Bedrock

This bedrock type occupies only small zones at the western margin of Bear Creek watershed: just east of Walker Ridge (three zones) and east of Love Lady Ridge (one zone). These rocks have undergone extensive metamorphism and deformation (Bergfeld et al. 2001). Deposition layers of Pacific Ocean sediments in the Franciscan Metasedimentary Assemblage are jumbled, unlike the orderly pattern of the Great Valley Sequence petrofacies.

Franciscan Volcanics and Metavolcanics

Bedrock of volcanic origin occupies a small area in the northwest part of the watershed in Mill Creek subwatershed. The bedrock layer consists principally of volcanic breccias, conglomerate tuff, and basalt pillows. A small volcanic rock peak appears near the confluence of Sulphur Creek with Bear Creek. Other information about these bedrock types is not available.

*Bear Valley Alluvial and Terrace Sedimentary Bedrock*

The newest bedrock found in Bear Creek watershed began forming less than two million years ago on the Bear Valley floor. Sediment sources came from decomposed sedimentary rocks from the north and east sides of Bear Valley and from sediment derived mostly from ultramafic rocks on the west side Bear Valley. Characterization in detail of this complex bedrock unit has yet to be undertaken.

### *Rock Types Characteristic of Bear Creek Bedrock Units*

Appendix C provides information on the major rock types found in the watershed, their origin, and mineralogy.

### *Plate Tectonics and Geologic Faults*

Movement and deformation of the earth crust ("tectonics") is responsible for the diverse geology and landforms of Bear Creek watershed. The Pacific Plate and the associated Juan de Fuca, Kula, and Farallon plates have converged with the North American Plate and are moving underneath (subducting) the North American Plate, far beneath what is now the

North Coast Range. Subduction of the Pacific Plate has caused the plate crust to partially melt from the subterranean heat from the earth's core. In the submarine environment of the subduction, an ophiolite series of rock types develops from magma. Subsequent deformation of the earth crust by rock upthrust and folding has exposed the ophiolite rock sequence at the earth surface as the Tehama-Colusa Serpentinite Mélange.

The interface between the Coast Ranges and the Great Valley geomorphic provinces creates the Coast Ranges-Great Valley thrust fault system. A thrust faults results from compression where one rock layer pushes up and over another layer. Other faults are strike-slip faults where one rock formation slips past another. Regional faults mostly move ("strike") to the northwest, paralleling the course of the San Andreas Fault. Smaller cross, tear, and transverse faults lie at opposing angles to regional faults.

<u>The Stony Creek Fault</u>

The Stony Creek Fault creates a major divide in Bear Creek watershed. It comprises the contact that separates the TCSM on the west from the Stony Creek Petrofacies on the east. The zone around Wilbur Springs is the south terminus of this fault in Bear Creek watershed, but the fault reappears in the Knoxville region of Napa and Lake counties just south of the watershed (Sherlock 2005). The fault is nearly vertical. Contact is generally sharp, well-defined, and with little movement over geologic time. Earthquakes rarely occur along this fault.

<u>Coast Range Fault</u>

The Coast Range Fault appears at several sites on the west edge of the watershed to divide the TCSM from the Franciscan Formation volcanic and metavolcanic bedrock.

<u>Resort Fault</u>

The young, steeply dipping Resort Fault (Rytuba et al. 1993) passes on a northwest to southeast track through the TCSM and passes northeast of Wilbur Springs. Churchill and Clinkenbeard (2003) propose that this fault may have helped form the Rathburn-Petray mercury deposits.

<u>Little Indian Valley Fault</u>

This fault may be an important conduit for geothermal fluids and asociated thermal springs are areas of hydrothermal alteration and mercury mines (Churchill and Clinkenbeard 2003). It passes by Elgin Mine and Cherry Mine east to west through Sulphur Creek subwatershed.

Bear Fault

Slowey and Rytuba (2008) describe this newly discovered fault. This fault does not appear in Figure 2.14. It has led to a creation of a series of cold springs with high mercury content on the floor of Bear Valley.

***Clear Lake Volcanic Field***

Volcanic fields occur where the earth crust has melted repeatedly from heat in the earth's mantle or where opposing tectonic plates have stretched the earth's crust so that the earth mantle rises close to the earth surface. In the Coast Ranges Geomorphic Province, the crust is seldom so thin that the crust heats sufficiently to melt and to release lava. The major exception is the Clear Lake volcanic field, the center of volcanism in the Coast Range geomorphic province (Rytuba et al. 1993). The Clear Lake volcanic field has not been active for more than 10,000 years. On its southwest side, the Clear Lake volcanic field contains the Geysers Geothermal Field, the most economically important geothermal field in the world. At its eastern edge, the volcanic field affects the belowground crustal formation and geothermal properties of the western portion of Bear Creek watershed, especially Sulphur Creek subwatershed (Moiseyev 1968). The Clear Lake volcanic field supplies mineral deposits in the subwatershed, including mercury and gold, from magma that has cooled below the earth surface and become concentrated as deposits of rocks rich in minerals (Sherlock 2005).

## 2.7 Soils

Bear Creek watershed soils and their distribution in the landscape resemble those found elsewhere along the interface between the inner North Coast Range and the Central Valley from northern Solano County to southwest Shasta County. However, the watershed also has unique soils not known to occur elsewhere.

***Major Soil Series in Bear Creek Watershed***

Soils in the watershed are diverse and complex in their distribution. A total of 39 soil map units as defined by USDA NRCS soil scientists occur in Bear Creek watershed. Table 2.9 lists the nineteen principal map units which cover 96 percent of the watershed area, and Figure 2.15 displays the distribution of these soils. The most extensive single soil is the Millsholm series, encompassing 20 percent of the watershed. Henneke and Okiota soils, the two most common ultramafic soils, comprise together about 24 percent of the watershed area.

Some 20 other soil types occur as minor components of the watershed area and cover three percent of the watershed area. About one percent of soils are designated as unknown. Apart from Arand and riverwash, which are hydric soils, these minor soil series are not discussed further.

Appendix D provides a synopsis of comparable soil properties for the principal soil series in the watershed summarized from the official USDA NRCS monographs of each soil series available online at http://soils.usda.gov/technical/classification/osd/index.html. Distributions and topographic positions of the soil series specific to Bear Creek watershed landscape are also included.

Table 2.9 – Principal USDA soils series in Bear Creek watershed

| Soil Series | Percent Land Base | Acres |
|---|---|---|
| Millsholm | 20.6 | 13,350 |
| Henneke | 14.9 | 9,636 |
| Okiota | 9.6 | 6,200 |
| Skyhigh | 7.3 | 4,754 |
| Leesville | 7.0 | 4,558 |
| Venado | 4.8 | 3,124 |
| Montara | 4.8 | 3,089 |
| Contra Costa | 4.6 | 2,967 |
| Sleeper | 4.5 | 2,895 |
| Saltcanyon | 2.8 | 1,830 |
| Maymen | 2.1 | 1,359 |
| Sehorn | 1.9 | 1,263 |
| Etsel | 1.9 | 1,236 |
| Dubakella | 1.8 | 1,152 |
| Boar | 1.6 | 1,025 |
| Bear Valley | 1.5 | 945 |
| Livermore | 1.2 | 780 |
| Hillgate | 1.1 | 704 |
| Misc. Haploxererts | 0.9 | 683 |
| Others and Unknown | 4.1 | 2,676 |

Source: USDA, NRCS Colusa County Soil Survey (Reed 2006)

Note: Soils highlighted in yellow are ultramafic. The total number of acres does not equal the total surface area of the watershed because water bodies and rock outcrops are omitted from the acre tally.

### *Ultramafic Soils*

Ultramafic soils, including serpentine soils, derive from ultramafic parent rocks such as peridotite or metamorphosed ultramafic rocks such as serpentinite. These soils are globally rare, covering less than one percent of the earth surface but are significant in the North Coast Range of California including Bear Creek watershed. Brooks (1987) summarizes four traits common to ultramafic soils as follows:

- low concentrations of the plant macronutrients nitrogen, phosphorus, and potassium
- unusually high concentrations of elements such as nickel, cobalt, cadmium, chromium, and iron
- a high ratio of magnesium to calcium
- a specialized endemic flora that can tolerate the unusual chemistry of ultramafic soils.

In Table 2.9, soil series highlighted in yellow are ultramafic (or "magnesic") soils. These soils are major drivers in determining plant species composition and vegetation patterns, and ultimately the water chemistry and sediment beds of many watershed streams (Holloway et al. 2009a). Ultramafic soils comprise 42 percent of the surface area of the watershed, and ultramafic rock contributes an additional three percent to the ground surface of the watershed. The small amount of phosphorus in ultramafic soils reduces their fertility and usually makes them unsuitable for agriculture and forestry but often very productive for mining economically important metals such as chromium and nickel.

### *Hydric Soils*

The USDA NRCS defines hydric soils as soils "that formed under conditions of saturation, flooding or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (Hurt and Vasilas 2006). In Mediterranean climate zones, hydric soil types often have seasonal or spatial phases that are not hydric, depending on water table, flooding, and ponding characteristics of local sites. Areas with a water table within 50 cm (20 inches) of the soil surface are uncommon even during the winter (Figures 2.12a and 2.12b). Flooding is rare over most of Bear Creek watershed (Figure 4.6), and ponding is present only in very small areas of Bear Creek watershed. Figure 12 does not display several smaller but significant winter-season hydric areas in Bear Valley. Much of the historic hydric soil environment in the watershed (Rogers 1891) may have been lost in the late nineteenth century.

The indicators used to make onsite determinations of hydric soils are specified in "Field Indicators of Hydric Soils in the United States" (Hurt and Vasilas 2006). Hydric soil criterion 4 from the USDA NRCS (undated) qualifies these soils as hydric: "soils that are frequently

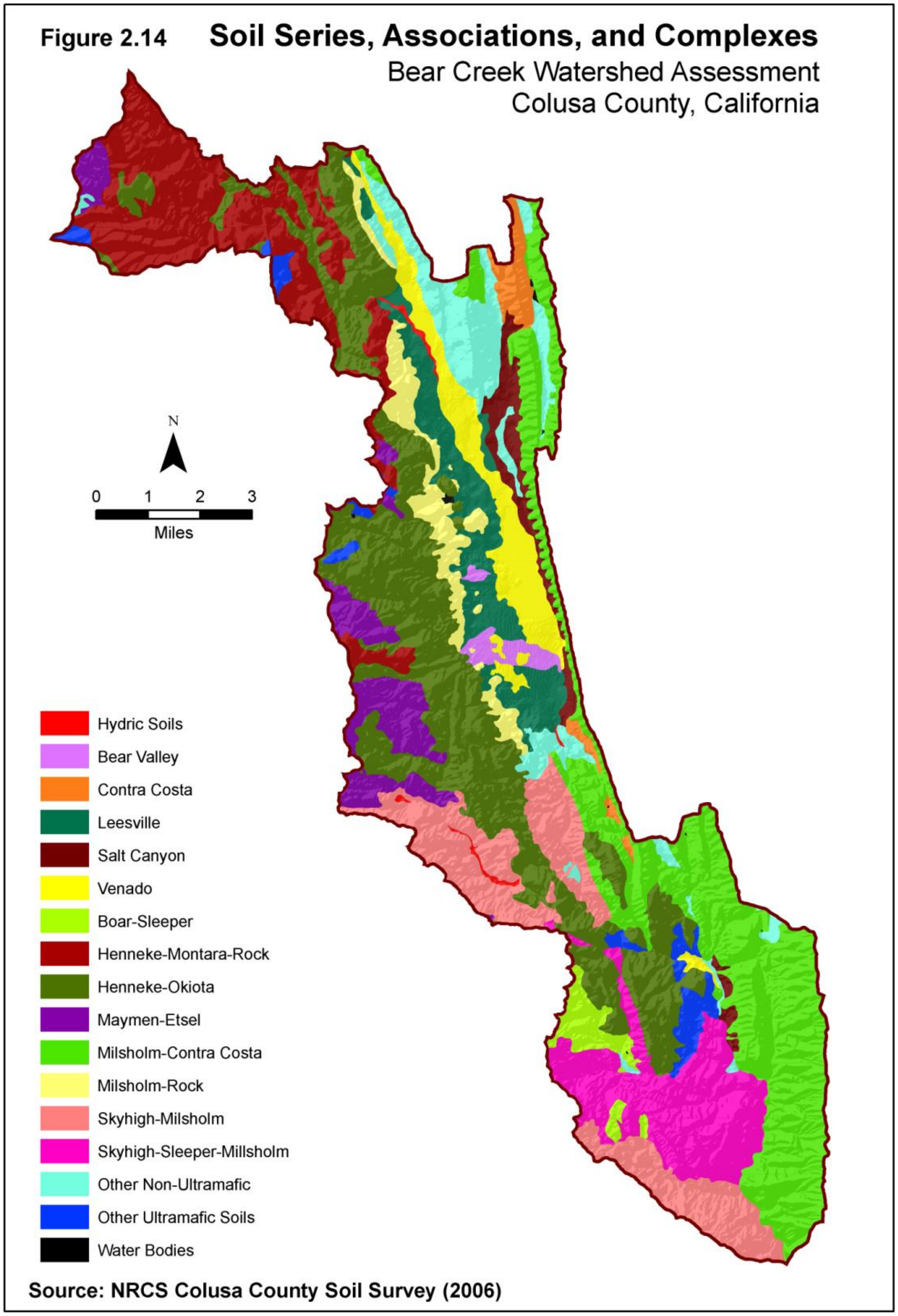


Figure 2.14 Soil Series, Associations, and Complexes
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Hydric Soils
Bear Valley
Contra Costa
Leesville
Salt Canyon
Venado
Boar-Sleeper
Henneke-Montara-Rock
Henneke-Okiota
Maymen-Etsel
Milsholm-Contra Costa
Milsholm-Rock
Skyhigh-Milsholm
Skyhigh-Sleeper-Millsholm
Other Non-Ultramafic
Other Ultramafic Soils
Water Bodies
Source: NRCS Colusa County Soil Survey (2006)

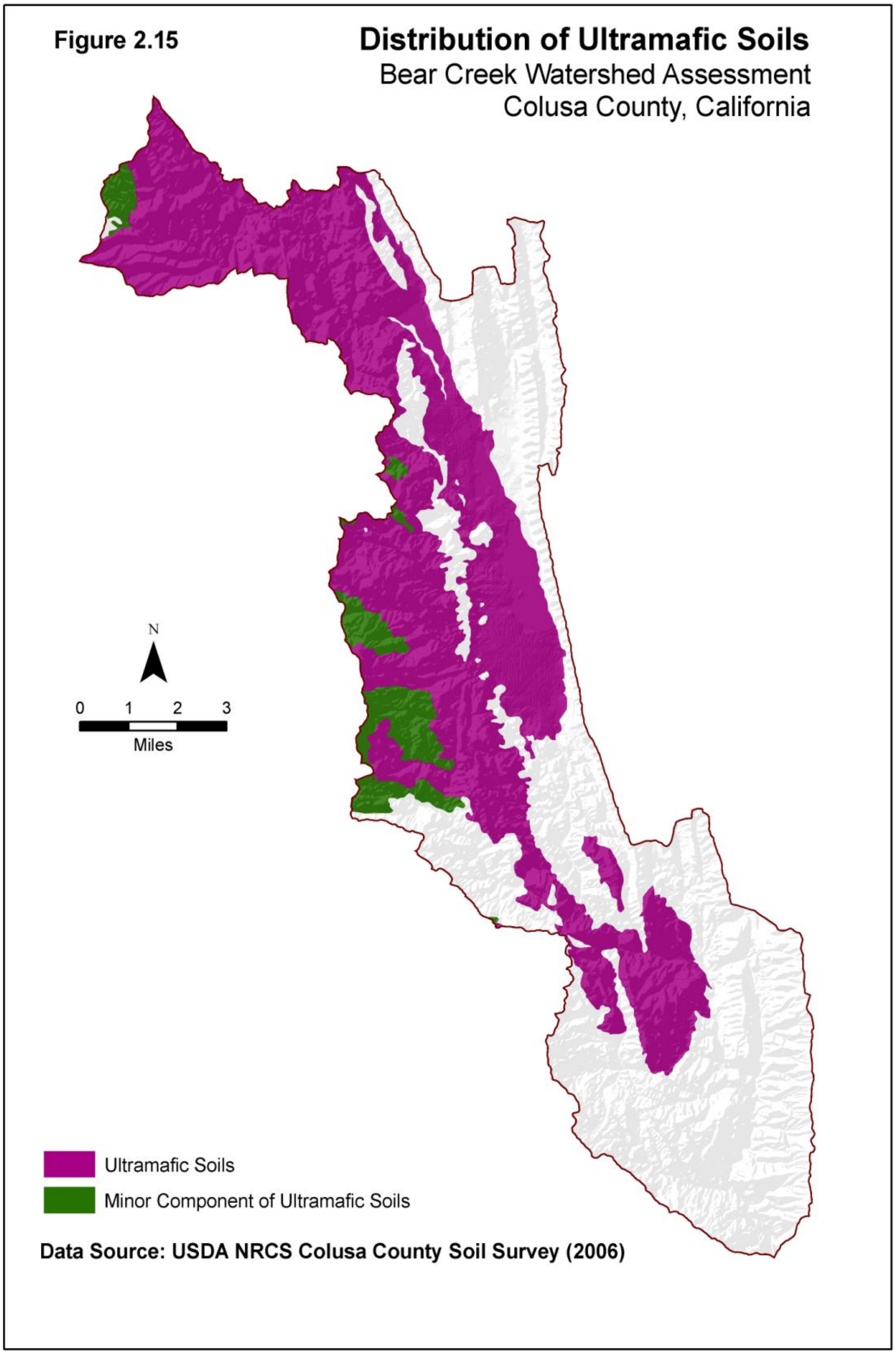


Figure 2.15
Distribution of Ultramafic Soils
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Ultramafic Soils
Minor Component of Ultramafic Soils
Data Source: USDA NRCS Colusa County Soil Survey (2006)

flooded for long duration or very long duration during the growing season.” Hydric soils in Bear Creek watershed include alluvial riverwash (unconsolidated alluvial materials along waterways not attributed to a specific soil series) and the Arand soil series. Riverwash soils are ultramafic, comprising a portion along Mill Creek west of Gravelly Buttes; and a very small area at the south end of Bear Valley along Bear Creek. Arand soils mixed with riverwash are typical of the stream corridor of Sulphur Creek in its mid-reach as the creek opens into a valley northwest of Wilbur Springs and in the vicinity of Eaton Springs. Soils in these locales are watered by perennial, comparatively slow-moving streams in nearly level terrain.

Ultramafic Venado clay soils may range from hydric to non-hydric depending on the location of the soil within Bear Valley, and approximately fourteen percent of the ultramafic Venado clay soils there are hydric (USDA Natural Resource Conservation Service 2009). A map of the exact extent of hydric Venado soils is not available.

Hydric soils are important because of their role wetland function, water storage, associated flora, and wildlife habitat. Anaerobic conditions in wetlands with hydric soils also create favorable environments for certain soil bacteria to “methylate”, i.e., add methyl ($-CH_3$) groups, to elements such as antimony, arsenic, and mercury to form organic compounds. These methylated compounds allow the toxic elements to be absorbed more readily into plants, aquatic organisms, and eventually people’s bodies. The restricted distribution of hydric soils in the watershed, their associated unusual vegetation, and potential for mercury methylation warrant their protection and careful management.

***Unique Soils***

Most ultramafic soils are found on steep and dissected terrain. The Bear Valley, Leesville, and Venado soil series are unusual as ultramafic soils in that they occur in flat terrain on the Bear Valley floor. These soils are blends of ultramafic and sedimentary materials and have a higher than average ratio of calcium to magnesium to qualify overall as ultramafic soils. Their hybrid origin makes the three ultramafic soils in Bear Valley noteworthy because these soils, unlike most other ultramafic soils, have supported agriculture – primarily livestock grazing – for over 150 years.

South of Highway 20 another ultramafic soil called only by its soil taxonomic name “Haploxererts, Unidentified” occupies about one percent of the watershed area. Much of the area covered with this soil consists of serpentine barrens, and recent botanical explorations indicate that this soil has many rare plant species and unusual plant alliances (E. Dean, UC Davis Herbarium, pers. comm.). In the remote Mill Creek subwatershed, ultramafic soils and a large barren have yet to be investigated.

Non-ultramafic Buttes soil formed from conglomerate rock is locally unique, limited to the Gravelly and Bear Valley buttes at the north end of the watershed. The soil has a coarser texture than other soils in the watershed. The island-like form of the buttes and the unusual soil host plant species and vegetation communities not found elsewhere in the watershed or elsewhere in the foothills of Colusa County (J. Alderson, pers. comm.).

***Information Needs***

Hydric soils are more widespread than indicated by the soil survey. Permanent wetlands are present on benches above the west side of Bear Valley, Walker Ridge, and the BLM Bear Creek Ranch. These ultramafic hydric soil sites are rare globally and deserve special study because of their unusual ecology. The little information available indicates that they support specialized plants species. Hydric soils and their wetlands are also important because they may be focal points for bacterial methylation of heavy metals. Information is incomplete about the locations and rates of methylation.

## 2.8 Geomorphology

Geomorphology is the study of the characteristics, origin, and development of landforms. Two parts of Bear Creek watershed are the focus for description and assessment of land forms: hill slopes and streambeds. The following subsections discuss these two processes and how they interact. Other environmental features that affect Bear Creek land forms include geologic faults, rock properties, topography, soils, climate, vegetation, and land uses. These features are described under their own separate headings in the assessment.

***Hill Slope Geomorphology and Mass Wasting***

Soil and rock become mobile when a disturbance such as an earthquake, cumulative wearing of rock faces, or a rainstorm overcome the cohesive physical or chemical forces in soil and rock. These materials move down slope at different rates, depending on gravitational force. Mass wasting may proceed as slow creep, a landslide, mud or debris flows, toppling, or falling. Where soil and rock come to rest and accumulate in the landscape, debris dams and talus piles may develop.

Two studies of landslides have considered parts of Bear Creek watershed. Manson (1989) mapped the southernmost part of Bear Creek watershed; few landslides had occurred on the Skyhigh and Millsholm soils in the area covered. Hoorn et al. (2008) interpreted aerial photographs between 1937 and 2005 to locate landslides and other earth movements in Bear

Creek watershed north of Highway 20. Landslides, most from natural causes, are not randomly or uniformly distributed in the watershed. Table 2.10 summarizes the distribution and magnitude of volumes of landslides north of Highway 20 by subwatershed.

Subwatersheds on the east side of Bear Valley (Hamilton, Hamilton Canyon, Leesville, Warnick Canyon) and at the north end of Walker Ridge (Doyle Canyon, Gaither Canyon, Robbers Flat, Stinchfield Canyon) have low frequency and volume of landslides. In the 22-year period between 1984 and 2005, the subwatersheds most prone to landslides have been Mill Creek (high frequency and high volume), Sulphur Creek (high frequency), and the main stem of Bear Creek, particularly in the canyon areas between Bear Valley and Highway 20.

Table 2.10 – Distribution and volume from landslides in Bear Creek watershed north of Highway 20

| Subwatershed | pre-1937 | | 1937-1984 | | 1984-2005 | |
|---|---|---|---|---|---|---|
| | landslides | sediment $yd^3$ | landslides | sediment $yd^3$ | landslides | Sediment $yd^3$ |
| Bear Creek, Lower | 5 | 42,887 | 4 | 19,799 | 8 | 14,593 |
| Bear Creek, Upper | 3 | 5230 | 0 | 0 | 4 | 12,622 |
| Deadshot Canyon | 4 | 102,166 | 0 | 0 | 4 | 3,963 |
| Doyle Canyon | 0 | 0 | 0 | 0 | 0 | 0 |
| Gaither Canyon | 1 | 793 | 0 | 0 | 2 | 2,874 |
| Hamilton | 0 | 0 | 0 | 0 | 1 | 1,039 |
| Hamilton Canyon | 0 | 0 | 1 | 23,728 | 1 | 734 |
| Leesville | 0 | 0 | 0 | 0 | 0 | 0 |
| Mill Creek | 26 | 117,775 | 2 | 14,703 | 8 | 30,260 |
| Robbers Flat | 0 | 0 | 0 | 0 | 2 | 7,508 |
| Stinchfield Canyon | 0 | 0 | 0 | 0 | 0 | 0† |
| Sulphur | 32 | 203,512 | 6 | 842 | 10 | 5,109 |
| Trout Creek | 5 | 26,727 | 4 | 30,090 | 5 | 3,524 |
| Warnick Canyon | 0 | 0 | 0 | 0 | 0 | 0 |

Source: Hoorn et al. (2008) $yd^3$= cubic yards

†One landslide in Robbers Flat occurred at the ridgeline with Stinchfield Canyon.

### *Gullies*

Gullies are erosion channels caused by runoff water becoming concentrated outside of stream banks. Hoorn et al. (2008) found that large gullies (49 in all) detected in Bear Creek watershed from aerial photographs are associated predominantly (84 percent) with human land uses, especially mining, road and trails, or water storage bodies such as stock ponds. The largest gully formations, however, all appear to be unrelated to land uses.

As human land uses in Bear Creek watershed have changed over time, causes of gullies and their accompanying sediment flows have changed over time. The locations of new gullies have shifted over time from steeper sites with chaparral vegetation to low-slope grasslands in recent years. This pattern coincides with the cessation of large-scale mining. With one exception, the largest gullies from mine sites originated before 1937, whereas the largest gullies appearing during the period 1984 to 2005 came from erosion in Upper Bear Creek rangelands.

***Stream Morphology***

Descriptions of stream channels for Bear Creek and its tributaries according to classification systems such as by Rosgen (1996) have occurred for small portions of Bear Creek, principally in Bear Valley (J. Alderson, pers. comm.). No historical photography or data are known to chronicle the change in streambeds although the streambeds in Bear Valley and in parts of Bear Creek Ranch have dropped over time (J. Alderson, C. Thomsen, pers. comm.). Channel cross sections of Bear Creek and its tributaries are not available for existing or past conditions from which to estimate bankfull water volume and model creek water flow. Table 2.11 depicts elevation changes with longitudinal sections for Bear Creek, Mill Creek, and Sulphur Creek.

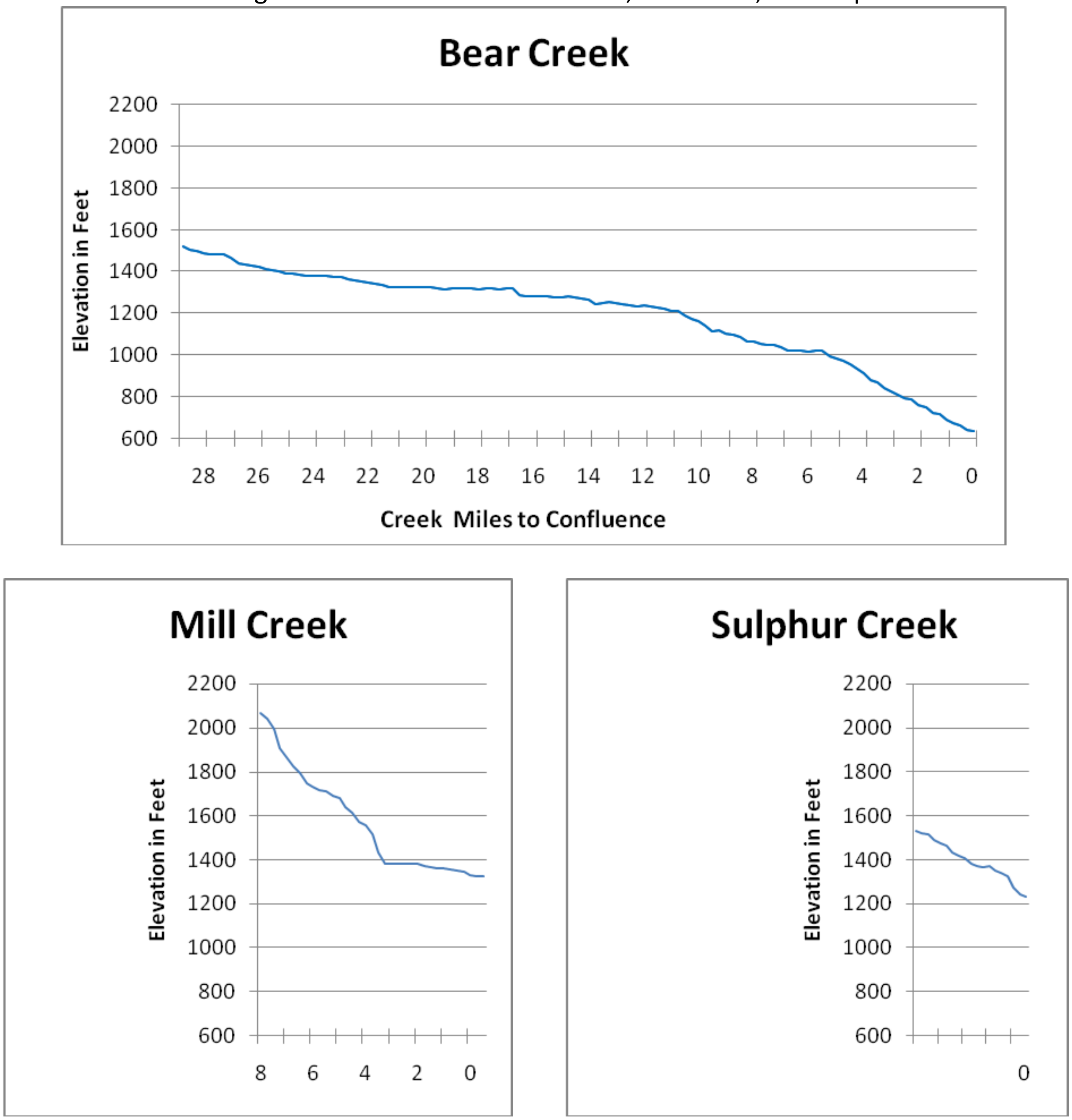
***Fluvial Geomorphology***

Sediment transported by slides and gullies contributes to sediment loads in streams and streambeds in Bear Creek and its tributaries. Sediment control in its own right is critical to water quality and stream and streambank function. Keeping sediment in place in the watershed for an extended time takes on added importance now that sediments derived from mercury-rich mine waste have caused Bear Creek and Sulphur Creek to be listed as impaired waters by the State Water Quality Control Board and the US EPA.

The environments most likely to exhibit changes in stream morphology, especially in sinuosity and shifting location, are the main stems of Bear Creek, Sulphur Creek, the lower reach of Mill Creek, and the creek in Long Valley near Leesville. These creeks pass through valley floor locations. As gullies and headcuts have been developing in these areas, alluvial soil, eroded from surrounding hillsides and deposited on valley floors, has become mobile once again and is entering the stream channel and moving downstream. Hoorn et al. (2008) estimated that the stock of stored sediment in floodplains of these creeks is declining over time and that the rate of decline may have been actually increasing in recent decades. Approximately 650,000 $yd^3$ were eroded from terraces and floodplains of Upper Bear Creek/Mill Creek in the 48 years between 1937 and 1984 (annual average 13,500 $yd^3$); for the 22-year period between 1984 and 2005, the net loss to erosion is estimated at 681,500 $yd^3$

(annual average 31,000 $yd^3$).

Table 2.11 – Longitudinal sections for Bear Creek, Mill Creek, and Sulphur Creek




Note: Data were interpolated using Google Earth with a standardized interpretative method. Bear Creek was tracked to its headwaters. Data for Mill Creek and Sulphur Creek track from their confluences with Bear Creek back to the point of confluence of their first major branch. Measures were at every quarter mile of creek length.

One symptom of undesired fluvial geomorphic change appears presently in Sulphur Creek above Wilbur Springs. Four headcuts have developed in the main stem since 1937, three of them since 1968. These nearly vertical downward shifts, ranging from two to eight feet, in the longitudinal profile of Sulphur Creek cause sudden jumps in the velocity of Sulphur Creek flow (Hoorn et al. 2008). The added power erodes adjacent banks and releases considerable sediment from the Arand and riverwash soils stored in the floodplain. These riparian and floodplain soils are known to contain, locally at least, high mercury concentrations. Hoorn et al. (2008) estimated that the volume of sediment from upstream migration of the two largest headcuts (moving 2,262 ft and 2,717 ft since 1937) have generated soil loss equal to 24,900 $yd^3$ of sediment since 1937; 19,900 $yd^3$ alone have been lost since 1968.

***Information Gaps***

Basic information on geomorphology would be helpful for planning potential watershed improvement projects, especially related to fluvial systems and hillslope stability:

- repeated field data collection for stream longitudinal sections and selected cross sections for Bear Creek and major tributaries, particularly from subwatersheds with ultramafic soils: Deadshot Canyon, Mill Creek, Sulphur Creek, and Trout Creek
- a model of the probable original structure of stream channels, banks, and floodplains as a basis for decision making about restoring the structure and function of streams
- a complete geological hazard map for the entire watershed to assist in better land use management and planning

## 2.9 Vegetation

Managing vegetation is essential for attaining watershed goals identified by stakeholders. Plant species, vegetation alliances/associations, and distribution patterns change markedly across Bear Creek watershed as a function of physical features, biological interactions, and disturbance history (including human land use). Vegetation influences hydrologic function, site stability, biological integrity, and water quality by moderating the impact of rainfall, holding soil in place, cycling nutrients, providing browse and forage for animals, habitat for wildlife, and storing carbon above and below ground. In large measure, vegetation also determines capability for land uses and needs for watershed management.

The Jepson Manual of Higher Plants of California (Hickman 1993) places Bear Creek watershed within the Inner North Coast Range subregion of the Northwest Region of the

California Floristic Province. This subregion extends from northwest Solano County to central Tehama County, along the east slopes of the Coast Range. Ultramafic rocks and soils are important for their role in providing unusual habitats for many species of rare plants and several animal species with restricted ranges.

Information about the flora of Bear Creek watershed to date covers parts of the watershed. Plants lists for specific areas are available for: the BLM Bear Creek Ranch (E. Dean, C. Thomsen, pers. comm.); the Bear Creek Botanical Management Area (C. Thomsen, pers. comm.); the lower drainage of Sulphur Creek subwatershed (Gennis and Associates 1978); and Walker Ridge and Bear Valley (Clark and Magney 1997, updated on line at http://www.sacvalleycnps.org/conservation/plantlists/BearValleyNosal.pdf).

***Vegetation Classification***

The CDFG leads the current effort to establish uniform and consistent standards, techniques, and documentation for classifying and mapping vegetation alliances and associations in California (Sawyer et al., 2009), consistent with national standards adopted by the Federal Geographic Data Committee. Using this classification protocol as a guide, Thorne et al. 2004 mapped the lands for the BLM Bear Creek Ranch consistent with the criteria for mapping habitats in nearby Napa County. The map is not presented here because it only covers part of the watershed and still requires groundtruthing.

Vegetation mapping with CalVeg 94 (Figure 2.16), the classification system developed by CALFIRE and the US Forest Service, covers the entire watershed. It has a forestry focus and only uses general categories to classify vegetation dominated by shrub and herbaceous plants. The “Lower Montane Chaparral” rubric in the vegetation classification system refers to the diverse serpentine, chamise, and mixed-species chaparral shrub vegetation found on most of the east-facing slopes from Walker Ridge and Mill Creek subwatershed. Riparian vegetation is not explicit in the vegetation map.

***Major Vegetation Alliances***

The wide range of environmental conditions in the watershed underlies the diversity of plant species and vegetation alliances present. Abrupt transitions in the chemical properties between adjoining sedimentary and ultramafic soils create differences in distributions of plant species and vegetation cover and in the appearance of landscapes. Ultramafic soils in Bear Creek watershed principally support chaparral shrublands, but also smaller areas of conifer woodlands, prairies, barrens, and wetlands. In contrast to sedimentary soils, the vegetation on ultramafic soils is often dwarfed, sparse in cover, reduced in overall species richness, and high in endemic species.

Appendix E describes the vegetation alliances known or suspected in the watershed, based on the California vegetation classification scheme established by Sawyer et al. (2009) plus notes on soils and environmental conditions (Reed 2006). Because mapping of vegetation alliances in Bear Creek watershed is incomplete, the presence of specific vegetation alliances and associations in the landscape remains uncertain. The large number of plant alliances in this comparatively small watershed underscores the high biological diversity in the watershed.

***Rare and Sensitive Plant Species***

No known federally listed plant species occur in Bear Creek watershed, but Indian Valley brodiaea (*Brodiaea coronaria* ssp. *rosea*), a State of California listed endangered species, is present in Bear Creek watershed. In addition, the California Native Plant Society (Rare Plant Database 2009) and databases from California herbaria have documented seventeen rare plant species (CNPS List 1B). Fifteen of these species are found on federal public lands and qualify as US Forest Service and BLM California Sentive Plant Species. Most rare species are found on ultramafic soils and most are annuals thought to require fire to spur seed germination.

Dr. Ellen Dean (per. comm.) is conducting a rare plant search of the areas covered by the four USGS quads that include and surround the watershed. Her botanical inventories thus far on the BLM Bear Creek Ranch have documented seven CNPS List 1B and eleven CNPS List 4 species. Habitats where these plants occur are displayed in the subwatershed analyses in Chapter 7. Section 2.11 provides greater detail on habitats set aside specifically to protect rare plant species and vegetation types.

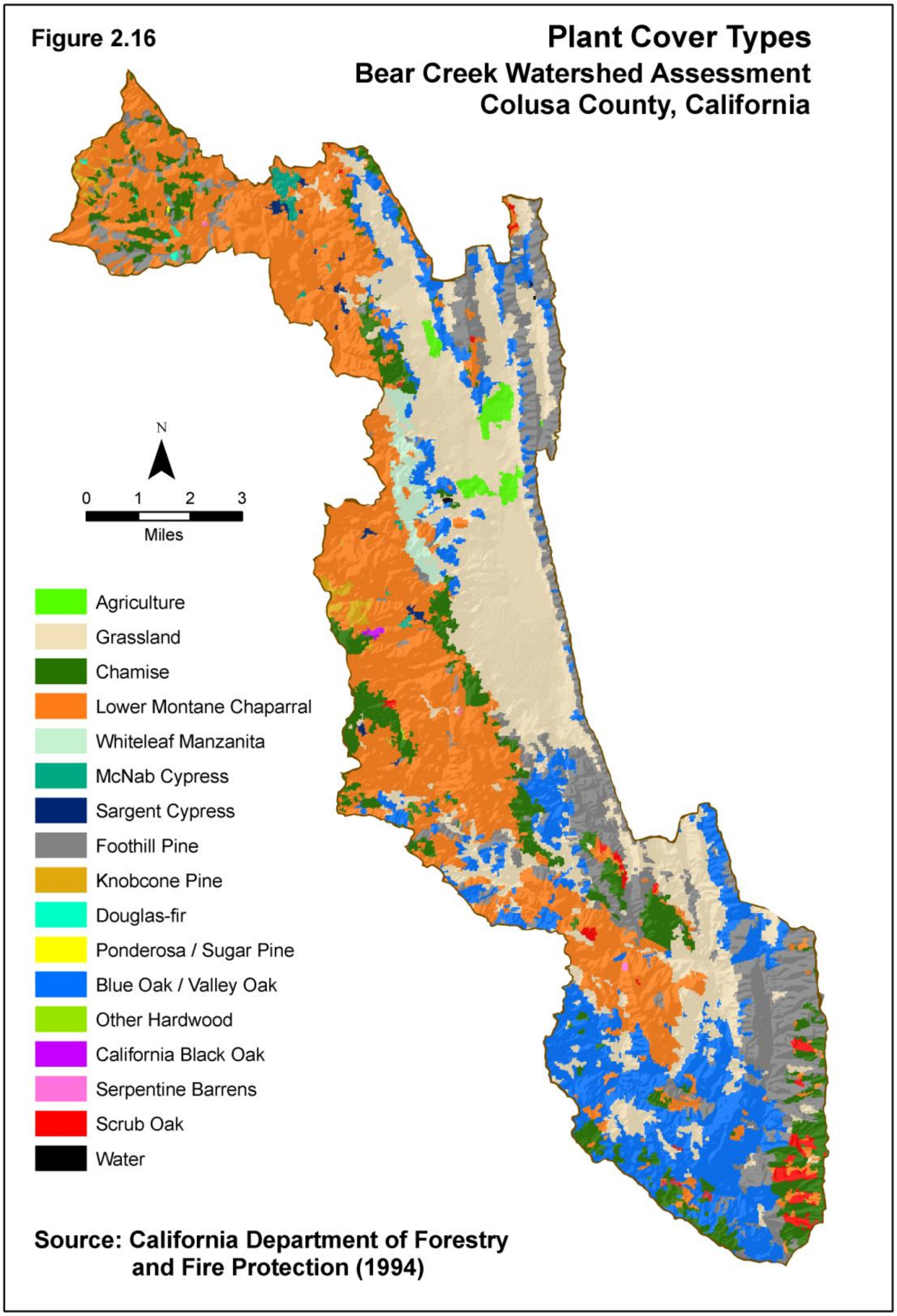


Figure 2.16
Plant Cover Types
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Agriculture
Grassland
Chamise
Lower Montane Chaparral
Whiteleaf Manzanita
McNab Cypress
Sargent Cypress
Foothill Pine
Knobcone Pine
Douglas-fir
Ponderosa / Sugar Pine
Blue Oak / Valley Oak
Other Hardwood
California Black Oak
Serpentine Barrens
Scrub Oak
Water
Source: California Department of Forestry and Fire Protection (1994)

Table 2.12 – Special status plant species in Bear Creek watershed

| Species | Listing Status | Habitat | Conservation Concerns | Management in the Watershed | Status |
|---|---|---|---|---|---|
| **Mosses** | | | | | |
| Norris' beard moss *Didymodon norrisii* Pottiaceae | CNPS List 2.2 | cypress woodland | habitat loss from the Walker Fire (2008); road maintenance and construction and wind energy development | No management to date | Distribution poorly known; habitat loss will likely mean popuation losses |
| **Dicots** | | | | | |
| Big-scale balsamroot *Balsamorhiza macrolepis* var. *macrolepis* Asteraceae | BLM SS USFS SS CNPS List 1B | chaparral, woodland, grassland, facultative on ultramafic soils | OHV trails through habitat, livestock grazing | Protected under management; no intervention to date | Recent searches have shown that this species occurs more widely than herbarium records indicate |
| Pappose tarplant *Centromadia parryi* ssp. *parryi* Asteraceae | BLM SS CNPS List 1B | chapparal, meadows, seeps, grassland | non-native invasive plants, livestock grazing, road maintenance | Protected under management; no intervention to date | No information on any changes to populations |
| Hall's harmonia *Harmonia hallii* Asteraceae | BLM SS CNPS List 1B | chaparral on ultramafic soils | mining operations and their legacies, wind energy development | Protected under management; no intervention to date | No information on any changes to populations |
| Colusa layia *Layia septentrionalis* Asteraceae | BLM SS CNPS List 1B | chaparral, woodland, grassland, on sandy ultramafic soils | none identified for the watershed | Protected under management; no intervention to date | No information on any changes to populations |
| Bent-flowered fiddleneck *Amsinckia lunaris* Boraginaceae | BLM SS CNPS List 1B | woodland, grassland | none identified for the watershed | Protected under management; no intervention to date | No information on any changes to populations |

| Species | Listing Status | Habitat | Conservation Concerns | Management in the Watershed | Status |
|---|---|---|---|---|---|
| Deep-scarred cryptantha<br>*Cryptantha excavata*<br>Boraginaceae | BLM SS<br>CNPS List 1B | woodland, on sandy or gravelly soil | none identified for the watershed | Protected under management; no intervention to date | No information on any changes to populations |
| Morrison's jewel-flower<br>*Streptanthus morrisonii*<br>Brassicaceae | BLM SS<br>CNPS List 1B | chaparral and cypress woodland on ultramafic soils | none identified for the watershed | Protected under management; no intervention to date | No information on any changes to populations |
| Sonoma canescent manzanita<br>*Arctostaphylos canescens* ssp. *sonomensis*<br>Ericaceae | BLM SS<br>CNPS List 1B | chaparral, facultative on ultramafic soils | wind energy development | Protected under management; no intervention to date | No information on any changes to populations |
| Jepson's milk-vetch<br>*Astragalus rattanii* var. *jepsonianus*<br>Fabaceae | BLM SS<br>CNPS List 1B | chaparral, woodland, grassland, facultative on ultramafic soils | wind energy development | Protected under management; no intervention to date | No information on any changes to populations |
| Cobb Mountain lupine<br>*Lupinus sericatus*<br>Fabaceae | CNPS List 1B | chaparral, woodland | geothermal development, road maintenance | Protected by CDFG | This population has been reported on private land in Sulphur Creek subwatershed. |
| Round-leaved filaree<br>*California macrophylla*<br>(=*Erodium macrophyllum*)<br>Geraniaceae | BLM SS<br>CNPS List 1B | woodland, grassland, often at seeps | none identified for the watershed | Protected under management; no intervention to date | More than 20 populations are present on Bear Creek Ranch. |
| Drymaria-like western flax<br>*Hesperolinon drymarioides*<br>Linaceae | BLM SS<br>USFS SS<br>CNPS List 1B | conifer woodlands, chaparral, grassland, on ultramafic soils | mining operations and off-road vehicles | Protected under management; no intervention to date | This species is known from Love Lady Ridge. |

| Species | Listing Status | Habitat | Conservation Concerns | Management in the Watershed | Status |
|---|---|---|---|---|---|
| Brandegee's woollystar<br>*Eriastrum brandegeeae*<br>Polemoniaceae | BLM SS<br>USFS SS<br>CNPS List 1B | chaparral, woodland on volcanic, sandy soils | livestock grazing, weed competition, off-road vehicles, road construction, energy development | Protected under management; no intervention to date | This species is known from Mill Creek subwatershed and has been recently found on Walker Ridge. |
| Snow Mountain buckwheat<br>*Eriogonum nervulosum*<br>Polygonaceae | BLM SS<br>USFS SS<br>CNPS List 1B | chaparral on ultramafic soils | energy development, mining, and off-road vehicles | Protected under management; no intervention to date | This species is known from the Frenzel Creek Research Natural Area at the edge of the watershed. |
| Bolander's horkelia<br>*Horkelia bolanderi*<br>Rosaceae | CNPS List 1B | chaparral, meadows, seeps, wet grasslands | none identified for the watershed | Protected by CDFG | The single record for this species in the watershed comes from the Leesville area in 1884. |
| Pink creamsacs<br>*Castilleja rubicundula* ssp. *rubicundula*<br>Scrophulariaceae | BLM SS<br>CNPS List 1B | openings in chaparral, meadows, seeps, grassland, on ultramfic soils | livestock grazing, mining, off-road vehicles, and road construction | Protected under management; no intervention to date | No information on any changes to populations |
| **Monocots** | | | | | |
| Indian Valley brodiaea<br>*Brodiaea coronaria* ssp. *rosea*<br>Liliaceae | BLM SS<br>USFS SS<br>CA Endangered | knobcone pine woodland, chaparral, grassland on ultramafic soils | off-road vehicles, dumping, wind energy development, illegal plant collecting | Protected under management; the BLM established the Indian Valley ACEC to protect this species | Populations may be declining but no monitoring data are available. |
| Adobe lily<br>*Fritillaria pluriflora*<br>Liliaceae | BLM SS<br>CNPS List 1B | chaparral, woodland, grassland, often on adobe-like soils | livestock grazing, off-road vehicles, mining, wind energy development, non-native invasive plants | Protected under management; no intervention to date | No information on any changes to populations |

Sources: California Native Plant Society (2009), Jepson Herbarium Consortium (2009), CalFlora (2009); BLM wind energy leases database (2009)

***Culturally Important Native Plant Species***

Bear Creek watershed is part of the ancestral lands of the Southern Wintun (Patwin) people. Two rancherias are near the boundary of Bear Creek watershed: the Cortina Band of Wintun Indians of California and the Yoche Dehe Wintun Nation. The ethnobotanical studies of Wintun people have focused on Wintun bands at the north end of the Sacramento Valley (Merriam 1966, Johnston 1973). Little is known about historic plant uses (M. Kat Anderson, pers. comm.) of the Hill Patwin people who resided in the watershed, and a complete list of plant foods was never obtained (Johnson 1978). Moreman (undated) lists the following major plant species found in Bear Creek watershed known to be used by neighboring tribes in the inner North Coast Range:

Food: blue, scrub, and valley oak (*Quercus douglasii, Q. dumosa*, and *Q. lobata*) acorns; blackberries (*Rubus* spp.); native grape (*Vitis californica*); elderberry (*Sambucus nigra*); foothill pine (*Pinus sabiniana*) nuts; manzanita (*Arctostaphylos* spp.) berries; biscuitroots (*Lomatium* spp.); yampahs (*Perideridia* spp.); native clovers (especially *Trifolium fucatum*); many bulbs ("onions") in the lily family; and saltgrass (*Distichlis spicata*) burned to obtain salt.

Basketry: redbud (*Cercis canadensis*)

Weaponry: chamise (*Adenostoma fasciculatum*) for bows and arrows

Medicinal/Cosmetic: wavyleaf soap plant (*Chloragalum pomeridianum*)

Apart from hunting and gathering, Southern Wintun people actively managed native grasslands in Bear Valley by burning for forage attractive to game species. Particular species were cultivated such as soap plant by breaking off stems, replanting root crowns, sowing seeds, and burning to stimulate growth and seed production. Also, valley oak woodlands and savannahs were traditionally managed to promote tree vigor by reducing the shrub understory and to encourage the growth of herbaceous plants that provided seeds and bulbs (Anderson 2005).

***Range Improvement Species***

People have introduced many range plants in Bear Creek watershed as animal forage and for erosion control. Among introduced grass and legume species are: tall fescue (*Schedonorus phoenix*), hardinggrass (*Phalaris aquatica*), orchardgrass (*Dactylis glomerata*), rye grasses (*Lolium* spp.), rose clover (*Trifolium hirtum*), birds-foot trefoil (*Lotus corniculatus*), and vetches (*Vicia* spp.) (Harradine 1948, Harrison et al. 2006). Tall wheatgrass (*Thinopyrum* *ponticum*), now a prominent invasive weed in Bear Valley and lower Bear Creek, was originally introduced for livestock production in Bear Valley. Smilograss (*Piptatherum miliaceum*), originally introduced for re-seeding burned over chaparral lands, has been observed spreading along the Sulphur Creek corridor, and is locally common in some drainages on the BLM Bear Creek Ranch. After a chaparral site dominated by chamise burned in the summer of 1998, smilograss flourished at the site in the spring of 1999.

***Non-Native Invasive Plant Species***

Non-native invasive plant species are a major issue for Bear Creek watershed stakeholders. These species, often introduced to provide economic benefits to people, may eventually entail high economic costs to eradicate or control their populations and to restore sites to native vegetation and productivity. Adverse impacts encompass increased competition with native plants, habitat degradation for land uses, genetic stock alterations, and changes to soil properties (Drenovsky and Batten 2007). Controlling plant invasions is at the core of protection of biological diversity and ecosystem productivity in the watershed.

Table 2.13 provides background information on the major non-native invasive plants in Bear Creek watershed. The most abundant upland noxious weeds are: barb goatgrass (*Aegilops triuncialis*), medusahead (*Taeniatherum caput-medusae*), and yellow starthistle (*Centaurea solstitialis*), but many other non-native grasses and forbs have also helped change the character of the pre-European native grassland-prairie communities and blue-oak woodland understory. Perennial pepperweed (*Lepidium latifolium*), small-flowered tamarisk (*Tamarix parviflora*), and tall wheatgrass are the dominant riparian weeds along the Bear Creek corridor. Section 5.3 Aquatic Biological Data presents more information on riparian and aquatic invasive species.

Some parts of Bear Creek watershed harbor more non-native plants than others. For example, non-native grasses and yellow starthistle predominate in many parts of Bear Valley after 150 years of agriculture, but chaparral vegetation on undisturbed sedimentary upland soils has few non-native invasive plant species (Harrison et al. 2003). Generally, where soil disturbances from land use have been less intensive, non-native plants invade less readily. Vegetation management is particularly important for controlling non-native plants along corridors such as roads and trails and riparian areas. Bulldozed fire lines are now a prominent feature in the watershed. These soil disturbances coupled with wildfire have the potential to accelerate the rate of spread of non-native plants into previously unoccupied chaparral habitats.

With their unusual chemistry and low human use, ultramafic soils and vegetation have been been historically resistant to non-native plant invasions. Few exotic invasive species have acclimated to chaparral vegetation sites on ultramafic soils in Bear Creek watershed. Annual non-native grasses and forbs from the Mediterranean basin are present but are much less extensive than in grasslands on non-ultramafic soils (Harrison et al. 2003). However, yellow starthistle, barb goatgrass, and bromes (*Bromus* spp.) are locally abundant on abandoned mine sites and livestock rangeland (Gelbard and Harrison 2003, 2005). Limited knowledge about best vegetation restoration practices for ultramafic soils makes controlling plant invasions difficult at present.

Table 2.13 – Invasive plants in Bear Creek watershed with ratings from the California Integrated Plant Council and the California Department of Food and Agriculture (CDFA), status, and preliminary management recommendations

| USDA Common Name, Scientific Name, and Family | Impacts | Invasiveness | Distribution | CDFA weed rating | Occurrence and Abundance | Preliminary Management Recommendations | Resource value |
|---|---|---|---|---|---|---|---|
| **Dicots** | | | | | | | |
| Poison hemlock *Conium maculatum* Apiaceae | B | B | B | - | A riparian species, occasional in moist disturbed areas | No action recommended | Pollinator support |
| Hedgeparsley *Torilis arvensis* Apiaceae | C | B | B | - | Common, but no apparent impacts | No action recommended | - |
| Italian thistle *Carduus pycnocephalus* Asteraceae | B | B | A | C | Occasional in disturbed areas | No action recommended | Pollinator support |
| Tocalote *Centaurea melitensis* Asteraceae | B | B | B | C | Occasional in grasslands and oak woodlands | No action recommended | - |
| Yellow starthistle *Centaurea solstitialis* Asteraceae | A | B | A | C | One of the most abundant noxious weeds in grasslands, forming dense, spiny canopies in summer. Known also from ultramafic sites such as Rathburn-Petray mines, the Bear Valley floor, and Bear Creek Botanical Management Area. | Nearly all treatments should be regarded as suppression because the species is widespread and its seedbank is persistent. Protection of non-target plant species is recommended when Transline is used. Current grazing practices appear ineffective and are probably leading to increases. The BLM has used an integrated approach, using prescribed burns and Transline applications to suppress this plant. Thomsen and Alderson have also reduced populations along Sulphur Creek. | Pollinator support, forage value before becoming spiny |
| Smooth cat's ear *Hypochaeris glabra* Asteraceae | C | B | B | - | Occasional to locally common | No action recommended | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Black mustard<br>*Brassica nigra*<br>Brassicaceae | B | B | A | - | Occasional in disturbed areas | No action recommended | - |
| Field mustard<br>*Brassica rapa*<br>Brassicaceae | C | B | B | - | | | - |
| Hoary cress<br>*Cardaria draba*<br>Brassicaceae | B | B | B | B | Rare, only known from Cowboy Camp on the BLM Bear Creek Ranch | Control efforts are warranted, although it is probably not highly invasive here with its current limited occurrence. | - |
| Summer mustard<br>*Hirschfeldia incana*<br>Brassicaceae | B | B | A | - | Occasional | No action recommended | - |
| Perennial pepperweed<br>*Lepidium latifolium*<br>Brassicaceae | A | A | A | B | A riparian species, increasing along Bear Creek and often the dominant in deep, moist soils; locally abundant in the BLM Bear Creek Ranch in the Cowboy Camp meadows and at "Road Kill Café". 40+ patches documented as a recent arrival in Sulphur Creek valley. Current status in Bear Valley along Bear Creek is unknown, although it was rare in 2001. This species also occurrs on ultramafic soils. | This is a priority species for control but controlling its rapid spread is difficult. Prompt response could contain the Sulphur Creek population. This species is the likely replacement plant once tamarisk is eradicated and when no active native plant revegetation follows. The most effective herbicide, Telar, is not registered for riparian settings. Control efforts are necessary in upper riparian zones on Bear Creek Ranch where rare and unusual plants occur. | Pollinator support and additional study needed to better understand its ecological impact beyond displacing native plants |
| Common teasel<br>*Dipsacus fullonum*<br>Dipsacaceae | B | B | B | - | Occasional to locally abundant on moist sites, especially along Bear Creek near Highway 20 and east along Highway 20, also Sulphur Creek Valley near the spring below Manzanita Mine | No action recommended | Pollinator support |
| Bird's foot trefoil<br>*Lotus corniculatus*<br>Fabaceae | D | B | B | - | A riparian species abundant along Bear Creek in moist floodplain and swales | No action recommended | Pollinator support and host plant for lycaenid butterflies |
| Bur medic<br>*Medicago polymorpha*<br>Fabaceae | C | C | A | - | Occasional, impact minor | No action recommended | Forage value |
| Sweet clover<br>*Melilotus officinalis* (= *M. alba*)<br>Fabaceae | D | C | C | - | A riparian species common along Bear Creek | No action recommended | Forage for tule elk. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Rose clover *Trifolium hirtum* Fabaceae | C | B | B | - | Uncommon, minor impact | No action recommended | - |
| Hairy vetch *Vicia villosa* Fabaceae | D | C | B | - | Locally abundant along Bear Creek and in its floodplain and some upland settings, especially in wet years. | No action recommended | Some forage value |
| Redstem filaree *Erodium cicutarium* Geraniaceae | C | C | A | - | Widespread | No action recommended | Forage value |
| Cutleaf geranium *Geranium dissectum* Geraniaceae | C | B | A | - | No obvious impact | No action recommended | - |
| White horehound *Marrubium vulgare* Lamiaceae | C | C | B | - | Uncommon, impacts minor | No action recommended | - |
| Curly dock *Rumex crispus* Polygonaceae | C | C | A | - | Widespread in grasslands and meadows | No action recommended | - |
| Tree of heaven *Ailanthus altissima* Simaroubaceae | B | B | B | C | Present along Bear Valley Road in the canyon between Bear Valley and Highway 20, forming single-species stands | Controlling with applications of appropriate herbicides oncut stumps or hack-and-squirt to reach the root system occurs late in the growing season. Establishing a dense canopy of native tree species needs to follow eradication to shade out any further tree of heaven seedlings. | - |
| Small-flowered tamarisk *Tamarix parviflora* Tamaricaceae | A | A | B | B | A riparian species, with heavy infestations along Bear Creek with Sulphur Creek as the original source of the infestation | Source population along three miles of Sulphur Creek is controlled; currently, some spot treatments are needed to remove seedlings. Herbicide residues can limit revegetation for at least four years. Control has led to rapid breakdown of some tamarisk hummocks and sediment release to streams. Downstream biocontrol is promising but not yet certain. If a biocontrol program is successful, most herbicide use is not warranted. | Early season pollinator support, cover and perching value for birds |
| **Monocots** | | | | | | | |
| Barbed goatgrass *Aegilops triuncialis* Poaceae | A | A | B | B | Abundant in Bear Valley and expanding on the BLM Bear Creek Ranch, especially on ultramafic soils. Still relatively rare on west side of the ranch. Only one known location within Sulphur Creek valley. | Controlling newly established populations is a high priority. Ongoing surveillance is necessary. | Some forage value to livestock, especially germinating seeds |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Giant reed<br>*Arundo donax*<br>Poaceae | A | B | A | B | Locally present in Bear Valley and along Highway 20 on the east side of the watershed | Cut or mow mature stems in the fall, apply herbicide to stems, leave stalks on the ground, apply herbicide to new shoot growth not suppressed by overlain dead mature stems 3 to 12 weeks later | Commercially grown for musical instrument reeds and structural material |
| Slender wild oat<br>*Avena barbata*<br>Poaceae | B | B | A | - | Common in grasslands | Prescribed burning and livestock grazing may be warranted in some sites to reduce thatch buildup. | Forage value |
| Wild oat<br>*Avena fatua*<br>Poaceae | B | B | A | - | | | |
| Ripgut brome<br>*Bromus diandrus*<br>Poaceae | B | B | A | - | Occasional to common in grasslands | No specific action recommended, although prescribed burning and livestock grazing may be warranted in some sites to reduce thatch. | Forage value prior to flowering |
| Soft brome<br>*Bromus hordeaceus*<br>Poaceae | B | C | A | - | Common in grasslands | | Forage value |
| Red brome<br>*Bromus rubens*<br>Poaceae | A | B | A | - | Common in grasslands | No action recommended | - |
| Bermuda grass<br>*Cynodon dactylon*<br>Poaceae | B | B | B | C | A riparian species abundant along Bear Creek, mixed in with native grasses such as saltgrass, creeping wildrye (*Leymus triticoides*), and scratch grass (*Muhlenbergia asperifolia*)) | Control without significant damage to non-target plants is unlikely; thus no action is recommended. | - |
| Seaside barley<br>*Hordeum marinum*<br>Poaceae | B | B | A | - | Locally abundant | No action recommended | - |
| Mediterranean barley<br>*Hordeum murinum*<br>Poaceae | B | B | A | - | | | |
| Italian ryegrass<br>*Lolium multiflorum*<br>Poaceae | B | B | A | - | A serious weed in moist areas. | Prescribed burning and livestock grazing may be warranted in sites to reduce thatch and seed output. Four years of prescribed burning on the Bear Creek Botanical Management Area did not reduce abundance. | Forage value |
| Harding grass<br>*Phalaris aquatica*<br>Poaceae | B | B | B | - | Limited, locally abundant at one stock pond | Control with glyphosate at pond sites to reduce its presence. | Forage value for livestock and probably tule elk. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Smilo<br>*Piptatherum miliaceum*<br>Poaceae | C | B | B | - | Increasing along Sulphur Creek, occasional along Bear Creek, and locally abundant after fires in chaparral; abundant downstream along Cache Creek in scoured floodplain settings. | Gather more information about distribution and abundance. | - |
| Ravenna grass<br>*Saccharum ravennae*<br>Poaceae | B | A | C | | Rare, thus far only known from Craig Canyon where the BLM has grubbed it out. However, it is abundant downstream along Cache Creek. Infestations are coming from North Fork Cache Creek. | Follow-up monitoring is needed. Individual plants are easy to grub out. A 3-percent glyphosate solution prior to fall dormancy is effective. | - |
| Tall fescue<br>*Schedonorus phoenix*<br>Poaceae | B | B | A | - | Locally dense stands along Bear Creek in several locations. Probably many more undocumented locations along Bear Creek floodplain. | Control with early fall applications of glyphosate, combined with native plant revegetation in specific zones on the BLM Bear Creek Ranch. | - |
| Medusahead<br>*Taeniatherum caput-medusae*<br>Poaceae | A | A | A | C | Widespread in grasslands and understory of blue oak woodland. Along with yellow starthistle, this is the most common weed on non-ultramafic soils. It forms dense thatch due to high silica content in flower heads that resists decomposition. | Prescribed burns are the most effective means of controlling large infestations. Livestock trampling breaks up thick layers of thatch and closely timed, intensive grazing reduces seed output. | Some forage value, prior to flowering |
| Tall wheatgrass<br>*Thinopyrum ponticum*<br>Poaceae | - | - | - | | This riparian species, now a major weed along Bear Creek, affects all zones along the riparian corridor It is not yet recognized by Cal-IPC as an invasive weedy species | Priority action is needed to protect prairie remnants and riparian sites. The relative ease of controlling parent plants justifies a control program with spot applications of glyphosate. Reinfestation from upstream sources will be an ongoing issue. Failure to act will continue the loss of native plants along Bear Creek. Thousands of plants have been removed manually by conservation crews at Cowboy Camp and in revegetation research sites. This rapidly spreading plant occurs where perennial pepperweed is absent. | Some forage value, although often avoided due to coarse, "stemmy" growth. Mowed by ranchers to remove old material and to stimulate fresh culm developement |
| Rattail fescue<br>*Vulpia myuros*<br>Poaceae | B | B | A | | Abundance unknown | Suppress | - |

California Invasive Plant Council Ratings: A = Severe, B = Moderate, C = Limited in California

California Department of Food and Agriculture Ratings: "A" – Eradication, containment, rejection, or other holding action at the state and county level. "B" – Eradication, containment, control or other holding action at the discretion of the commissioner. "C" – State endorsed holding action and eradication only when found in a nursery; action to retard spread outside of nurseries at the discretion of the commissioner

### *Exotic Plant Pathogens*

No evidence for sudden oak death caused by the root fungus *Phytophthora ramorum* exists in Colusa County oak woodlands as of 2006 according to the OakMapper database (California Oak Mortality Task Force, undated). Meetemeyer et al. (2004) state that woodlands in western Colusa County are too dry to support *P. ramorum*; thus the risk of sudden oak death in Bear Creek watershed is low.

No other exotic insect, bacterial, fungal, and non-native parasitic plant species are known to be problematic in the watershed.

### *Information Gaps*

Gaps in information about vegetation are having a significant impact on outcomes for land management in Bear Creek watershed. Addressing the following information gaps would assist land managers and property owners to increase land productivity or recover native vegetation and watershed processes:

- developing ecological site descriptions of the vegetation associated with the soil mapping units found in Bear Creek watershed from the Colusa County Soil Survey (Reed 2006) to correlate presence of major plant species with soils
- mapping of native and non-native vegetation alliances described in Sawyer et al. (2009) for the entire watershed, with special attention to delineating plant alliances on ultramafic soils
- continuing systematic surveillance and mapping of non-native invasive plants for GIS analysis and restoration planning
- surveying and documenting the flora of Walker Ridge and upper Mill Creek subwatershed, with special emphasis on locating US Forest Service and BLM sensitive plant species.

## 2.10 Wildlife

In keeping with federal and California state agency mandates for protecting and enhancing native biological diversity, public land managers manage species and habitats to ensure their long-term viability. Wildlife species are important for ecological services that they provide, such as subsistence food production, recreational opportunities for hunting, nature tourism, and wildlife viewing.

This section covers both invertebrate species (mollusks and insects) and vertebrate species (fish, amphibians, reptiles, birds, mammals). Species of major interest are special-status species and game species. To assist habitat planners, this section also presents a table that relates special-status wildlife species to the plant and aquatic communities identified and mapped in the 1994 version of CalVeg. Information on focal aquatic species used in water quality monitoring appears in Section 5.3.

***Special-Status Species: Sensitive Species and Species of Special Concern***

In addition to animal species listed as threatened or endangered under the Federal Endangered Species Act or the California Endangered Species Act, BLM and the US Forest Service compile lists of sensitive species. These species receive special management protection from the agencies to ensure that federal land management actions do not contribute to the species becoming listed under endangered species acts.

The California Department of Fish and Game (CDFG) also maintains an equivalent list of "species of special concern". Species of special concern are undergoing long-term declines in California or already have small populations that put them at risk of. The Department also has a category of "fully protected animals" that may not be hunted or captured at any time except for permitted scientific research and animal relocation.

***Significant Invertebrates***

A full discussion of all terrestrial invertebrates in Bear Creek watershed is beyond the scope of this assessment. However, the role of invertebrates in the watershed can be profound. For example, the grasshopper *Melanoplus devastator* can multiply to huge populations. The capacity of the species to defoliate vegetation in some years can cause yellow starthistle to fail to bloom (J. Alderson, pers. comm.). Several classes of invertebrate species are important because of their remarkable diversity in the watershed or their importance to agriculture.

*Dragonflies and Damselflies (Class Odonata)*

Bear Creek is an important hotspot of diversity for dragonflies and damselflies (Odonata) that has national attention (K. Biggs, pers. comm.). Forty-eight dragonfly and damselfly species are known to occur at Bear Creek, comprising 42 percent of all the species found in California. The City of Williams, east of Bear Creek, was chosen as the site of the 2003 Annual Meeting of the Dragonfly Society of the Americas because of its proximity to Bear Creek. One hypothesis for this high diversity of dragonflies is the diverse range of water chemistry and varied aquatic habitats available for larval dragonflies in Bear Creek watershed. None of the Odonata species found in Bear Creek watershed are listed as part of the CDFG's Special Animals list (2008). Researchers have conducted multiple studies on dragonflies and damselflies (Grether 1996, Luttbeg et al. 2009, Switzer and Grether 2000) located in the watershed.

*Butterflies (Class Lepidoptera)*

Eighty-five butterfly species (80 confirmed and five more expected) occur in Bear Creek watershed (Arthur Shapiro pers. comm.). Several butterfly species are the only known pollinators of several plant species limited to ultramafic soils (Shapiro and Manolis 2007), particularly in the genera *Eriogonum* (buckwheats) and *Lomatium* (biscuitroots). Maintaining populations of plants limited to rare soils and their butterfly pollinators is a core task of biodiversity conservation.

*Threatened, Rare, and Endemic Insects and Mollusks*

The Federal Endangered Species Act lists one insect, the Valley elderberry longhorn beetle, which may occur in the watershed. The BLM in California includes no additional insect or other invertebrate species among its sensitive species for special management. The US Forest Service, Pacific Southwest Region, has recently updated its sensitive species category in California to include invertebrate species that merit conservation management (J. Furnish, pers. comm.); however, no Forest Service sensitive invertebrate species are definitely known from US Forest Service lands in Bear Creek watershed.

The CDFG (Biogeographic Data Branch 2009) has prepared a list of special animals that includes rare and endemic insects and other invertebrates in California. One of these, the serpentine cypress wood-boring beetle, is present on BLM public lands and is very likely in the National Forest lands in the watershed. Table 2.14 lists invertebrate species known to occur or suspected to occur in Bear Creek watershed. In November 2008, shells of a mollusk, the California floater (*Anodonta californiensis*), were found in Bear Creek along Bear Valley Road. This species has all but disappeared from National Forests in California (J. Furnish, pers. comm.).

Four special environments host endemic invertebrate species in Bear Creek watershed: the Bear Creek riparian and aquatic corridor; the springs of Sulphur Creek subwatershed; the Sulphur Creek riparian corridor; and the MacNab cypress (*Cupressus macnabiana*) woodlands on Walker Ridge.

Table 2.14 – Threatened, rare, and endemic invertebrate species in Bear Creek watershed

| Order | Family | Common Name | Scientific Name | Federal Protection Status | California Protection Status |
|---|---|---|---|---|---|
| **Mollusks** | | | | | |
| Unionoida (Freshwater Mussels) | Unionidae | California floater | *Anodonta californiensis* | USFS Sensitive Species | None |
| **Insects** | | | | | |
| Coleoptera (Beetles) | Buprestidae | Serpentine cypress wood-boring beetle | *Trachykele hartmani* | None | None |
| | Cerambycidae | Valley elderberry longhorn beetle | *Desmocerus californicus* ssp. *dimorphus* | Threatened | None |
| | Hydraenidae | Wilbur Springs minute moss beetle | *Ochthebius recticulus* | None | None |
| Diptera (Flies) | Ephydridae | Wilbur Springs shore fly | *Paracoenia calida* | None | None |
| Hemiptera (True Bugs) | Saldidae | Wilbur Springs shorebug | *Saldula usingeri* | None | None |

Valley Elderberry Longhorn Beetle (VELB)

VELB is known to occur 3.5 miles southeast of the south end of the watershed in the Capay Valley, Yolo County. Biologists from the US Fish and Wildlife Service have observed markings on plants at Wilbur Hot Springs, thought to be VELB exit holes (C. Thomsen, pers. comm.).

Elderberry (*Sambucus nigra* = *S. mexicana*) shrubs are critical to the life cycle of VELB and is one of few native shrubs that regenerate in Bear Creek riparian zones under the canopy of dead tamarisk shrubs after herbicide treatments (C. Thomsen, pers. obs.). Collinge et al. (2001) found that VELB thrives in dense clumps of elderberries having branches two to four inches thick at a foot or more aboveground. Holyoak and Koch-Munz (2008) found that VELB populations are higher in mature elderberry sites with some dead and damaged stems from animal browse and flooding. Expanding elderberry shrub cover along Bear Creek as tamarisk control proceeds may promote VELB conservation. Details of habitat size, water flow and flood pattern, and time needed to grow elderberry shrubs suitable for VELB are critical for successful riparian restoration and VELB conservation (Talley 2007).

Serpentine Cypress Wood-Boring Beetle

The habitat of this species consists of native cypress trees on ultramafic soils in the Interior Coast Range from Napa to Colusa counties. In Bear Creek watershed, this species occurs on Walker Ridge in stands of McNab cypress. Because it is restricted to cypress trees, this species is especially vulnerable to habitat changes, such as the stand-replacing 2008 Walker fire.

Endemic Insects in the Vicinity of Wilbur Springs

Three insect species are known only from the vicinity of Wilbur Springs. These species have evolved to adapt to the unusual chemical and temperature conditions at spring sites and creek waters in Sulphur Creek subwatershed.

The Wilbur Springs minute moss beetle inhabits the edges of Sulphur Creek. A major threat to this species would result from unintended consequences of management of the creek margin, for example, placing large riprap pieces over the side of Wilbur Springs Road for bank stabilization along Sulphur Creek. The CDFG lists no records for this species more recent than 1971.

The Wilbur Springs shore fly is endemic to Wilbur Springs and favors water temperatures between 20 and 40°C flowing from that complex of springs. Changes in the spring flow and water use could eliminate this highly restricted species. Scientists have not formally documented the presence of this species since 1984.

By contrast the Wilbur Springs shorebug occurs more widely at multiple thermal and cold springs and their effluent areas in the Sulphur Creek watershed, even being adapted to sites with very high sodium and lithium concentrations in spring water (Resh and Sorg 1983). One major prey species for the Wilbur Springs shorebug is the Wilbur Springs shore fly. The shorebug derives its fluids by preying on the larvae of the shore fly rather than from direct consumption of spring waters with their high chemical ion content (Resh and Barnaby 1987). Development of geothermal energy at hot springs may adversely impact populations of the shorebug and the shore fly if management practices are not in place to protect species habitat. The latest museum specimen of this species is from 1979. This species was the first invertebrate species to be proposed as federally listed threatened or endangered species in the United States (New 1995).

***Special-Status Vertebrate Species***

Table 2.15 lists all special-status vertebrate species known from Bear Creek watershed. The table summarizes required habitat features for the species, stakeholders' concerns, and the status of species populations and their habitats. The following is a description of watershed issues and land uses that may affect the conservation of these species.

*Special-Status Fish Species*

There are no special-status fish species in Bear Creek watershed. Dr. Peter Moyle, however, considers Bear Creek a rare aquatic ecosystem, in part due the intact populations of resident native fishes. Unusual water chemistry in many parts of the watershed may be an important factor to limiting the invasion of non-native fishes and keeping the natural assemblage of native fishes intact in the watershed.

*Special-Status Amphibians and Reptiles*

One special-status amphibian and one special-status reptile occur in the watershed: foothill yellow-legged frog *(Rana boylii*) and western pond turtle (*Actinemys marmorata*), respectively. Foothill yellow-legged frogs appear to be absent from the lower reach of Sulphur Creek but are present in Bear Creek and its other tributaries. Watershed residents have noted western pond turtles using the Sulphur Creek bed as a travel corridor during seasons with low water flow.

The following watershed issues may affect populations of these species in Bear Creek.

<u>Toxic Chemicals</u> High loads of mercury and perhaps other toxic elements in Bear Creek and its tributaries may reduce survival, inhibit growth, and impair reproduction of amphibians (Unrine et al. 2004). Tadpoles consume algae and invertebrates from creek beds and take in mercury at the same time. Adults consume invertebrates, mostly insects, many of which may have larval stages that inhabit streambeds and accumulate mercury that they pass on to adult frogs. Tissue samples gathered from all foothill yellow-legged frogs in Harley Gulch immediately west of Bear Creek watershed had concentrations of methylmercury in excess of the US EPA criterion for issuing human health advisories about fish consumption (Hothem 2008).

<u>Sediment Delivery</u> Western pond turtles deposit their eggs in stream banks that may eventually erode so that the banks are out of reach for turtle use. High sediment loads may degrade water quality and foraging habitat for yellow-legged frog tadpoles.

Non-Native Species Bullfrogs (*Lithobates catesbeianus*) predate very young western pond turtles and all life stages of foothill yellow-legged frogs. Non-native sunfish prey on the frog and may limit frog populations. No information is available about the presence of non-native aquatic fungi in Bear Creek watershed that are lethal to foothill yellow-legged frogs.

Climate Change A drying climate may reduce the amount of permanent water available as suitable habitat for frogs and turtles in Bear Creek and its tributaries.

The land uses that are potentially harming aquatic amphibians and reptiles include: mining (mercury legacy), agriculture (sedimentation, altered stream channels), recreation (habitat disturbance, pet trade), and transportation (vehicle collision, habitat fragmentation).

*Special-Status Birds*

Eagles, falcons, kites, and owls, all collectively known as "raptors," comprise a large portion of special-status birds found in the watershed. One raptor bird species that occurs in the watershed is Swainson's hawk (*Buteo swainsonii*) is a State of California endangered species and a BLM sensitive species. The hawk recently nested just north of Bear Creek watershed (California Natural Diversity Database 2009). This species could occur in grasslands and foothill woodland in Bear Valley and in the Leesville area.

Other noteworthy breeding birds, indicative of the diversity of habitats in the watershed, include common merganser (*Mergus merganser*), spotted sandpiper (*Actitis macularius*), and greater roadrunner (*Geococcyx californianus*). The first two species nest along lower Bear Creek in the BLM Bear Creek Ranch. Roadrunners, thought of usually as desert birds, occur in the foothill woodland and open chaparral habitat in the watershed. The local population is one of the few remaining in the inner North Coast Range in northern California. Notable large flocks of long-billed curlews (*Numenius americanus*) overwinter on ranch lands in Bear Valley.

Land Uses Potentially Harming Bird Species

The following existing land uses have the potential to harm birds: agriculture (habitat disturbance), forestry (tree cutting), mining (mercury poisoning), recreation (habitat disturbance, falconry), and transportation (road kills). Development of wind energy on Walker Ridge may cause mortalities to raptor birds, some of which are species of concern for the CDFG.

*Special-Status Mammals*

The special-status mammals are poorly known in Bear Creek watershed. Three of the species are nocturnal: Townsend's big-eared bat (*Corynorhinus townsendii*), pallid bat (*Antrozous pallidus*), and ringtail (*Bassaricus astutus*). The other special-status mammal, American badger (*Taxidea taxus*) occurs with a low population density in Bear Valley so that monitoring and field studies for badgers are difficult.

The first Townsend's big-eared bat population noted in Sulphur Creek subwatershed was in 1966 (P. Leitner, pers. comm.). Two hundred bats were noted at that time at the colony site, and Pierson and Rainey (1998) found 145 bats at the same site, indicating that the colony had remained intact between 1966 and 1994. The colony is part of the inner North Coast Range population subgroup which is one of the four remaining strongholds for these bats in California. Bats are using abandoned mines for summer roosts, and hibernating bats have been found in three features (Pierson 1988).

<u>Land Uses Potentially Harming Mammal Species</u>

The following land uses may be impact mammals: agriculture (habitat disturbance or creation), forestry (tree cutting/habitat loss), recreation (habitat disturbance, pet trade), and transportation (road kills, habitat fragmentation)

*Crosswalk of Habitats of Species of Concern and CalVeg Vegetation Communities*

Managing the habitats of species of concern is an important element of a conservation strategy in the watershed to sustain species populations. Wildlife biologists work to maintain the landscape pattern of connectivity and patch sizes of key habitats to maintain the life histories of animal species of concern. The US Forest Service in California has developed a crosswalk between the habitat types specified by the California Wildlife Habitat Relationships from Zeiner et al. (1988 – 1990) and vegetation types mapped in the CalVeg database (1994 version). Table 2.16 presents the crosswalk for Bear Creek watershed animal species of concern by CalVeg habitat types.

***Sport Fish and Game Species***

A major management focus for public lands in Bear Creek watershed is development and conservation of game species. The CDFG stocks both native and non-native fish and game species. Information on hunting is part of the Section 3.8 (Recreation and Tourism). The most detailed analysis of the distribution of game species in the area comes from Mann (1974) and the BLM (1982).

*Sport Fish*

Information on past fish stocking is not available. Trout of uncertain origin have been present in Mill Creek and Trout Creek, and local anglers fished these creeks in past decades (J. Garr, pers. comm.). The present status of trout stocking and persistence of populations is unclear.

*Game Birds*

The following game bird species are present in the watershed: wild turkey (*Meleagris gallopavo*), mountain quail (*Oreotyx pictus*), California quail (*Callipepla californica*), band-tailed pigeon (*Patagioenas fasciata*), and mourning dove (*Zenaida macroura*). Quail and mourning dove forage most commonly in chaparral, tamarisk thickets, and open oak woodland edge. Band-tailed pigeons frequent oak woodland and riparian woodland corridors. Wild turkeys are not native to California, but the CDFG has introduced them to diversify game bird species. Turkeys now thrive in oak woodlands where acorns are a favored food source.

*Black-tailed Deer (Odocoileus hemionus)*

Bear Creek watershed occupies part of the regional range of the East Park – Capay deer herd. The herd ranges from western Solano County north to the Glenn-Tehama county line west of Interstate 5, covering approximately 1,286 square miles. Historically, the total deer herd population reached more than 11,000 in 1960 and then again in 1968. A strong downturn in population numbers led to fewer than 2,300 animals by 1973 (Thornton et al. 1983). Livestock grazing is the dominant land use in the herd's range. Competition with livestock, loss of oak woodlands for habitat cover and acorns (a major fall food source), fire suppression and resulting loss of regenerating shrub and grass species, and urbanization are thought to have been causes of the population decline. Major animal predators are coyotes (*Canis latrans*), feral dogs (*C. lupus familiaris*), and mountain lions (*Puma concolor*).

Management for deer habitat emphasizes prescribed burning particularly in chamise-dominated chaparral and protecting oak woodlands (Thornton et al. 1983). Since the downturn in the early 1970s, more intensive herd management has allowed the East Park – Capay deer herd to stabilize. At the south end of the BLM Bear Creek Ranch that burned a decade ago, deer are thriving in the patches of mixed chaparral and oak woodland (J.Alderson, pers. comm.).

*Tule Elk (Cervus elaphus nannodes)*

Overhunting long ago extirpated tule elk from Bear Creek watershed. Today's elk herds originated from animals imported from Monterey County in 1922 by the CDFG (McCullough et al. 1996). With assistance from the Rocky Mountain Elk Foundation and the CDFG, tule elk are once again thriving in the area. Two elk herds use the watershed: the Cache Creek herd in the southern third of the watershed and the East Park herd in the northeast corner of the watershed at Leesville. The hunting zone for the Cache Creek herd coincides with the boundary of the Cache Creek Natural Area (Figure 2.17).

The BLM Cache Creek elk herd management plan emphasizes prescribed burning to improve browse for elk in chamise chaparral and mixed chaparral habitats, some of which may be overdue for burning according to the expected fire-return cycle (BLM 1985). Currently, off-highway vehicles and most cattle grazing are kept away from rutting and calving areas for the Cache Creek elk herd. Restoration of native willows and cottonwoods to the riparian zone of lower Bear Creek is also a cornerstone of enhancing elk habitat in the watershed. To date, however, efforts to reestablish them have not been possible because of heavy beaver and elk browsing on young plants. Since acquisition of the Bear Creek Ranch, the BLM focuses on developing alternate water sources for tule elk from ponds designed originally for domestic livestock.

The Bureau of Reclamation is the lead agency in managing the East Park elk herd on public lands. The objective of the elk habitat at East Park Reservoir is to create attractive wetland and marsh areas so that tule elk remain off of private ranch lands (TetraTech undated). A full management plan for the East Park herd is not yet in place.

The Cache Creek herd, managed by the CDFG, ranges across approximately 100,000 acres of oak woodland, grassland, and chaparral habitat in Colusa, Lake, and Yolo counties. Historical data indicate that the Cache Creek herd has remained stable in the long term as the January 1985 helicopter survey similarly showed a total of 167 animals (BLM 1985), in line with results from 2005 and 2008.

In most years, the CDFG surveys the two elk herds by helicopter both inside and outside the watershed. Table 2.17 displays results of recent helicopter surveys for the two herds that use the watershed.

Table 2.15 – Special-status vertebrate species

| Species | Protection Status | Habitat | Concerns | Management in the Watershed | Population Status |
|---|---|---|---|---|---|
| **Amphibians** | | | | | |
| Foothill yellow-legged frog<br>*Rana boylii*<br>Ranidae | BLM SS<br>CA SSC<br>FS SS | Resides in sites with permanent water, without highly unusual chemical properties. Feeds on algae, invertebrates, and detritus | Predation by bullfrogs, loss of permanent habitat from stream alterations and long-term drought | Development projects in the ten-year floodplain of the watershed require a permit. | Populations appear robust at present in contrast to many other sites. |
| **Reptiles** | | | | | |
| Western pond turtle<br>*Actineyms marmorata*<br>Emydidae | BLM SS<br>CA SSC<br>FS SS | Resides near permanent water. Nests are in nearby uplands and require soil moisture and depth > 4” | Trapping for the pet trade, loss of high-quality habitat and water quality | Required permit for development projects in the ten-year floodplain of the watershed | Western pond turtles appear to have stable numbers. |
| **Birds** | | | | | |
| White-tailed kite<br>*Elanus leucurus*<br>Accipitridae | BLM SS<br>CA<br>Fully Protected | Nests and roosts in dense tree stands. Forages in open grasslands, meadows, and wetlands. Feeds on rodents. | Shooting, loss of woodland cover for nest sites | Conservation easements on private lands | Now more common than a century ago, kites are most frequent in Bear Valley |
| Bald eagle<br>*Haliaeetus leucocephalus*<br>Accipitridae | BLM SS<br>CA<br>Endangered<br>FS SS | Roosts in large trees and snags, often next to creeks. Forages along creeks for fish. | High mercury content of prey fish, loss of woodland cover for roosting sites, shooting | Conservation of all large oaks on public lands; conservation easements on private lands | The non-breeding foraging population uses the lower Bear Creek corridor most frequently. The population is stable. |
| Golden eagle<br>*Aquila chrysaetos*<br>Accipitridae | CA<br>Fully Protected | Ranges widely to hunt in foothill and grassland terrain. Nests on cliffs and in oak stands. | Shooting, loss of undisturbed habitat for nesting, potential mortality from wind energy projects | Conservation easements on private lands | Nesting status is not known at present. |

| Species | Protection Status | Habitat | Concerns | Management in the Watershed | Population Status |
|---|---|---|---|---|---|
| Prairie falcon<br>*Falco mexicanus*<br>Accipitridae | CDFG locally significant | Nests on cliffs and in large trees in open areas. Ranges widely to hunt in foothill and grassland terrain. | Trapping for captive use in falconry; shooting; potential mortality from wind energy projects | Conservation easements on private lands | This species nests in the watershed. Its numbers are thought to be stable. |
| Long-billed curlew<br>*Numenius americanus*<br>Scolopacidae | CDFG locally significant | Winters on grasslands in Bear Valley and the BLM Bear Creek Ranch. Feeds on insects, spiders, and other invertebrates. | Shooting, globally small population, loss of breeding habitat | Conservation easements on private lands | Between 50 and 150 birds overwinter in the watershed. Population numbers are thought to be stable. |
| Long-eared owl<br>*Asio otus*<br>Strigidae | CA SSC | Nests in abandoned nests of other large birds near or in riparian zones. Feeds on rodents, occasionally other birds. | Long-term population decline | Conservation of all large oaks on public lands; conservation easements on private lands; required permit for development projects in the ten-year floodplain of the watershed | Information on population trend in the watershed is not available. |
| Burrowing owl<br>*Athene cunicularia*<br>Strigidae | BLM SS<br>CA SSC | Nests in burrows or culverts in drier grasslands in Bear Valley. Hunts day or night for rodents. | Shooting, strikes from motor vehicles, large reduction in breeding population across California | Conservation easements on private lands | This species nests in the watershed. Population numbers over the years are not documented. |
| Loggerhead shrike<br>*Lanius ludovicianus*<br>Lanidae | CA SSC | Nests in dense shrubs or trees in grassland and woodland habitats. Feeds on insects, occasionally other small vertebrates | Large reduction in breeding population in northern California | Conservation easements on private lands | This species nests in the watershed. Population numbers over the years are not documented. |

| Species | Protection Status | Habitat | Concerns | Management in the Watershed | Population Status |
|---|---|---|---|---|---|
| **Mammals** | | | | | |
| Pallid bat<br>*Antrozous pallidus*<br>Vespertillionidae | BLM SS<br>CA SSC | Forages in dry, open habitats; roosts in cliffs, caves, and mines most commonly | Human disturbances at roosts cause bats to abandon sites; loss of native grassland habitat | Conservation easements on private land | Recorded in Sulphur Creek subwatershed (Gennis and Associates 1978). Current population status is unknown. |
| Townsend's nig-eared bat<br>*Corynorhinus townsendii*<br>Vespertillionidae | BLM SS<br>CA SSC<br>FS SS | Roosts where young are nursed are using caves and abandoned mines with warm temperatures; winter hibernation takes place in cold-temperature caves and mines. | Human disturbances at roosts cause bats to abandon sites; scarcity of suitable habitat; steep decline in populations throughout California | Appropriate bat gating for the species undertaken by the private landowner; conservation easements on private land | First studied by Leitner (pers. comm.) and Pierson (1988). Population appears to be stable. |
| American badger<br>*Taxidea taxus*<br>Mustelidae | CA SSC | Burrows in easily dug out soils. Forages widely in woodland, chaparral, and grasslands for prey, mostly consisting of rodents. | Trapping and poisoning; requirement for large range; low population density | Conservation easements on private lands | No information is available on population trends. |
| Ringtail<br>*Bassariscus astutus*<br>Procyonidae | CA<br>Fully<br>Protected | Inhabits riparian areas where trees and shrubs are plentiful. Rears young and hides in crevices, tree cavities, and burrows | Trapping for the pet trade | Conservation of all large oaks on public lands; conservation easements on private lands; required permit for development projects in the ten-year floodplain of the watershed | No information is available on population trends. |

**Abbreviations:** BLM SS = Bureau of Land Management Sensitive Species in California, CA SSC = California Department of Fish and Game Species of Special Concern, FS SS = US Forest Service Sensitive Species in California

**Sources:** California Department of Fish and Game (CDFG) and Paul Hofmann, CDFG associate wildlife biologist (pers. comm.); Bureau of Land Management (BLM) California State Office and Gregg Mangan, BLM Cache Creek Natural Area Manager (pers. comm.); and US Forest Service, Region 5

Table 2.16: Crosswalk between California Wildlife Habitat Relationships and CalVeg habitat types for animal species of concern in Bear Creek Watershed

| Species | Annual Grass / Forb | Blue Oak | Interior Live Oak | Foothill Pine | Knobcone Pine | McNab Cypress | Sargent Cypress | Tule - Cattail | Wet Meadows | Pastures and Crop Agriculture | Agricultural Ponds, Water Features | Ceanothus Chaparral | Chamise Chaparral | Lower Montane Mixed Chaparral | Manzanita Chaparral | Scrub Oak | Perennial Herbs | General Water | Riparian Mixed Shrub |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| California floater | | | | | | | | | | | | | | | | | | x | |
| Serpentine cypress wood-boring beetle | | | | | | x | x | | | | | | | | | | | | |
| Valley elderberry longhorn beetle | | | | | | | | | | | | | | | | | | | x |
| Wilbur Springs minute moss beetle | | | | | | | | | | | | | | | | | | x | |
| Wilbur Springs shore fly | | | | | | | | | | | | | | | | | | x | |
| Wilbur Springs shorebug | | | | | | | | | | | | | | | | | | x | |
| Foothill yellow-legged frog | | | | | | | | x | x | | x | | | | | | | x | x |
| Western pond turtle | | | | | | | | x | x | | x | | | | | | | x | x |
| Golden eagle | x | x | | | | | | | | | | | | x | | | x | | |
| White-tailed kite | x | x | x | | | | | | x | x | x | | | | | | x | | x |
| Bald eagle | | x | x | x | | | | | | | | | | | | | | x | x |

| Species | Annual Grass / Forb | Blue Oak | Interior Live Oak | Foothill Pine | Knobcone Pine | McNab Cypress | Sargent Cypress | Tule - Cattail | Wet Meadows | Pastures and Crop Agriculture | Agricultural Ponds, Water Features | Ceanothus Chaparral | Chamise Chaparral | Lower Montane Mixed Chaparral | Manzanita Chaparral | Scrub Oak | Perennial Herbs | General Water | Riparian Mixed Shrub |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Prairie falcon | x | x | | | | | | | x | x | x | | | | | | x | | |
| Long-billed curlew | x | | | | | | | | x | x | x | | | | | | x | x | |
| Long-eared owl | | x | x | x | x | x | x | | x | | | | | | | | | | x |
| Burrowing owl | x | | | | | | | | x | x | | | | | | | x | | |
| Loggerhead shrike | x | | | | | | | | x | x | | | | | | | x | | |
| Pallid bat | | x | x | x | x | x | x | | | | | x | x | x | x | | | x | x |
| Townsend's big-eared Bat | | x | x | x | x | x | x | | | | | x | x | x | x | | | x | x |
| Ringtail | | x | x | x | x | x | x | | | | x | x | x | x | x | x | | | x |
| American badger | x | x | | | x | x | x | | | x | | | x | | | | x | | |

Source: USDA Forest Service, Pacific Southwest Region (2004)

*Pronghorn (Antilocarpa americana)*

Pronghorn, also known as "antelope", was once a common species in Bear Valley, as the Antelope Valley northeast of Bear Valley attests. Efforts regionally sponsored by the CDFG are underway to reintroduce pronghorn into the Inner North Coast Range landscape. Surviving animals from a herd released east of Cortina Ridge (Paul Hofmann, pers. comm.) eventually left the area, migrating north to Willows in Glenn County. Otherwise, pronghorn have been absent from the watershed in recent times.

*Other Game Animals*

Mann (1974) lists the following game animals as popular for hunting in the region: brush rabbit (*Sylvilagus bachmanii*), black-tailed jackrabbit (*Lepus californicus*), western gray squirrel (*Sciurus griseus*), coyote, gray fox (*Urocyon cineroargenteus*), black bear (*Ursus americanus*), raccoon (*Procyon lotor*), bobcat (*Lynx rufus*), and wild pig (*Sus scrofa*).

Table 2.17 – Helicopter surveys of elk herds in Bear Creek watershed

Cache Creek Elk Herd Survey Results

| Year | Bulls | | | | Total Bulls | Cows | Calves | Total Elk |
|---|---|---|---|---|---|---|---|---|
| | Yearling | Raghorn | Mature | Unk | | | | |
| 2005 | 9 | 0 | 37 | 1 | 47 | 85 | 24 | **156** |
| 2006* | 5 | 5 | 18 | 0 | 28 | 46 | 17 | **91** |
| 2008 | 9 | 9 | 17 | 0 | 35 | 110 | 42 | **187** |

East Park Elk Herd Survey Results

| Year | Bulls | | | | Total Bulls | Cows | Calves | Total Elk |
|---|---|---|---|---|---|---|---|---|
| | Yearling | Raghorn | Mature | Unk | | | | |
| 2005 | **no data** | | | | | | | |
| 2006 | 9 | 10 | 16 | 0 | 35 | 19 | 15 | **69** |
| 2008 | 6 | 8 | 21 | 0 | 35 | 39 | 21 | **95** |

The 2006 Cache Creek Herd data included only the elk located in Bear Creek watershed and the North Fork Cache Creek watershed.
Source: Joe Hobbs (pers. comm.), associate wildlife biologist, CDFG

Although listed as a California species of special concern by the CDFG, the Department also allows trapping of American badger. Beaver (*Castor canadensis*) may also be trapped. Trappers used to "cache" or hide their beaver pelts along creeks in the region, hence the name for Cache Creek (G. Mangan, pers. comm.).

*Stakeholder Issues in regard to Large Game Animals*

Stakeholders value large game animals in Bear Creek watershed. The major concerns for stakeholder issues are:

Fire Lack of fire in oak woodlands and chaparral reduces the available forage and browse for large game animals such as elk and deer. By reinstating fire regimes more similar to a historical pattern through prescribed burning, elk and deer may have more and higher-quality food.

Oak woodlands Oak woodland habitat is scarcer than in the past. Blue oaks are important to wildlife for their acorn crops and provide thermal cover for young animals.

Impacts from browsing and gnawing animals + Low recruitment of native woody riparian plants A major concern is damage to regenerating riparian vegetation when elk browse and rub their antlers on stems of small trees (C. Thomsen, pers. obs.).

Several landowners in the watershed have also mentioned that poaching is becoming more frequent.

*Proposed Management for Big Game Management*
Management planning for deer and elk (Thornton et al. 1983, BLM 1985, respectively) emphasizes habitat management that protects all native riparian vegetation, implements prescribed burning, and develops alternative watering sources for game away from Bear Creek and its major tributaries. One especially important proposed feature of management is to protect and enhance the diversity of native vegetation within a 300-foot radius of all meadows, glades, springs, and seeps in the watershed. These management practices also begin to address stakeholder issues of creek channel alterations and headcuts, soil erosion, sediment delivery to waterways, and impaired water quality.

***Information Gaps***
Gaps in information and integration needed to protect rare species and conserve game species include:

- distribution maps of the invertebrate species limited to springs and creek edges in Sulphur Creek subwatershed, riparian edges along Bear Creek, and cypress woodlands on Walker Ridge and Mill Creek subwatershed
- best management practices to protect unique spring and creek environments in Sulphur Creek subwatershed, with special focus on the three endemic insect species
- an updated BLM tule elk management plan
- vulnerability of wildlife species to habitat changes, critical habitats likely to be lost, likely new species to arrive, habitats likely to develop, and a strategy to provide corridors and minimize habitat barriers to help species adapt to climate change.

## 2.11 Ecologically Important Areas and Special Conservation Areas

### *Ecologically Unique and Sensitive Areas*

Locations of biologically unique and ecologically sensitive areas are mapped as part of subwatershed analyses in Chapter 7. Table 2.18 lists these areas and provides background information on them.

Table 2.18 – Ecologically unique and sensitive areas in Bear Creek watershed

| Resource | Site(s) | Subwatershed(s) | Background |
|---|---|---|---|
| buttes | Bear Valley Buttes, Gravelly Buttes | Mill Creek, Upper Bear Creek | These striking north-south buttes at the north end of Bear Creek watershed provide high-quality habitat for raptor birds. Little is known about other species of plants and wildlife that inhabit the buttes. The buttes consist of non-ultramafic rocks and soil. |
| rare ultramafic (serpentine) plant alliances, including barrens | Bear Creek Ranch, Love Lady Ridge, Walker Ridge | Craig Canyon, Deadshot Canyon, Eula Canyon, Gaither Canyon, Mill Creek, Robber's Flat, Stinchfield Canyon, Sulphur Creek, Thompson Canyon, Warnick Canyon | Outcrops and small barrens dot the landscape of ultramafic chaparral mixed with unusual plant alliances of knobcone pine (*Pinus attenuata*), cypress stands, and *Eriogonum wrightii*. Trout Creek carries enough water to support an ultramafic riparian forest deserving closer study. Four hundred species of vascular plants occur on Walker Ridge alone, of which 60 are found only on ultramafic soils (Hunter 2005). Thirteen BLM Sensitive Plant Species are found on public lands on the Colusa County side of Walker Ridge. McCarten and Rogers (1991) have recorded Snow Mountain buckwheat and drymaria-like western flax near Love Lady Ridge. |
| springs and seeps with unusual water chemistry | Bear Valley, Wilbur Hot Springs | Sulphur Creek, Upper Bear Creek | Most thermal springs occur in Sulphur Creek subwatershed, while Bear Valley has only cold springs. Both have high concentrations of mercury and other heavy metals in their waters. The unusual water chemistry of springs and seeps has created unique habitats for three endemic insects in the vicinity of Wilbur Hot Springs. Microbes are another element of unusual diversity, particularly those living in anaerobic environments. They facilitate combining heavy metals with methyl-organic compounds that can subsequently enter the biological food chain (Bentley and Chasteen 2002; Holloway et al. 2009b). |
| stock ponds | Bear Creek Ranch, Bear Valley, Long Valley, West of Cortina Ridge | Brophy Canyon, Hamilton, Hamilton Canyon, Jackson Canyon, Leesville, South Jackson Canyon, Upper Bear Creek | Stock ponds created for watering livestock increase biological diversity and supplement the naturally occurring wetlands. Aquatic flora not typical of Bear Creek watershed appears at these sites. Ponds that hold a year-round supply of water become an important water source and aquatic habitat for wildlife, including the western pond turtle. |
| valley native grasslands | Bear Valley | Upper Bear Creek | Designated by the CDFG as important statewide for landscape conservation of rare native plant alliances, the Bear Valley grasslands occur on ultramafic Venado clay soils that remain moist in the winter and hold water longer than adjacent oak woodlands. |
| valley oak stands | Bear Valley | Lower Bear Creek, Upper Bear Creek | A 35-acre valley oak woodland stands at the south end of Bear Valley on the border between Upper and Lower Bear Creek subwatersheds. Valley oaks occur typically in bottomland riparian forests, and were once common on the best agricultural land in central California. The woodland is dense enough to support nesting pileated woodpeckers (*Dryocopus pileatus*) at an unusually low elevation (Scheidt 2000). |
| variant native grasslands | Bear Valley | Upper Bear Creek | Variant grasslands also occur in Bear Valley. Alkali ultramafic meadows on Venado soils have saltgrass and meadow barley (*Hordeum brachyantherum*) as dominants. A small blue wildrye (*Elymus glaucus*) grassland has remained on seasonally wet soils in east-central Bear Valley (Thomsen 2001). |
| wetlands on ultramafic soils outside Bear Valley | Destinella Flat, Eaton Springs, Walker Ridge | Gaither Canyon, Sulphur Creek, Lynch Canyon | The species found in these rare wetlands are poorly known. Each wetland is in proximity of a highway, road, or BLM-designated OHV trail. None of the areas is afforded protection at present. |

| Resource | Site(s) | Subwatershed(s) | Background |
|---|---|---|---|
| wildflower fields and prairies | Bear Valley | Upper Bear Creek | Designated by CDFG as important statewide for landscape conservation of areas with spectacular wildflower bloom, the famous Bear Valley wildflower areas occur on ultramafic Bear Valley, Leesville, and Venado soils. Coarser, fast-draining Bear Valley soils support annuals, while Venado soils produce longer flower displays with a larger share of perennial plants (Thomson 2001). Gelbard and Harrison (2003) found that the diversity of wildflowers benefitted from livestock grazing that reduces the vigor and seeding of non-native annual grasses. |

***Special Conservation Areas in Bear Creek Watershed***

Special conservation areas occupy relatively little territory on public lands in Bear Creek watershed compared to adjacent watersheds such as the North Fork Cache Creek and the Middle Cache Creek. Figure 2.17 displays those conservation areas having defined boundaries. The following sections describe the areas and their conservation management.

<u>Bear Creek Biological Study Area and Bear Creek Botanical Management Area</u>

The 31-acre Bear Creek Biological Study Area takes in the California Department of Transportation's right-of-way on both sides of Highway 20 for one mile west from the intersection with Highway 16. Twelve plant alliances are present in the study area: non-native annual and perennial grasslands, mixed species ultramafic grassland, purple needlegrass grassland, saltgrass grassland, baltic rush wetland, cattail wetland, common spikerush wetland, sedge wetlands, bulrush wetlands, blue oak woodland, and foothill pine woodland. The University of California at Davis promotes and maintains the growth and spread of the high native plant diversity present at the site (California Department of Transportation 2006).

The most sensitive native grassland alliances in the Study Area cover 5.6 acres of remnant prairie, known as the Bear Creek Botanical Management Area. More than 100 species of native prairie plants, including eleven species of native grasses, make the Botanical Management Area a remarkable example of Inner Coast Range vegetation in just a small area. Past management has focused on control of invasive plants – primarily yellow starthistle and barb goatgrass – through prescribed burning, mowing, and hand removal. Boundary data for the areas are not available in GIS.

The reconstruction of the Bear Creek Bridge has required the Department of Transportation to disturb large areas of the Biological Study Area. The biological and visual quality of the Study Area will be restored to the condition before project construction. After mitigation to restore cut slopes, the native vegetation originally present will once again cover the ground disturbed during the project.

Cache Creek Area of Critical Environment Concern (ACEC)
Cache Creek Area of Critical Environmental Concerns extends over 11,228 acres along the main stem of Cache Creek. A small part of the ACEC overlaps into Bear Creek watershed at the confluence of Bear Creek with Cache Creek at the south end of the watershed. The ACEC protects riparian habitats, the resident bald eagle population, and the Cache Creek tule elk herd. Protection of cultural resources and opportunities for primitive recreation are also important management goals. Considerable eradication of small-flowered tamarisk is ongoing in the ACEC.

Cache Creek Natural Area
More than 70,000 acres of BLM public lands as well as 4,700 acres of CDFG and County of Yolo public lands comprise the Cache Creek Natural Area. Management of the Area is undertaken cooperatively by the three partners. Blue oak woodlands, non-ultramafic chaparral, and ultramafic barrens characterize the dominant vegetation in the part of the Natural Area in Bear Creek watershed. Past grazing management created extensive non-native annual grasslands. The BLM acquired most of the Bear Creek watershed portion of the Natural Area in 2003 with funding from the State of California Wildlife Conservation Board and the Rocky Mountain Elk Foundation.

The Cache Creek Coordinated Resource Management Plan (Bureau of Land Management 2004) directs management for the Natural Area. Management permits only primitive, non-motorized recreation and encourages mountain biking, equestrian riding, and hiking. Elk herd and habitat management, control of invasive non-native plants, management for aquatic species diversity at stock ponds, riparian zone restoration, ecosystem services, and research for ecosystem restoration are major emphases for the Bear Creek watershed portion of the Natural Area.

Indian Valley Area of Critical Environmental Concern (ACEC) and Research Natural Area (formerly Indian Valley Brodiaea ACEC)
Originally established to protect populations of the Indian Valley brodiaea at the north end of Indian Valley Reservoir in the North Fork Cache Creek watershed to the west of Bear Creek watershed, the ACEC was renamed and expanded under the BLM Ukiah Field Office Resource Management Plan (2006) to include to nearly 700 acres in Sulphur Creek subwatershed which have a number of BLM Sensitive Plant Species. The California Native Plant Society (Hunter 2005) has proposed expansion of the ACEC to cover all BLM public lands on Walker Ridge.

***Special Conservation Areas Immediately Adjacent to Bear Creek Watershed***
Particularly along the main stem of Cache Creek south of Bear Creek watershed and in Lake County west of the watershed, multiple layers of special conservation are in place to maintain

the natural features of the Inner Coast Range landscape.

Cache Creek State Wild and Scenic River

In 2005, Governor Schwarzenegger signed Assembly Bill 1328 to designate 31 miles of Cache Creek as a California Wild and Scenic River. This designation covers Cache Creek from one-quarter mile below Cache Creek Dam (Lake County) to Camp Haswell (Yolo County) as well as the North Fork Cache Creek from the Highway 20 bridge in Lake County to the confluence with the main stem. Various segments are designated as wild or scenic. The Wild and Scenic River stretch passes the mouth of Bear Creek. Much of the length of the Wild and Scenic River travels through the Cache Creek Corridor ACEC. The California Resources Agency administers the Cache Creek Wild and Scenic River.

Cache Creek Wilderness and the Northern California Chaparral ACEC

President George W. Bush signed into law in 2006 the Northern California Coastal Wild Heritage Wilderness Act designating Cache Creek Wilderness. The wilderness consists of 27,245 acres in Lake County and directly adjoins the southwest side of Bear Creek watershed. Most of the Wilderness is also part of the Cache Creek Natural Area. Wildlife flourishes here, including breeding and wintering bald eagles. No mechanical recreation is permitted in the Wilderness. The Northern California Chaparral ACEC is wholly included in the Cache Creek Wilderness. It was established as a research natural area to protect botanical values found in undisturbed chaparral habitat.

Frenzel Creek Research Natural Area

This Research Natural Area lies just to the north of Love Lady Ridge on the Mendocino National Forest. It has been established for preserving and studying its MacNab cypress and Sargent cypress stands (Cheung 2004). In addition there are many ultramafic-endemic herbaceous plants (McCarten and Rogers 1991). Most of the plant alliances resemble those on Walker Ridge: ultramafic and non-ultramafic chaparral, serpentine barrens, and ultramafic riparian.

***Information Gaps***

Parts of Bear Creek watershed merit further study as to their special natural resources. Obtaining information in the following areas would assist in conservation planning within the watershed:

- multi-season wildlife monitoring, including for invertebrate species, and botanical inventories, especially during the entire length of spring-early summer flowering period, in areas with unusual soils
- inventories of the biological diversity of springs and seeps with unusual water chemistry, focusing on documenting their microbial diversity

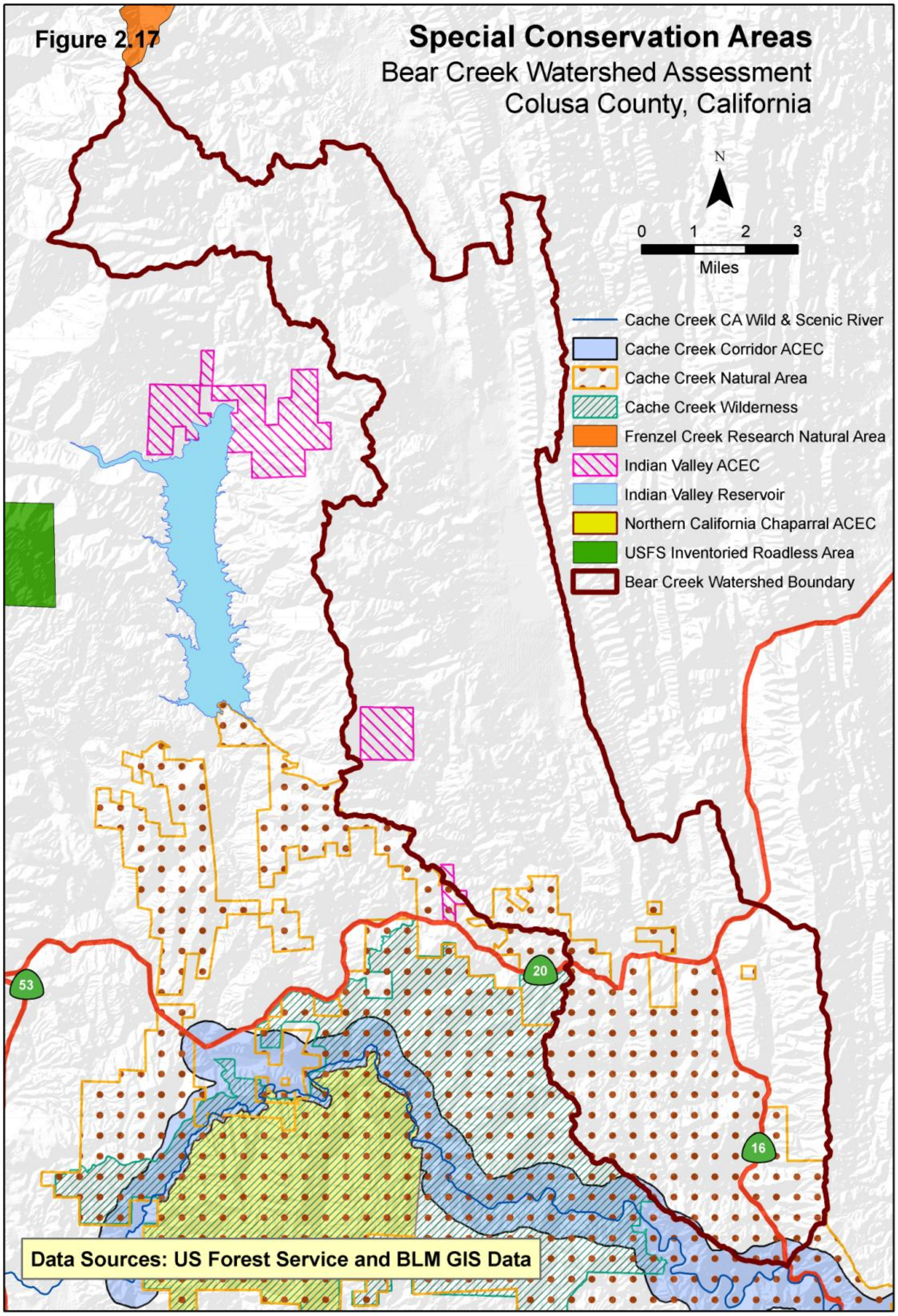


Figure 2.17
Special Conservation Areas
Bear Creek Watershed Assessment
Colusa County, California
N
0 1 2 3
Miles
Cache Creek CA Wild & Scenic River
Cache Creek Corridor ACEC
Cache Creek Natural Area
Cache Creek Wilderness
Frenzel Creek Research Natural Area
Indian Valley ACEC
Indian Valley Reservoir
Northern California Chaparral ACEC
USFS Inventoried Roadless Area
Bear Creek Watershed Boundary
53
20
16
Data Sources: US Forest Service and BLM GIS Data

- inventories of plants and animals in Mill Creek subwatershed, including Gravelly Buttes and the large serpentine barrens in the center of the subwatershed
- wetland delineations to create a benchmark upon which to base wetland restoration or enhancement projects in Bear Valley and elsewhere
- information on environmental change at ecological reference sites having rare plant alliances (native grasslands, ultramafic chaparral, and riparian habitats).

## 2.12 Air Resources

Bear Creek watershed lies entirely within the Sacramento Valley Air Basin, an eleven-county region that extends 217 miles in a north-south direction and has a maximum width of 90 miles. However, the location of the watershed at the western boundary of the Air Basin and its topographic isolation within the Air Basin requires taking into account conditions in the adjacent Clear Lake Air Basin.

### *Meteorological Basis for Poor Air Quality*

Persistent temperature inversions, where the air temperature increases with height, often limit the dispersion of air pollutants vertically in the Basin. Air quality problems arise when high-pressure air masses keep low-pressure air, which bring rain and winds, away from the Sacramento Valley for much of the year. Warm air above cold air in the inversion prevents air movement as the heavier, cooler air does not rise above the warm air. Stagnation in air movement generates and traps ozone and raises concentrations of particulate matter less than 10 microns in diameter ($PM_{10}$). Summer inversions usually occur at about 2,000 feet. When storms are absent, winter inversions also keep cold air near the ground below warmer air at night; these inversions typically occur between 500 and 1,000 feet above the Valley. Being at considerable distance west of Sacramento Valley inversions, Bear Valley watershed generates a low amount of $PM_{10}$ and health impacts from inversions are not reported. Smoke from wildfires and outdoor burning may create health problems, however.

### *Criteria Pollutants*

The Clean Air Act requires that air quality agencies monitor criteria pollutants according to established protocols, or analogous protocols with the same or better detection capability. Monitoring determines whether a particular pollutant has concentrations equaling or exceeding criteria set by state and federal agencies that regulate air quality. The primary air quality problems with criteria pollutants in the Sacramento Valley Air Basin come from ozone and particulate matter.

#### *Ozone*

Ozone becomes a problem in the Sacramento Valley Air Basin especially from April through October when it can aggravate asthma other breathing ailments, and heart disease in sensitive people. Chemical reactions in the air between nitrogen oxide gases (known as $NO_X$) and reactive organic gases (ROGs) produce ozone at about 2,000 ft elevation. Sunlight is the catalyst for these reactions. In turn, $NO_X$ and ROGs stem principally from human activities: combustion of fuels in the case of $NO_X$ – mostly by motor vehicles; and for ROGs, the volatile organic compounds emitted from vehicles, refuse burning, and evaporation of volatile organic compounds such as industrial solvents. The latter two sources of emissions are likely not significant in Bear Creek watershed normally. Spills of industrial solvents resulting from truck accidents and wildfire smoke would be exceptional events. Low traffic volume also makes for low ozone generation in the watershed. Refer to Section 3.11 for vehicle traffic counts.

*Suspended Particulates ($PM_{2.5}$ and $PM_{10}$)*
Suspended particulate matter consists of tiny solid or liquid particles in the air. Substances in particulate matter relevant to this assessment include dust, soot from wildland fires, and vaporized mercury. Of greatest concern for human health are the particulates that people inhale into their lungs, generally particulates less than 10 microns in diameter ($PM_{10}$). Finer particles less than 2.5 microns in diameter ($PM_{2.5}$) are a subset of $PM_{10}$.

Dust in Bear Creek watershed is most likely to come from fugitive dust from agricultural and ranch lands and from vehicle travel on unpaved roads and off-road trails. More development and more dirt roads would further increase dust generation unless road maintenance addressed dust reduction.

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*Nitrogen Oxide (NOx) Gases*
$NO_X$ gases are precursors to ozone formation. The major component of $NO_X$, nitrogen dioxide ($NO_2$), is a reddish-brown gas often visible to the eye during air inversions in the Sacramento Valley Air Basin. $NO_X$ results primarily from the combustion of fossil fuels on hot days with high atmospheric pressure. $NO_X$ gases affect people sensitive to chronic bronchitis, and irritations to lungs and eyes.

*Hydrogen Sulfide*
Hydrogen sulfide stems from geothermal energy extraction, hot springs, and confined animal facilities. It impacts people with an unpleasant odor of rotting eggs and can cause dizziness, nausea, and headaches.

***Attainment of Air Quality Standards***
The US EPA and the California Air Resources Board (CARB) evaluate how well counties are meeting state or federal air quality standards (“attainment”). Neighboring Lake County has the highest air quality in California and attains both US EPA and CARB standards for all criteria pollutants. Predominant winds from the west and southwest, the proximity to Lake

County, the remoteness of the watershed from atmospheric conditions that create non-attainment for some criteria pollutants in the Sacramento Valley, the watershed's low population, and rural economy, all point to air quality conditions that resemble those found in Lake County.

Appendix F contains information about standards and regulated actions in effect to protect air quality in Bear Creek watershed.

Table 2.19 -- Air Quality Standard Compliance, 2006 - 2008

| Criteria Pollutant | Lake County | | Colusa County | |
|---|---|---|---|---|
| | Regulatory Standard | | | |
| | CARB | US EPA | CARB | US EPA |
| Ozone – 8 hour | Attainment | Attainment | Transitional | Attainment |
| Ozone – 1 hour | Attainment | not applicable | Moderate | not applicable |
| $PM_{2.5}$ | Attainment | Attainment | Unclassified | Attainment |
| $PM_{10}$ | Attainment | Attainment | Nonattainment | Attainment |
| Carbon Monoxide | Attainment | Attainment | Unclassified | Attainment |
| Nitrogen Dioxide | Attainment | Attainment | Attainment | Attainment |
| Sulfur Dioxide | Attainment | Attainment | Attainment | Attainment |
| Sulfates | Attainment | not applicable | Attainment | not applicable |
| Lead | Attainment | Attainment | Attainment | Attainment |
| Hydrogen Sulfide | Attainment | not applicable | Unclassified | not applicable |

Sources: State of California Air Resources Board, Air Quality Data Branch (2006)
US Environmental Protection Agency, Green Book Data (2008)

***Other Gases Commonly of Concern***

No state or national air quality standards for these gases discussed below are presently in effect.

*Carbon Dioxide*

Carbon dioxide is the major "greenhouse" gas. Bear Creek watershed does not produce high amounts of carbon dioxide from either vehicular or industrial sources. One outcome of maintaining low human density and having public lands as open space is that Bear Creek stores carbon (as a "carbon sequestration" site) taken from the atmosphere. Land management can promote maximizing biomass accumulation in vegetation aboveground and in plant root systems and soil belowground over a long time. Through photosynthesis, plants transform atmospheric carbon dioxide into carbohydrates that create plant biomass.

*Methane*

Methane is an odorless gas that absorbs and reflects terrestrial radiation back to earth. It figures as a key “greenhouse gas”, contributing to global warming and climate change. Methane is emitted into the environment naturally from hot springs and from livestock and livestock manure. One hot spring in Sulphur Creek subwatershed, Jones Fountain of Life, emits a large proportion of methane in its total gas output (44 to 52%) but the total volume over time is not now known (Goff et al. 2001). Large confined livestock holding facilities, major sources of methane pollution in California, are not present in the watershed.

*Ammonia*

Although not a criteria pollutant, ammonia is a precursor to $PM_{2.5}$. The California Office of Environmental Health Hazard Assessment has established acute and chronic reference exposure levels (REL’s) for ammonia. Ammonia is generated from decomposition of manure. It is a strong alkali that reacts in the atmosphere with sulfuric acid (a criteria pollutant in California) and nitric acid to produce fine particulates of ammonium sulfate or ammonium nitrate (part of $PM_{2.5}$).

In Bear Creek watershed, sources of ammonia in unknown amounts come from anaerobic decomposition of manure and in small quantities from hot springs.

***Air Quality Monitoring***

The Air Resources Board does not monitor air quality in the watershed. The closest air quality monitoring station is 23 miles away at the Colusa County Airport south of the City of Colusa. The site monitors ozone and $PM_{2.5}$. Three monitoring sites to the west and slightly farther away in Lake County monitor for hydrogen sulfide, and another site in Lakeport on the west side of Clear Lake monitors for ozone. Hydrogen sulfide is a concern for the Air Resources Board in Lake County because of emissions from geothermal sites.

No data are available from emissions from vehicle combustion or agricultural and ranch enterprises in the watershed.

The only data pertaining to air quality in Bear Creek watershed are instantaneous readings taken of the percent of emissions of gases from hot springs in Sulphur Creek subwatershed. Gases such as ammonia, hydrogen sulfide, methane, and carbon dioxide from hot springs are the same gases emitted from confined animal facilities in the Sacramento Valley.

Table 2.20 – Gas emissions as a percent of total gas molecules emitted from springs in Sulphur Creek subwatershed, excluding water vapor

| Springs Sampling Years (# Samples) | Carbon Dioxide | Hydrogen Sulfide | Hydrogen | Methane | Nitrogen | Ammonia | Argon | Oxygen |
|---|---|---|---|---|---|---|---|---|
| | mol-% | | | | | | | |
| Wilbur Hot Spring 1995, 1996 (3) | 83.8 – 91.1 | 3.14 – 3.16 | <0.003 | 2.87 – 4.88 | 0.84 – 8.45 | <0.002 | 0.02 – 0.13 | <0.023 |
| Elbow Hot Spring 1993, 1995, 1996 (3) | 95.5 – 95.8 | 1.83 – 1.93 | 0.27 – 0.47 | 1.61 – 1.89 | 0.17 – 0.59 | <0.001 | < 0.011 | <0.005 |
| Elgin Spring, Main 1993, 1996, 1997 (3) | 97.0 – 97.1 | 2.09 – 2.12 | <0.008 | 0.64 – 0.75 | 0.07 – 0.23 | <0.003 | <0.005 | <0.002 |
| Jones Fountain of Life 1991, 1992, 1996 (5) | 40.7 – 53.3 | 0.37 – 1.08 | 0.04 – 0.18 | 44.0 – 51.9 | 2.03 – 6.76 | <0.149 | 0.01 – 0.04 | 0.03 – 0.14 |

Source: Goff et al. (2001)

Carbon dioxide orginates from inorganic carbonate minerals in thermally heated rocks. Cold springs found in Bear Valley discharge almost entirely carbon dioxide (Barnes 1973b). Nitrogen originates from magma emissions trapped belowground (Goff et al. 1993).

In the presence of the subterranean carbon dioxide, ultramafic peridotite rocks deep in the spring metamorphose into serpentinite, the major ultramafic mineral in Bear Creek watershed. As a result, hydrogen gas is produced. Sulfates and carbonates dissolved in the spring water combine with the hydrogen to form methane and hydrogen sulfide, both criteria pollutants. It is likely that total gas emissions from spring sources are small and contribute insignificantly to total hydrogen sulfide emissions calculated for Colusa County by the Air Resources Board.

***Other Unmonitored Airborne Particulate Matter of Potential Concern***

Refer to Section 5.10 Air Quality Contaminants for the account of air-borne asbestos and mercury.