# COLUSA BASIN
# WATERSHED ASSESSMENT

**Final**

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15 December 2008 Project No. 2850-01

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# INTRODUCTION

## Overview

The H. T. Harvey & Associates' Team, under contract to the Colusa County Resource Conservation District, has prepared this Watershed Assessment for the Colusa Basin Watershed. We worked with the Colusa County Resource Conservation District to conduct the assessment according to the following steps:

1. Conduct telephone interviews to identify stakeholder concerns
2. Characterize watershed conditions based on existing information
3. Conduct a qualitative assessment of historical changes in key ecosystem features and processes based on existing information
4. Identify data gaps
5. Recommend next steps toward the development of a watershed management plan

The Colusa Basin Watershed is located in northern California and covers approximately 1,045,445 acres (1634 square miles) which encompasses a substantial portion of the west side of the Sacramento Valley. The watershed extends from the Cache Creek Watershed in the south, to lower Stony Creek Watershed in the north and from the Sacramento River westward to the ridge crest of the Coast Range foothills. Overall, the watershed is relatively flat but steeper slopes are present to the west as the watershed climbs into the lower foothills of the Inner Coastal Range. Major landforms within the watershed include the levees along the west side of the Sacramento River; the broad floodplains and basins of the valley floor; and the foothills, ridges, and valleys of the Inner Coast Range. A low trough of relatively flat basin lands runs parallel to the Sacramento River levees. These flat basin lands are referred to herein as the Colusa Basin. Ephemeral streams draining winter rainfall from the Coast Range foothills coupled with overflow from the Sacramento River, have historically contributed to regular seasonal flooding of the Colusa Basin. The natural physical and biological conditions of the Colusa Basin Watershed have been dramatically altered over the past ~160 years through Euro-American settlement, the development of flood control and water supply projects, and the transformation of the Colusa Basin into a highly productive agricultural region.

## Assessment Purpose

The Colusa County Resource Conservation District intends to develop a management plan for the Colusa Basin Watershed that will identify and prioritize projects that are "best for the watershed" and locally driven. This Watershed Assessment is the first step in this process and compiles existing information and stakeholder concerns into a user-friendly document to support the future development of a management plan. The assessment describes where we have been (history), where we are now (current conditions), and will help local stakeholders determine where they would like to be (a plan for the future).

## FINDINGS

### Land Use and Social Characteristics

**Historical Conditions.** American Indian Tribes such as the Patwin or Wintun, inhabited the Colusa Basin Watershed for at least 10,000 years prior to Euro-American settlement in the mid 1800s. Their subsistence hunter/gatherer economy was based on sustainable management and use of the watershed's once abundant natural resources. For example, they utilized the vast tule marshes of the Colusa Basin for building material harvesting tules to construct their boats, huts, and baskets. The population of American Indians in the watershed plummeted from numbering in the thousands in 1850 to approximately 100 in the modern era due to introduced disease, displacement, and warfare.

Initial Euro-American settlement of the region occurred in the mid 1800s with the Gold Rush ushering in a mass migration to the Sierra foothills. Establishment of the earliest towns (Colusa, Grimes, Princeton) occurred along the Sacramento River corridor where barges of supplies could be loaded and unloaded en route to the Sierra gold mines. Following the initial boom of gold mining, as agricultural production increased in the 1860s and 1870s, the City of Colusa gained prominence as a shipping port delivering the wheat harvest downriver. Towns such as Williams, Maxwell, and Arbuckle later grew up around the Northern Railroad line during the 1870s serving as transportation centers for the grain harvest.

Initially farmers avoided the vast tule marsh of the Colusa Basin lowlands because they did not yet have the technology to drain them or protect them from regular flooding. They established farms and orchards on the well-drained, fertile, levees along the Sacramento River and higher ground at the base of the foothills. However, landmark federal and state water resource management legislation was passed between 1850 and 1870 to provide flood protection, drainage, and irrigation to these floodprone regions [Arkansas Act (1850), State Assembly Bill 54 (1861), Green Act (1868)]. This legislation set in motion numerous projects that, through trial and error, rapidly converted the vast wetland and riparian habitat of the Colusa Basin to lands suitable for agriculture and urbanization. The Green Act, in particular, dramatically stimulated the purchase and reclamation of wetlands. Between 1868 and 1871, nearly a million acres, practically all of the swamplands once owned by the state, passed into private ownership. Reclamation districts were fragmented into numerous small districts that enacted flood control measures independently rather than in a coordinated, valley-wide fashion.

As railroad construction in the region expanded and river navigation improved through dredging the Sacramento River, agricultural production and population growth within the watershed increased. The improved flood control and irrigation water supply provided by legislative ruling also played a major role in the production and population increases. The era around 1913, in particular, saw great increases in the conversion of floodprone swamplands to productive agricultural land.

Great increases in agricultural acreage and shifts toward more valuable crops indicate that agricultural growth in the region has continued to this day. Using Colusa County as an example to illustrate this general historic trend for the whole watershed, in 1939 barley was the largest field crop in Colusa County at 75,000 ac and rice was the second largest at approximately 25,000 ac. while almonds were the largest crop among fruit and nuts at 7,418 ac. Barley remained the largest field crop (on an acreage basis) until the late 1950s when rice acreage (58,770 ac) exceeded barley (46,000 ac) as the largest field crop in Colusa County. By 2006, rice acreage in Colusa County had grown to 142,600 ac and tomatoes were the second largest field crop at 18,400 ac. while almonds remained the largest crop among fruit and nut crops at 28,600 ac.

**Existing Conditions.** The vast majority of the watershed is rural, dominated by agricultural and rangeland activities. Less than 1% of the watershed is urbanized. The majority of the lands within the watershed's three counties (Yolo, Colusa, and Glenn) are mapped as "Important Farmland" by the U.S. Department of Agriculture and the State of California Department of Conservation. The preservation of important agricultural land is among the highest priorities in the respective county general plans. The counties aim to achieve this goal by encouraging new development to occur within or adjacent to existing cities, communities, and major transportation corridors. The general plans for these three counties are rather old (prepared 15-25 years ago) and are in the process or slated to be updated. Beyond the County General Plans, Williamson Act contracts are the second principal way that agricultural land is protected from conversion to urban land use within the Colusa Basin Watershed. The California Land Conservation Act of 1965 (commonly known as the Williamson Act) allows landowners to voluntarily place restrictions on development and use on their agricultural lands in exchange for tax reductions and other incentives. In the Colusa Basin Watershed, 34% of the prime soils are under Williamson Act Contract (144,711 ac) and 14% are in Farmland Security Zone contract (58,952 ac). Sixty-one percent (61%) of non-prime soils in the Colusa Basin Watershed are under Williamson Act contract (301,508 ac) and less than 1% are under Farmland Security Zone contract.

### Physical Processes (Geology, Geomorphology, Soils, Hydrology)

**Geology.** The Colusa Basin Watershed lies entirely within the Great Valley geologic province, an area that includes the Sacramento Valley bordered by the Coast Range, Klamath, Cascade, and Sierra Nevada mountains and its fringe of foothills underlain by the valley's older sedimentary bedrock. The bedrock formed when a Cretaceous sea filled the Sacramento Valley. Broad warping of the Cretaceous marine sedimentary bedrock layers uplifted and tilted them giving rise to the foothills along the western edge of the Watershed and lowered the rocks along the valley centerline where the aggrading floodplains of the ancestral Sacramento River created the valley flat. Erosional dissection of the uplifted foothills by Tertiary and Quaternary streams poured sediment into the sinking valley, forming a sequence of older semi-consolidated alluvial deposits that flank the foothills. These alluvial deposits in-turn have been uplifted and dissected by still younger streams. Holocene streams continue to dissect the Cretaceous bedrock foothills and the older alluvial deposits transporting sediments onto the valley floor. Holocene streams form contemporary alluvial fans that grade into the wide band of valley flat and basin lands – the Colusa Basin. The Colusa Basin is a complex of loamy floodplain deposits, slough channels, and frequently flooded basins formed by modern fluvial processes on the aggrading Sacramento River floodplain.

**Geomorphology.** East of the foothill front, the Colusa Basin Watershed landscape is dominated by broad, gradually-sloping alluvial fans grading into the fine-grained deposits of the Sacramento River forming the valley flat and the Colusa Basin. Streams draining from the foothills over the alluvial fan surfaces are variably meandering, sand-and-gravel bedded streams with naturally erodible banks except where channels are cut in semi-consolidated older alluvial deposits occurring primarily nearer the foothill front. The foothill streams are naturally flood-prone especially along their downstream reaches where the channel slope decreases, the banks and natural levees are increasingly fine-grained, and there may be local stormwater ponding and flood backwater effects from the poorly-drained valley flat and Colusa Basin. The foothill streams have been variably channelized and leveed to conform with transportation infrastructure and general agricultural development, especially the downstream reaches which are more shallowly incised and prone to erosion and flooding. Closer to the foothill front there are still numerous unmodified, isolated stream sections with relatively intact riparian vegetation.

The streams on the valley flat and within the Colusa Basin are sinuous, very gradually-sloping, sand-, silt-, and clay-bedded streams. These streams are commonly referred to as "sloughs." Broad loamy deposits along the borders of slough channels once hosted extensive riparian forests and today provide valuable agricultural soils, including for example Vina and Moonbend soils. Today there are only a few remnants of the slough channels, such as a remnant of Sycamore Slough, south of Colusa. Levee building and drainage works for flood protection and reclamation eliminated routine Sacramento River overflow onto the valley flat, and most of the slough channels have been farmed over.

**Soils.** The types and patterns of soils on the Colusa Basin Watershed lands follow somewhat directly from its geology and geomorphology:

*Upland Soils.* Upland soils are generally shallow residual soils that occur in rolling, hilly to mountainous topography, mostly having been formed in place through decomposition and disintegration of the underlying parent bedrock. Low to moderate rainfall can support vegetation for grazing on upland soils. Upland soils cover the western third of the Colusa Basin Watershed area within the Coast Range foothills.

*Terrace Land Soils.* Terrace land soils are formed in the older and younger valley fill alluvium occurring in the foothill valleys and on the alluvial fans sloping up from the edges of the valley and basin lands, usually at elevations of 5-300 ft above the valley floor. Terrace land soils with dense subsoils exhibit poor drainage and are satisfactory for annual grasses and shallow-rooted crops. Terrace land soils with moderately dense subsoils usually have brownish, neutral surface soils and occupy the lower elevation alluvial fan surfaces where younger alluvium is present, and covered with grass or woodland with a grass understory.

*Valley Land Soils.* In contrast to the relatively poorly drained terrace land soils, valley land soils are predominately well-drained alluvial soils formed in loamy alluvial fan and floodplain deposits. Valley land soils are generally brown in color and highly valued for irrigated crops. Some of these soils are slightly to moderately saline to alkali. They are located along the Sacramento River, in the streamside areas dissected in the Tehama Formation, and the oldest part of the relict Stony Creek alluvial fan lying northwest of Willows.

*Valley Basin Soils.* Valley basin soils occur in the lowest elevation parts of the watershed that are nearly flat and poorly drained. These soils are generally dark-colored and clayey, with a high water table. They are subject to frequent stormwater overflow and extended ponding and are primarily used for rice growing. Valley basin soils occur on the valley flat lying west of the Sacramento River floodplain deposits and east of the gently sloped alluvial fan deposits from the Coast Range foothills, comprising an area often referred to as a “low trough” extending from north of Willows to Knights Landing. The Colusa Basin comprises the southerly and lowest elevation part of the low trough on the valley flat. Valley basin soils also occur upslope from the rim of the Colusa Basin in the interfan basin area in the Maxwell vicinity.

**Surfacewater Hydrology.** There is limited stream flow hydrology gage data available for the foothill streams in the Colusa Basin Watershed. There are only three active gages in the watershed: The California Department of Water Resources [DWR] gages along the Colusa Basin Drain at Highway 20 and at the Knights Landing Outfall Gates, and the discontinued U. S. Geological Survey [USGS] station on South Fork Willow Creek near Fruto that DWR began operating after the 1998 flood. The Colusa Basin Drain gages only measure mean daily flow contained in the drainage canal. Flood flows escaping the canal are not measured, and DWR does not publish estimated annual peak flows at those sites. The USGS currently publishes historical records for three discontinued gages: Walker Creek at Artois (16 years), South Fork Willow Creek near Fruto (16 years), and on Stone Corral Creek near Sites (28 years).

Stone Corral Creek had zero or near-zero flow most of the year during normal and dry years with positive flow typically occurring only as the result of individual rainstorms between November and April. South Fork Willow Creek near Fruto has a similar-sized drainage area as Stone Corral Creek with a similar pattern of mean annual precipitation as its upper watershed is adjacent to and within the same range of elevations, and it is underlain by similarly dissected Cretaceous bedrock. Gage records show that both streams had similarly timed and similarly sized peak flows resulting from individual winter rainstorms, with very few exceptions. Walker Creek at Artois captures a larger drainage area, approximately twice as large as the Stone Corral and Willow Creek gages. Walker Creek sustained a measurable winter baseflow for a larger portion of the November to April rainy season, but at times had zero or near-zero streamflow between storms, especially during dry years but also most normal rainfall years.

The drainage area tributary to the Colusa Basin Drain at the Highway 20 gage is 973 $mi^2$ (about 623,000 ac), approximately 60% of the Colusa Basin Watershed area. Annual average runoff at the Highway 20 gage for the period of record is 496 thousand acre-ft per year – equivalent to an average runoff depth of 9.6 inches. This is much more than the natural amount of runoff from a watershed area with mean annual precipitation ranging generally from 17-27 inches, primarily reflecting the influence of irrigation water imports on the hydrology of the Colusa Basin Drain. It is generally understood that irrigation development substantially increased peak stormwater runoff tributary to the Colusa Basin Drain but few data are available to quantify these historical effects.

**Groundwater Hydrology.** Groundwater occurs in the alluvial deposits underlying the alluvial fans, low plains, and basin flats of the Colusa Basin Watershed. The Colusa Groundwater Subbasin comprises the part of the larger Sacramento Valley Groundwater Basin lying approximately under the Colusa Basin Watershed footprint, being “bounded on the east by the Sacramento River, on the west by the Coast Range and foothills, on the south by Cache Creek, and on the north by Stony Creek”(DWR 1990). The base of the Tehama Formation is the base of groundwater-bearing alluvial deposits in the Colusa Groundwater Subbasin. The groundwater-bearing geologic formations in the subbasin include all of the alluvial deposits overlying the Cretaceous bedrock: the Tehama Formation of Tertiary age and the overlying Quaternary alluvial fan, flood basin, and alluvial deposits.

DWR published the most recent analysis of typical seasonal and long-term groundwater elevation trends in 1990, finding no indication of groundwater overdraft. Sufficient groundwater data exist for monitoring changes in groundwater storage and to provide baseline data for evaluating future groundwater management efforts. DWR monitors groundwater levels in 98 wells approximately semi-annually and maintains up-to-date published databases of the well data.

**Flood Management.** The eastern third of the Colusa Basin Watershed lies within the frequently flooded Sacramento River floodplain. The early locally-driven flood control efforts constructed levees along the western bank of the Sacramento River. Ever higher generations of these levees failed one after the other. The levees were ultimately uniformly bolstered and incorporated into the federal Sacramento River Flood Control Project. The project was deemed largely successful when it substantially prevented flooding in the watershed during the Sacramento River flood of February-March 1940.

There were also substantial but lesser contributions of flood waters from the relict Stony Creek alluvial fan area north of Willows and the foothill streams bordering the valley on the west. Managing these smaller flood waters was partly neglected in the all-consuming struggle to control the more damaging Sacramento River overflows. Also owing to the practical difficulty of managing these foothill stream flood waters, the watershed has been left with residual flooding in the Willows vicinity and along the western edge of the Colusa Basin Drain. The Colusa Basin Drain was originally constructed to provide adequate drainage for agricultural production, not to provide minimum necessary conveyance for winter flood prevention. As agricultural production and volumes of applied irrigation water have expanded, the Drain has also been shown to be undersized in places for handling summer irrigation return flows. According to DWR, the typical pattern of flooding occurring along the Colusa Basin Drain is primarily the result of runoff from foothill streams during the winter and releases of irrigation water from rice fields during the summer.

Beginning in the 1960's, DWR prepared hydraulic models of the Colusa Basin Drain channel to serve as a basis for evaluating the flood control benefits resulting from a range of management actions: (1) improved drainage facilities from the Knights Landing Ridge Cut through the Yolo Bypass, (2) systems of levees along the Colusa Basin Drain, (3) flood control reservoirs in the western foothills, and (4) watershed management. DWR updated the hydraulic model and cost-benefit evaluation of these alternatives in 1990, and evaluated a fifth alternative of enlarging the Knights Landing Ridge Cut. Flood control reservoirs in the western foothills are currently under the most serious consideration. Most recently, the Colusa Basin Drainage District evaluated the feasibility for proposed reservoirs on two foothill streams in the northern part of the watershed – South Fork Willow Creek and Wilson Creek.

## Water Quality

**Prior to Euro-American Contact (pre-1850).** Prior to Euro-American contact, the Colusa Basin likely served as a substantial nutrient and sediment filter during high flows when the flood waters of the Sacramento River and Coast Range tributaries would flow into the once vast riparian and wetland habitats of the Colusa Basin. It is likely that the Colusa Basin thereby improved downstream water quality and flood attenuation on the Sacramento River by reducing sediment loads, nutrient concentrations, and peak flows.

**Rice Pesticides in Surface Water.** Some of the major pesticides that have historically been used on rice have included Molinate, Thiobencarb, and Carbofuran. During the late 1970s, the levels of rice pesticides in the Colusa Basin Drain sometimes caused declines to fish, such as carp, due to high concentrations of Molinate. In addition, the concentration of some of these pesticides, particularly Thiobencarb, caused taste and odor problems at the cities of Sacramento and West Sacramento in the late 1970s and early 1980s due to interactions with chemicals at the water treatment plant. As a result, a management program (the Rice Pesticides Program, now part of the Regional Water Quality Control Board's Basin Plan) was enacted to reduce the levels of rice pesticides in surface water. The management program has led to numerous improvements in water and pest management techniques. One of the most effective techniques is the retention of rice-field water on fields for one month following pesticide application. This allows pesticide concentrations in water to be reduced through mechanisms such as volatilization, biological processes, or sunlight-induced degradation.

The management program has effectively reduced the discharge of rice pesticides to receiving waters. The total herbicide load (Molinate and Thiobencarb) carried by the Sacramento River dropped from approximately 40,000 lbs in 1982 to less than 125 lbs in 1992. The concentration of rice herbicides in the Colusa Basin Drain has also declined to less than 10% of pre-1985 levels. According to the latest reports from the CA Rice Commission, use of Carbofuran has been cancelled since 2000 and Molinate will no longer be in use after August 31, 2009.

**Non-Rice Pesticides in Surface Water.** Trace concentrations of a variety of non-rice pesticides have been detected in the Colusa Basin Drain from the mid 1990s to 2007. These include the insecticides Diazinon, Dimethoate, the herbicide Simazine, and legacy organochlorine insecticides such as Dichlorodiphenyldichloroethylene. This is not unexpected given the intensity and history of production agriculture in the watershed. The concentration of some of these pesticides are in excess of regulatory limits, and a variety of regulatory programs, such as the Irrigated Lands Program and 303(d) listing, are in place to address this issue. In spite of detected water quality impacts from the presence of these pesticides, the surface water quality in the Colusa Basin Watershed is adequate to support existing uses which are predominantly agricultural. The quality of surface water in the Sacramento River appears to be largely unaffected by the presence of pesticides and as a result is of high quality.

**Groundwater Quality.** The California Department of Pesticide Regulation and the U. S. Geological Survey have conducted extensive investigations of groundwater quality in the Colusa Basin since 1983 and 1997, respectively. Groundwater quality in the Colusa Basin is generally acceptable for agricultural uses. With the exception of boron, no naturally occurring groundwater constituent prevents the use of groundwater for irrigation. In some portions of the

Colusa Basin groundwater has elevated salt concentrations that may adversely affect yields of commonly grown crops. For example, high electrical conductivity, total dissolved solids, and adjusted sodium absorption ratio occur near the City of Colusa and high total dissolved solids and boron occur near Knights Landing.

## Biology

**Historical Conditions.** Prior to Euro-American contact, the historic vegetation in the Colusa Basin Watershed was primarily determined by the patterns of soil texture, soil moisture, and flooding cycles. Grassland was perhaps the most extensive original vegetation cover throughout the watershed. Regularly flooded, yet well-drained, fertile soils (e.g., loams and silt loams) occurred on the broad natural levees adjacent to the Sacramento River. In contrast, the intervening basin soils were poorly drained and seasonally flooded for extended periods. A wide corridor (~900 ft wide) of valley oak riparian forest grew atop the river and slough levees and a vast sea of emergent freshwater marsh (~ 5 miles wide and 40 miles long) grew within the basins. Two additional types of seasonal wetland habitat (vernal pool and alkali sinks) were also present, though less extensive than the emergent freshwater marsh. The ephemeral streams draining the foothills supported less extensive riparian vegetation than the perennial flows of the Sacramento River and adjacent sloughs. Beyond the riparian corridor of these foothill streams, native grasslands, chamise chaparral, and blue oak woodland formed a mosaic of habitats along the western foothills.

Based on accounts from the early 1800s by the earliest Spanish explorers of the Sacramento Valley, thousands of tule elk, antelope (pronghorn), and deer browsed the grasslands and wetlands of the valley floor. Will S. Green wrote of his first trip up the Sacramento River towards Colusa that there were "myriads of ducks and wild fowl…deer…and even grizzly bear," along the banks of the river.

Following Euro-American contact, flood control and drainage projects rapidly and dramatically altered hydrologic cycles and pathways, which in turn eliminated or converted the vast majority of the riparian, wetland, and grassland habitat. Beginning in 1860 major flood control and irrigation development projects altered this historic hydrologic/sedimentation regime. Tree species were felled for firewood and construction, woodlands on levees were cleared for cropland, tule marshes were drained for agricultural use, and grasslands were tilled for crops.

**Existing Conditions.** Patterns of vegetation within Colusa Basin Watershed generally correspond to the watershed's major topographic features and current land-use activity. The existing habitats of Colusa Basin Watershed can be grouped broadly into the following seven types according to vegetation and landscape position:

| Habitat Type | Primary Landscape Position | Surface Area (acres) | Percent of Watershed Surface Area |
|---|---|---|---|
| Cultivated | Colusa Basin | 606,737 | 58% |
| Blue Oak/Foothill Pine Woodlands | Western Foothills | 189,068 | 18% |
| Annual Grasslands | Western Foothills | 185,143 | 18% |
| Emergent Wetland | Colusa Basin | 31,392 | 3% |
| Shrublands | Western Foothills | 23,108 | 2% |
| Riparian | Sacramento River and Its Tributaries | 4,715 | 0.5% |
| Developed/Urban | Colusa Basin | 2,974 | 0.3% |

**Special-status Wildlife.** The Colusa Basin Watershed provides suitable habitat for numerous (~44) special-status wildlife species during certain times of year. The watershed provides suitable breeding habitat for nine federal or state listed threatened or endangered species; bank swallow, California tiger salamander, Conservancy fairy shrimp, giant garter snake, Swainson's hawk, western yellow-billed cuckoo, valley longhorn elderberry beetle, vernal pool fairy shrimp, and vernal pool tadpole shrimp. The watershed also provides suitable breeding habitat for 18 wildlife species considered by the state as species of special concern or protected species. The majority of these species utilize freshwater emergent wetlands, vernal pools, and/or riparian habitat; habitats that have been dramatically reduced compared to their historic distribution.

**Special-status Plants.** Twenty four special-status plant species are known to occur, while 33 species have the potential to occur within the Colusa Basin Watershed. Many (28) of these species are associated with vernal pool habitats. Seven of these species are listed as state and/or federally threatened or endangered and six of these threatened or endangered species are associated with vernal pool habitats. The known occurrences of the special-status plant species associated with vernal pools are located in the Colusa Basin between the Colusa Basin Drain and Interstate 5. Numerous occurrences are located within the Sacramento National Wildlife Refuge.

## WATERSHED ACTION ITEMS

As noted above, the Colusa County Resource Conservation District intends to develop a management plan for the Colusa Basin Watershed to identify and prioritize projects that are "best for the watershed" and locally driven. We recommend the preparation of an Integrated Watershed Management Plan [IWMP] for the Colusa Basin Watershed. Adopting the watershed as the planning area facilitates the successful management of water-related resources and issues because the management unit (i.e., the watershed) is the natural boundary of water flow as opposed to more arbitrary property and governmental boundaries. An "integrated watershed management" approach facilitates productive dialogue among local stakeholders within the watershed to establish a clear set of management goals and develop collaborative, innovative solutions to achieve those goals. The solutions of an IWMP strive to balance environmental, economic, and social concerns (triple bottom line). An "integrated" approach involves developing interdisciplinary solutions that serve multiple objectives and are based upon a sound, scientifically-based understanding of ecosystem processes. For example, projects that reconnect floodplains to creek channels (at appropriate landscape locations) can reduce flooding, reduce downstream channel/bank erosion, increase groundwater recharge, and improve riparian habitat quality and quantity.

An Integrated Watershed Management Planning process for the Colusa Basin Watershed should involve the following basic elements:

- Establish a workgroup of key stakeholders to guide the preparation of the management plan. The workgroup should include representatives of local land owners and land users from all three counties and statewide groups such as: County RCDs, CA Rice Commission, University of California Cooperative Extension Advisors, County Planning Departments, Drainage Districts, and Agricultural Commissioners. In addition, it will be essential for the workgroup to also include those government agencies that will have regulatory authority over future projects and/or have resource management responsibilities that overlap with the planning goals. Such agencies include the various water/irrigation districts, DWR, RWQCB, CDFG, USFWS, and USACE.
- Create a Memorandum of Understanding, signed by the workgroup members, to ensure their commitment to participation and collaboration.
- Facilitate the workgroups' establishment of a focused, well-defined, and achievable set of watershed management goals and measurable objectives. The goals should address the workgroups' top land management concerns, while preserving and restoring natural watershed resources and processes.
- As part of the goals development process, the workgroup should determine how the IWMP process will interface with the existing major planning processes in the Colusa Basin Watershed including County and City General Plan Updates, the Colusa Basin Water District's Integrated Resource Management Program for Flood Control, and the Yolo, Colusa, and Glenn County Groundwater Management Planning process. In other words, will this IWMP serve as a vehicle for integrating all, or a subset, of the above planning processes with broader watershed-scale goals that reach beyond strictly flood control, groundwater management and development planning? Or will the IWMP serve to fill "holes" in the above, existing planning processes?
- Fill those data gaps necessary to conceptualize and prioritize projects to achieve the workgroups goals and objectives.
- Formulate a suite of proposed projects (at a broad, conceptual level) that achieve the workgroup's goals and objectives. For each project, identify a project leader from the workgroup, partnering agencies and landowners, environmental review/permitting requirements, estimated duration, and planning-level cost estimates. Group certain projects into programs, if appropriate.
- Prioritize the proposed project/program list. This process will then serve as a basis for the acquisition of funds to implement the management plan. Consider pilot projects where there is considerable uncertainty in the science to predict results and to get actions started on the ground.

# INTRODUCTION

The H. T. Harvey & Associates' Team, under contract to the Colusa County Resource Conservation District [CCRCD], has prepared this Watershed Assessment for the Colusa Basin Watershed. The assessment was funded by a grant from the CALFED Watershed Program, administered by the California Department of Water Resources ([DWR] see **Appendix 1-Introduction**, for list of acronyms). We worked with the CCRCD to conduct the assessment according to the following steps:

1. Conduct stakeholder telephone interviews to identify stakeholder concerns and available information
2. Characterize existing watershed conditions based on available existing information
3. Conduct a qualitative assessment of historical changes in key ecosystem features and processes based on available existing information
4. Identify data gaps
5. Recommend next steps toward the development of a future watershed management plan

This Watershed Assessment integrates established methodologies from the following sources:

California Watershed Assessment Manual ([CWAM], Shilling et al. 2005)
Bay Area Watershed Assessment Approach (San Francisco Estuary Institute 1998)
Watershed Planning Guide (California Coastal Conservancy 2001)

## GENERAL WATERSHED DESCRIPTION AND GEOMORPHIC SETTING

The Colusa Basin Watershed comprises an area of 1,045,445 acres (1634 $mi^2$) on the western side of the Sacramento Valley up to the ridge crest of the Coast Range foothills that drain eastward into it; (**Figure 1-Introduction**). The Colusa Basin Watershed is bounded on the northwest by the Upper Stony Creek Watershed, on the southwest by the Cache Creek Watershed, and on the east by the levees of the Sacramento River (**Figure 1-Introduction**). It is bounded on the south by a natural levee of Cache Creek Slough, a former alignment of Cache Creek that discharged to the Sacramento River near the present location of Knights Landing (**Figure 2-Introduction**). The Colusa Basin Watershed is bounded on the north by the recent terraces and active channel of lower Stony Creek. The Colusa Basin Watershed therefore includes portions of the Stony Creek alluvial fan and consequently, the northern boundary of the watershed is not as precisely defined by physiography as the eastern, western, and southern boundaries.

A low trough of relatively flat basin lands runs parallel to the 5- to 20-ft high Sacramento River levees along the length of the watershed. These flat basin lands are referred to herein as the Colusa Basin. Viewed in more detail, the Colusa Basin surface is a complex of individual smaller flood basins isolated by a meandering and intermingled network of floodplain channel ridges formed along adjacent slough channels. The floodprone flat basin lands run about 70 miles north to south and are up to 8 miles wide. Streams draining winter rainfall from the Coast Range foothills, portions of the Stony Creek alluvial fan, and overflow from the Sacramento

River historically have contributed to regular seasonal flooding of the Colusa Basin (**Figure 2-Introduction**).

Overall, the watershed appears relatively flat with gentle slopes rising upwards towards the northwest as one approaches the lower foothills of the Inner Coastal Range and rising slightly along the natural levees of the Sacramento River (**Figure 3-Introduction**). Elevations in the Colusa Basin Watershed range from 30 ft in the southeast to 2800 ft along the western perimeter in the foothills of the Inner Coast Range (**Figure 3-Introduction**). Major landforms include the natural levees along the west side of the Sacramento River; the broad floodplains and basin of the valley floor; and the foothills, ridges, and valleys of the Inner Coast Range.

For the purpose of this assessment, the Colusa Basin Watershed has been subdivided into 24 subwatersheds. These subwatersheds are drained by the major tributaries of the Inner Coast Range that flow eastward to the Colusa Basin Drainage Canal (herein referred to as Colusa Drain, also called Colusa Trough within the region, and ultimately to the Sacramento River at Knights Landing (**Figure 2-Introduction**). The Colusa Drain runs along the eastern side of the watershed, draining the land to the Sacramento River. The Glenn-Colusa Canal runs north to south through the central portion of the watershed, draining to the Colusa Drainage Canal and the Tehama-Colusa Canal runs from north to south along the western edge of the valley until it connects to Bird Creek in the south (**Figure 2-Introduction**).

The climate in Colusa Basin Watershed is Mediterranean, with mild winters and distinctly seasonal precipitation. At Colusa, about 81% of annual precipitation falls in the months of November to April (USDA/NRCS 1998). Accordingly, the highest foothill streamflow occurs December through March. Precipitation patterns show a strong orographic control, with average annual precipitation ranging from 17 to 27 inches, and higher precipitation occurring in the Coast Range foothills on the western side of Colusa Basin Watershed (DWR 2006).

The vast majority of the valley floor consists of irrigated crops (primarily rice), which comprise the primary land use and vegetation type in the watershed. Freshwater wetland habitats occur in the central portion of the watershed on the valley floor at the Sacramento, Delevan, and Colusa National Wildlife Refuges [NWRs]. Plant communities in the foothills are distributed in part, in relation to topographic relief. Annual grasslands are located along the base of the foothills and transition into blue oak woodlands and blue oak-foothill pine woodlands at the higher elevations along the western edge of the watershed. Land uses transition from agricultural crops on the valley floor to more cattle and sheep grazing in the annual grasslands and blue oak woodlands of the foothills.

The majority of land within the watershed is unincorporated and occurs within portions of Glenn, Colusa, and Yolo counties. Interstate 5, a major thoroughfare, bisects the watershed from north to south. The towns of Willows and Williams, located along Interstate 5 and Colusa, located along Highway 20 are the primary urban centers in the watershed (**Figure 1-Introduction**).

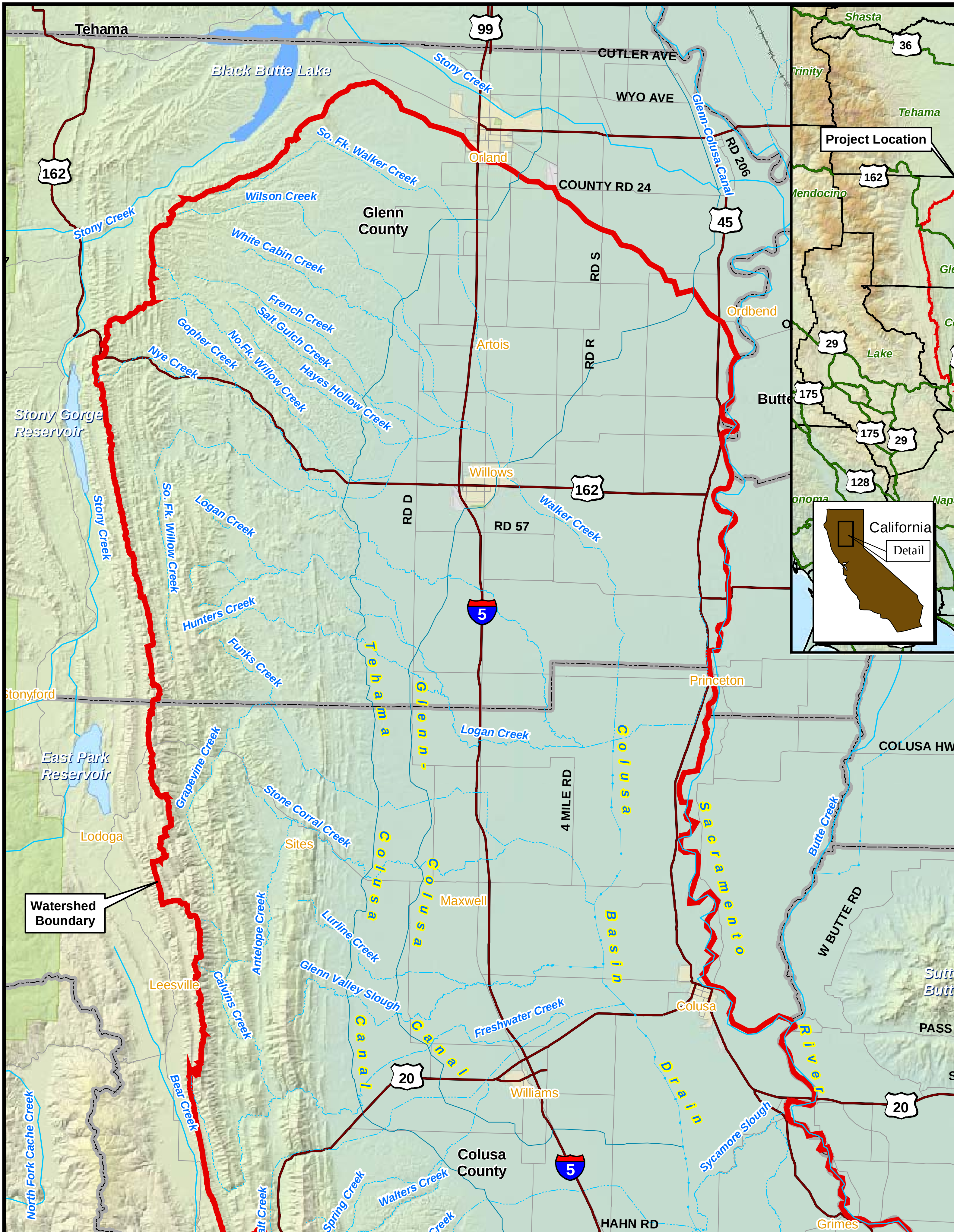
## ASSESSMENT PURPOSE AND STRUCTURE

The CCRCD has a successful history of assisting landowners with land stewardship projects throughout the Colusa Basin Watershed; however, these projects were not necessarily linked to a comprehensive conservation and management strategy for the Colusa Basin Watershed. Therefore, the CCRCD intends to develop a management plan for the Colusa Basin Watershed to identify and prioritize projects that are “best for the watershed” and locally driven. This Watershed Assessment is the first step in this process and compiles existing information and stakeholder concerns into a user-friendly document to support the future development of a management plan. The purpose of the assessment is therefore to create a comprehensive document that both landowners and policymakers can utilize to make informed decisions. The assessment describes where we have been (history), where we are now (current conditions), and will help local stakeholders formulate future actions to improve the holistic health of the watershed.

This assessment synthesizes existing information to provide a broad, landscape-scale description of the historical and existing watershed conditions and processes. Additionally, existing information on historical conditions (pre- and post-1850) has been gathered to facilitate a description of how the physical, biological, and land-use components have changed over time. This approach allows the historical conditions assessment to elucidate cause-effect relationships and thereby provide an understanding of ecosystem processes within the watershed.

## STAKEHOLDER ORGANIZATION AND PROCESS

This Watershed Assessment process has been integrated with stakeholder outreach led by the CCRCD. The CCRCD has established a Technical Advisory Committee [TAC] composed of 20 individuals representing various government agencies (**Appendix 2-Introduction**). The TAC members have committed to providing guidance to the Watershed Assessment approach and technical review of the Watershed Assessment document. The CCRCD has also held 2 public meetings to gather landowner concerns in the watershed. These meetings were held on 18 January 2007 and 18 September 2007. In addition, the CCRCD and the H. T. Harvey & Associates’ Team conducted telephone interviews with stakeholders in the Colusa Basin Watershed representing public agencies and long-time landowners (**Appendix 3-Introduction**). The Draft Watershed Assessment will be distributed for public review, and one public meeting will be held in Fall 2008 to gather public comments on the Draft Watershed Assessment for incorporation into the Final Watershed Assessment.



Tehama
Black Butte Lake
99
CUTLER AVE
Stony Creek
WYO AVE
Glenn-Colusa Canal
RD 206
So. Fk. Walker Creek
Orland
COUNTY RD 24
162
Wilson Creek
Glenn
County
45
Stony Creek
White Cabin Creek
RD S
Ordbend
French Creek
Salt Gulch Creek
Gopher Creek
No.Fk. Willow Creek
Artois
RD R
Nye Creek
Hayes Hollow Creek
Butte
Stony Gorge
Reservoir
Willows
162
Stony Creek
So. Fk. Willow Creek
Logan Creek
RD D
RD 57
Walker Creek
5
Hunters Creek
Funks Creek
Tehama
Glenn -
Princeton
Stonyford
Logan Creek
Colusa
COLUSA HW
East Park
Reservoir
Grapevine Creek
4 MILE RD
Stone Corral Creek
Lodoga
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Colusa
Colusa
Sacramento
Butte Creek
W BUTTE RD
Maxwell
Watershed
Boundary
Antelope Creek
Lurline Creek
Basin
Glenn Valley Slough
Leesville
Calvins Creek
Canal
Canal
Colusa
Freshwater Creek
River
PASS
20
Williams
Drain
20
Bear Creek
Sycamore Slough
North Fork Cache Creek
Colusa
County
5
Spring Creek
Walters Creek
HAHN RD
Grimes
Shasta
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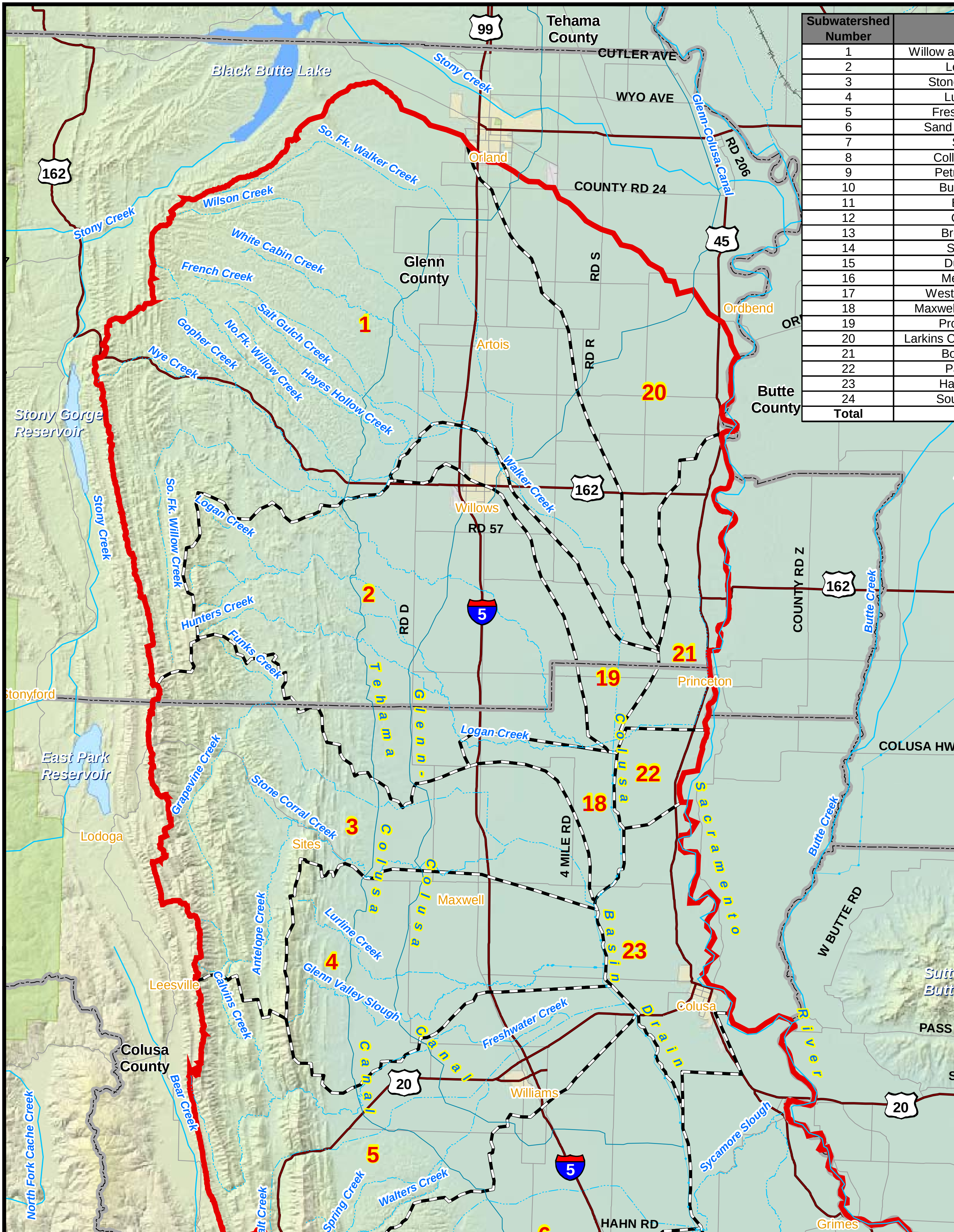
Trinity
Tehama
Project Location
162
Mendocino
29
Lake
175
175
29
128
California
Detail


Tehama County
Glenn County
Colusa County
Butte County
Black Butte Lake
Stony Gorge Reservoir
East Park Reservoir
Orland
Artois
Willows
Ordbend
Princeton
Stonyford
Lodoga
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Leesville
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Hunters Creek
Funks Creek
Grapevine Creek
Stone Corral Creek
Antelope Creek
Lurline Creek
Glenn Valley Slough
Calvins Creek
Bear Creek
North Fork Cache Creek
Spring Creek
Walters Creek
Freshwater Creek
Sycamore Slough
Butte Creek
Glenn-Colusa Canal
Tehama Colusa Canal
Glenn-Colusa Canal
Colusa Basin Drain
Sacramento River
1
2
3
4
5
18
19
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21
22
23
Subwatershed Number
1 Willow a
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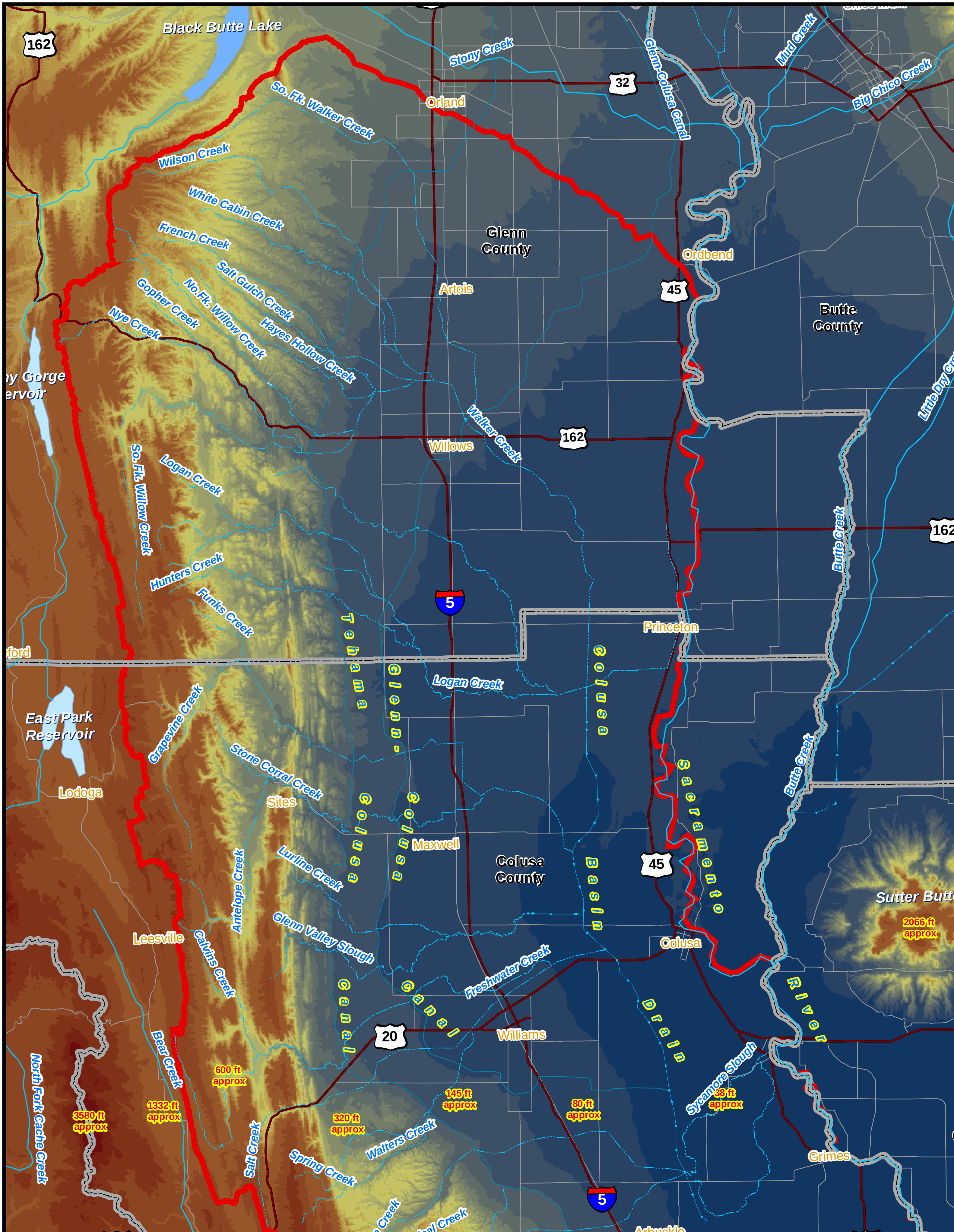
Total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So. Fk. Walker Creek
Orland
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Glenn-Colusa Canal
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Wilson Creek
White Cabin Creek
French Creek
Glenn County
Ordbend
Salt Gulch Creek
Gopher Creek
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Walker Creek
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Logan Creek
Butte Creek
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Hunters Creek
Funks Creek
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Tehama
Glenn-
Colusa
Princeton
Logan Creek
East Park Reservoir
Grapevine Creek
Lodoga
Stone Corral Creek
Sites
Sacramento
Butte Creek
Colusa
Colusa
Maxwell
Lurline Creek
Antelope Creek
Colusa County
Basin
45
Sutter Butte
2066 ft approx
Glenn Valley Slough
Leesville
Calvins Creek
Colusa
Freshwater Creek
River
Canal
Canal
Drain
20
Williams
Bear Creek
600 ft approx
145 ft approx
80 ft approx
38 ft approx
Sycamore Slough
North Fork Cache Creek
3580 ft approx
1332 ft approx
320 ft approx
Salt Creek
Walters Creek
Spring Creek
Grimes
5
Arbuckle

# CLIMATE

The most recent published synthesis of climate data located during the preparation of this assessment was presented in the Colusa County Soil Survey (USDA/NRCS 1998). This summary was intended to cover the Colusa County area, including the Coast Range Mountains lying to the east of the watershed. It was based on 1961-1990 precipitation data from the Colusa and East Park Reservoir stations, among other data, and is thought to be the most recent and essentially representative climate summary available for the Colusa Basin Watershed area as a whole. USDA/NRCS has since published 1971-2000 climate data summaries. (USDA/NRCS 1998):

> The climate of Colusa County is characterized by warm, dry summer. Winters are cool and moist in the Sacramento Valley and cold and wet on the Coast Range. The climate varies widely because of variations in the topography of the county.
>
> Table 1 gives data on temperatures and precipitation for the survey area as recorded at Colusa and East Park Reservoir in the period 1961 to 1990. Table 2 shows probable dates of the first freeze in fall and the last freeze in spring. Table 3 provides data on the length of the growing season.
>
> The Coast Range receives abundant precipitation. The higher elevations receive more than 50 inches per year. The Coast Range shields the Sacramento Valley from excessive precipitation. Pacific storms generally enter the county from the west, and precipitation diminishes as elevations drop from the crest of the Coast Range to the Sacramento Valley in the rain-shadow effect. Pacific storms are generally mild. Occasionally, a strong, warm, persistent storm generated to the southwest in the north-central Pacific drops a large amount of rainfall that causes widespread flooding along streams and in the Colusa Basin and in Butte Sink.
>
> Most precipitation falls during a pronounced rainy season from November through March. Colusa receives more than 81 percent of its average annual precipitation during this season. Little, if any, precipitation usually falls in the period June through August. On the average, less than 1 inch of precipitation falls at Colusa from May through September. Thunderstorms occur on only 5 days of the year, on average, at Colusa and are not severe. They are more frequent on the Coast Range.
>
> Temperatures vary with elevation across the county. The Sacramento Valley is the warmest part of the county. It has summer afternoon temperatures in the upper 90s. The Coast Range, above an elevation of 5,000 feet, has summer afternoon temperatures in the 70s. At Colusa, average winter temperatures are 49.8 degrees F and average summer temperatures are 74.6 degrees F. Cool south winds, of coastal marine origin, flow through the Carquinez Straits and cool the Sacramento Valley in the summer months. Occasional heat waves with temperatures over 100 degrees F occur when an air-pressure pattern with resultant north winds cuts off the flow of cool marine air into the Sacramento Valley from the San Francisco Bay area. Winter temperatures are moderated by the relative proximity of the county to the Pacific Ocean and to the Sierra Nevada Mountains to the east, which deflect cold continental air. Temperatures below freezing generally occur from November to March and become more frequent with increasing elevation.
>
> Snowfall is very rare in the Sacramento Valley and increases in amount with elevation through the foothills and into the Coast Range. The greatest snow depth recorded at Colusa was 8 inches on January 8, 1973. Snowfall occurs occasionally in the foothills below 2,000 feet and may

accumulate to depths of a few inches. On the Coast Range snow can accumulate to depths of 5 or 6 feet at elevations above 5,000 feet. Snow is usually evident on Snow Mountain from November to May.

Prevailing winds are from the southwest and are generally light throughout the survey area, except for exposed ridgetops on the Coast Range and open areas of the Sacramento Valley. Strong winds are rare. Thunderstorms are uncommon and are not severe, and tornadoes are almost unknown.

Cloud cover is considerable in the winter months and averages 52 percent at Colusa. Radiational cooling fog, forming in late night and early morning hours, is common in December and January. Under stagnant weather conditions, this fog can persist for many days. Clear skies are typical in late spring, summer, and early fall. At Colusa the sun shines an average of 96 percent of the time possible during the summer months.

Relative humidity is very low on summer afternoons, making the summer heat more tolerable. Humidity is high throughout the rainy season (November through March).

Note that Tables 1-3 are reproduced in this assessment as **Tables 1-Climate** through **3-Climate.**

The climate summary reproduced above does not distinguish between the county lands and the Colusa Basin Watershed lands. The data and observations it provides for the Coast Range area are representative of the higher Coast Range Mountains lying to the east of the watershed's lower foothills. Data and observations it provides for the Colusa vicinity are probably representative of the valley flat and low plains areas on the eastern half of the watershed. A map of long term mean annual precipitation data would be useful for determining the maximum precipitation in the upper watersheds of the foothill streams. It is generally understood that the annual precipitation within the Colusa Basin Watershed ranges from 27 inches along its western edge to about 17 inches on the valley flat (DWR 2006). These data are probably for 1900-1960 as they are most likely taken from Rantz (1971).

**Table 1. Climate. Temperature and Precipitation Recorded in the Period 1961-1990 at Colusa and East P**
**Adapted from Reed 2006.**

| Month | Temperature | | | | | | Precipit | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average Daily Maximum | Average Daily Minimum | Average | 2 Years in 10 Will Have | | Average Number of Growing Degree Days* | Average | 2 Years in 10 W Have | |
| | | | | Maximum Temperature Higher than | Minimum Temperature Higher than | | | Less than | More than |
| | °F | °F | °F | °F | °F | Days | In | in | in |
| **Station: Colusa 2 SSW** | | | | | | | | | |
| **January** | 53.8 | 36.4 | 45.1 | 70 | 23 | 172 | 3.15 | 0.92 | 4.95 |
| **February** | 61.0 | 39.9 | 50.5 | 75 | 28 | 297 | 2.54 | 0.72 | 4.16 |
| **March** | 65.9 | 41.9 | 53.9 | 82 | 28 | 430 | 2.18 | 0.98 | 3.21 |
| **April** | 73.4 | 44.5 | 59.0 | 91 | 32 | 570 | 0.88 | 0.16 | 1.44 |
| **May** | 82.4 | 51.4 | 66.9 | 99 | 38 | 834 | 0.32 | 0.08 | 0.8 |
| **June** | 90.4 | 56.4 | 73.4 | 106 | 45 | 1,001 | 0.22 | 0.07 | 0.59 |
| **July** | 95.5 | 58.6 | 77.1 | 108 | 48 | 1,149 | 0.04 | 0.01 | 0.27 |
| **August** | 94.1 | 57.3 | 75.7 | 107 | 47 | 1,105 | 0.07 | 0.05 | 0.43 |
| **September** | 88.8 | 53.7 | 71.2 | 103 | 42 | 937 | 0.34 | 0.07 | 0.83 |
| **October** | 78.6 | 47.6 | 63.1 | 96 | 35 | 715 | 1.04 | 0.28 | 1.92 |
| **November** | 63.2 | 41.1 | 52.2 | 80 | 27 | 365 | 2.51 | 0.68 | 3.68 |
| **December** | 53.8 | 36.6 | 45.2 | 69 | 22 | 178 | 2.47 | 1.27 | 3.98 |
| **Yearly** | | | | | | | | | |
| **Average** | 75.1 | 47.1 | 61.1 | | | | | | |
| **Extreme** | 113 | 15 | | 109 | 21 | | | | |
| **Total** | | | | | | 7,752 | 15.76 | 10.65 | 20.04 |
| **Station: East Park Reservoir** | | | | | | | | | |
| **January** | 54.5 | 31.5 | 43.0 | 71 | 18 | 130 | 4.50 | 1.77 | 6.8 |
| **February** | 58.6 | 35.0 | 46.8 | 74 | 22 | 198 | 3.48 | 0.87 | 5.89 |
| **March** | 61.2 | 37.2 | 49.2 | 79 | 24 | 290 | 2.44 | 0.73 | 3.95 |
| **April** | 68.1 | 40.5 | 54.3 | 87 | 28 | 429 | 1.13 | 0.37 | 1.92 |

* A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily te sum by 2, and subtracting the temperature below which grown is minimal for the principal crops in the area (40 °F)

| Month | Temperature | | | | | | Precipita | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average Daily Maximum | Average Daily Minimum | Average | 2 Years in 10 Will Have | | Average Number of Growing Degree Days* | Average | 2 Years in 10 W Have | |
| | | | | Maximum Temperature Higher than | Minimum Temperature Higher than | | | Less than | More than |
| | °F | °F | °F | °F | °F | Days | In | in | in |
| **May** | 77.7 | 47.0 | 62.4 | 97 | 32 | 693 | 0.39 | 0.11 | 0.78 |
| **June** | 86.7 | 54.3 | 70.5 | 105 | 40 | 893 | 0.27 | 0.10 | 0.73 |
| **July** | 93.7 | 58.8 | 76.2 | 107 | 47 | 1,117 | 0.04 | 0.06 | 0.32 |
| **August** | 92.1 | 57.0 | 74.5 | 106 | 46 | 1,070 | 0.15 | 0.07 | 0.51 |
| **September** | 87.2 | 52.2 | 69.7 | 104 | 40 | 890 | 0.26 | 0.09 | 0.63 |
| **October** | 76.9 | 45.2 | 61.0 | 96 | 31 | 665 | 1.10 | 0.28 | 2.12 |
| **November** | 64.0 | 37.3 | 50.6 | 83 | 23 | 320 | 2.62 | 0.58 | 4.34 |
| **December** | 56.1 | 32.4 | 44.3 | 72 | 19 | 115 | 3.79 | 1.28 | 6.03 |
| **Yearly** | | | | | | | | | |
| **Average** | 73.1 | 44.0 | 58.6 | | | | | | |
| **Extreme** | 113 | 10 | | 109 | 16 | | | | |
| **Total** | | | | | | 6,851 | 20.18 | 10.62 | 26.93 |

In addition, a data set for average annual precipitation based on the more recent 30-year period 1971 – 2000 has been developed through PRISM. [http://www.wcc.nrcs.usda.gov/climate/prism.html] **Tables 4-Climate** through **5-Climate** contain 1971-2000 data for comparison to **Tables 1-Climate** through **3-Climate**. An update of frost data at Colusa (**Table 2-Climate**) was not published at the time of this assessment. The complete available data for this period can be downloaded from USDA Geospatial Data Gateway. [http://datagateway.nrcs.usda.gov/] The USDA/NRCS database contains 30-year summary data for the following stations:

Colusa County
- Colusa
- Williams (frost data only)
- Williams Airport (frost data only)
- East Park Reservoir (outside watershed)
- Stonyford Ranger Station (outside watershed)

Glenn County
- Orland (outside watershed)
- Stony Gorge Reservoir (outside watershed)
- Willows

Yolo County
- Brooks Farnham Ranch (frost data only) (outside watershed)
- Davis (outside watershed)

**Table 2. Climate. Freeze Dates in Spring and Fall Recorded for the Period 1961-1990; Adapted from Reed 2006.**

| **Probability** | **Temperature** | | |
|---|---|---|---|
| | **24 °F or Lower** | **28 °F or Lower** | **32 °F or Lower** |
| Last Freezing Temperature in Spring | | | |
| 1 Year in 10 Later than | January 22 | March 16 | April 16 |
| 2 Year in 10 Later than | January 12 | February 28 | April 1 |
| 5 Year in 10 Later than | December 12 | January 27 | March 2 |
| First Freezing Temperature in Fall | | | |
| 1 Year in 10 Earlier than | December 1 | November 16 | November 1 |
| 2 Year in 10 Earlier than | December 14 | November 24 | November 9 |
| 5 Year in 10 Earlier than | January 18 | December 9 | November 24 |

**Table 3. Climate. Growing Season Recorded for the Period 1961-1990; Adapted from Reed 2006.**

| **Probability** | **Daily Minimum Temperature during Growing Season** | | |
|---|---|---|---|
| | **Higher than 24 °F** | **Higher than 28 °F** | **Higher than 32 °F** |
| | **Days** | **Days** | **Days** |
| 9 Years in 10 | 338 | 358 | 208 |
| 8 Years in 10 | >365 | 276 | 228 |
| 5 Years in 10 | >365 | 312 | 266 |
| 2 Years in 10 | >365 | >365 | 304 |
| 1 Years in 10 | >365 | >365 | 324 |

**Table 4. Climate. Temperature and Precipitation Recorded in the Period 1971-2000 at Colusa.**

| Month | Temperature | | | | | | Precipit | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average Daily Maximum | Average Daily Minimum | Average | 2 Years in 10 Will Have | | Average Number of Growing Degree Days* | Average | 2 Years in 10 W Have | |
| | | | | Maximum Temperature Higher than | Minimum Temperature Higher than | | | Less than | More than |
| | °F | °F | °F | °F | °F | Days | In | in | in |
| Station: Colusa 2 SSW | | | | | | | | | |
| **January** | 58.2 | 37.6 | 45.9 | 69 | 25 | 191 | 3.58 | 0.92 | 6.17 |
| **February** | 60.6 | 40.9 | 50.7 | 75 | 29 | 304 | 3.09 | 0.66 | 5.42 |
| **March** | 65.9 | 43.4 | 54.7 | 81 | 29 | 454 | 2.66 | 1.05 | 3.96 |
| **April** | 73.9 | 45.6 | 59.7 | 91 | 33 | 590 | 0.76 | 0.20 | 1.26 |
| **May** | 81.7 | 52.7 | 67.2 | 100 | 39 | 840 | 0.67 | 0.00 | 1.18 |
| **June** | 89.5 | 57.3 | 73.4 | 105 | 45 | 1,001 | 0.20 | 0.00 | 0.42 |
| **July** | 94.1 | 59.2 | 76.6 | 108 | 48 | 1,136 | 0.04 | 0.00 | 0.00 |
| **August** | 93.0 | 57.3 | 75.2 | 107 | 48 | 1,088 | 0.04 | 0.00 | 0.00 |
| **September** | 89.1 | 54.1 | 71.6 | 104 | 43 | 947 | 0.34 | 0.00 | 0.59 |
| **October** | 79.5 | 47.9 | 63.7 | 97 | 36 | 734 | 0.94 | 0.14 | 1.68 |
| **November** | 63.3 | 40.9 | 52.1 | 80 | 27 | 361 | 2.22 | 0.58 | 3.51 |
| **December** | 54.6 | 36.6 | 45.6 | 69 | 23 | 187 | 2.34 | 0.80 | 3.87 |
| **Yearly** | | | | | | | | | |
| **Average** | 74.9 | 47.8 | 61.4 | | | | | | |
| **Extreme** | 113 | 15 | | 109 | 22 | | | | |
| **Total** | | | | | | 7,832 | 16.89 | 10.66 | 22.08 |

* A growing degree day is a unit of heat available for plant growth. It can be calculated by adding the maximum and minimum daily te sum by 2, and subtracting the temperature below which grown is minimal for the principal crops in the area (40 °F)

**Table 5. Climate. Growing Season Recorded at Colusa for the Period 1971-2000.**

| Probability | Daily Minimum Temperature during Growing Season | | |
|---|---|---|---|
| | Higher than 24 °F | Higher than 28 °F | Higher than 32 °F |
| | Days | Days | Days |
| 9 Years in 10 | >365 | 270 | 210 |
| 8 Years in 10 | >365 | 292 | 231 |
| 5 Years in 10 | >365 | 343 | 272 |
| 2 Years in 10 | >365 | >365 | 312 |
| 1 Years in 10 | >365 | >365 | 334 |

# LAND USE AND SOCIAL CHARACTERISTICS

## HISTORICAL CONDITIONS AND TEMPORAL CHANGE

### Scope and Methods

The scope of the historical assessment of the Colusa Basin Watershed was defined with TAC member input to focus on contrasting 2 particular time periods: pre-1850 (corresponding to the period prior to Euro-American settlement) and post-1850 (corresponding to the post-Euro-American settlement period), rather than an exhaustive annual or decadal report on temporal changes. Information sources about watershed conditions at the time of Euro-American settlement was limited to only a few early histories of the region written around the turn of the century (Green 1880, Rogers 1891) and a few more recent retrospective reports by various sources (Kelley 1989, Thompson 1961, Hall 1975). Note that some of the categories in the historical assessment are somewhat different from Existing Conditions based on available information.

### Watershed Community Characteristics (Demography and Economy Overview)

It has been estimated from archeological evidence that native people have been present in California from as early as 12,000 years ago (SDSU 2008). Evidence from the adjacent Stony Creek Watershed suggests that American Indians first utilized that area at least 10,500 years ago, and it seems reasonable to assume that inhabitation of the adjacent Colusa Basin Watershed occurred at the same time (White 2003). Early historical writing by European and American settlers identified the main American Indian group in the Colusa Basin Watershed as the *Colus* (or *Colu*) people based on the pronunciation of the village site in the modern-day City of Colusa (Green 1880, Rogers 1891). Since population estimates in these early historical accounts were certainly not based on systematic census, they vary widely. Nonetheless, they indicate that the Colusa Basin Watershed was thoroughly populated by American Indian villages prior to Euro-American contact. John Bidwell estimated that the population of American Indians living in the Colusa County region was around 10,000 individuals in the mid 1800s (Rogers 1891). Will Green reported that there were a thousand or more Colus Indians in this region in 1850 and that the Colus were comprised of about 12 sub-groups (Rogers 1891). Contemporary ethnographic descriptions of the American Indians that lived in this region identify them as Patwin, which are a culturally and linguistically unique sub-group of the larger Penutian language group, also called Wintun. The Wintun are separated into 3 cultural and linguistic groups, each of which consisted of a number of local dialects: the northern Wintu, the central Wintun or Nomlaki, and the southern Wintun or Patwin (ARP CSU Chico 2005). The Patwin are distinguished even further into 2 groups: those that resided along the Sacramento River and those that lived in the foothills of the Coast Range (ARP CSU Chico 2005). The central Colus village was sited where the City of Colusa stands today and was presumably a village site of the river-dwelling Patwin (Sedway Cooke Associates 1989). At least a dozen other villages were known to exist between Princeton and Sycamore (ARP CSU Chico 2005).

The subsistence hunter/gatherer economy of the American Indians living in the Colusa Basin Watershed was based on sustainable management and use of the once abundant natural resources such as acorns, fish, game, and wild fruits, as well as regional trading with coastal tribes (ARP CSU Chico 2005). The vast tule marshes of the Colusa Basin Watershed were a resource for building material since tules were used for building boats, huts, and baskets (Anderson 2005). The American Indians living in the Colusa Basin Watershed recognized the twice-annual flooding cycle in the Basins and moved accordingly; they even warned the earliest Euro-American settlers about the dangers of their choice of settlement locations (Kelley 1989). Throughout California's oak woodland habitats, the California Indians historically practiced land management activities such as burning understory grasslands and selective planting and harvesting of culturally important plant species for food and fiber (Anderson 2005). These activities carried out by thousands in the region certainly shaped the vegetation that the first Euro-American settlers encountered in the Colusa Basin Watershed.

The 2 Rancheria that currently exist in the area are associated with the Wintun Tribe and are located at Cortina and Colusa Rancherias (**Figure 1-Land Use**). Their combined current population has been reported to be around 100 people (SDSU 2008). A few of the principle causes of the dramatic decrease in population of American Indians in this region, from the tens of thousands in 1850 to approximately 100 in the modern era, include decimating disease epidemics (smallpox, malaria, etc.), tragic acts of violence by some Euro-Americans, and numerous unfulfilled land agreements resulting in relatively small reservation lands today (Rogers 1891, Kelley 1989).

The earliest European exploration of the Sacramento Valley occurred in 1808 by the Spanish Ensign, Gabriel Moraga (**Table 1-Land Use**, Kelley 1989). Further settlement by European immigrants did not occur until at least 30 years later when Mexico began granting rancho lands to the earliest European and American settlers (Kelley 1989). In 1843-1844 John Bidwell sketched one of the earliest surveys of Colusa County as he accompanied a group of settlers that had arrived via the Oregon Trail (Rogers 1891). Settlement initially followed established navigation routes along the Sacramento River.

**Table 1. Land Use. Key Dates in the History of the Colusa Basin Watershed.**

| Date | Events |
|---|---|
| 1808 | Ensign Moraga explores up Sacramento River-first Euro-American exploration of the region |
| 1830-1833 | Malaria epidemic among American Indians of the Central Valley |
| 1840-1848 | Initial settlement period by Mexican, European, and Americans |
| 1848 | California Gold Rush |
| 1848 | Treaty of Guadelupe Hildalgo-transferred California from Mexican control to US control |
| 1850 | California Statehood |
| 1850 | Arkansas Act-"Swampland Reclamation Act" transferred federal land that was floodprone to states control with reclamation stipulation |
| 1861 | State Assembly Bill 54-flood control and drainage would be coordinated by the State government and created the swampland districts |
| 1868 | Green Act-shifted most of the state-held swamplands into private ownership and radically localized reclamation districts without regional coordination of existing overland drainage pathways |

| Date | Events |
|---|---|
| 1887 | Central Irrigation District forms and begins raising funds to build the Central Canal (i.e., Glenn-Colusa Irrigation Canal) |
| 1888 | Colusa Irrigation District-established |
| 1910 | Rivers and Harbors Act-regulates discharging pollutants including fill into navigable waters of the United States without a permit |
| 1911 | Sacramento Flood Control Project-initiated and included the concept of creating bypass channels |
| 1917 | CA Flood Control Act-flood control transferred to federal responsibility |
| 1919 | Reclamation District 2047-further developed the Colusa Basin Drain |
| 1928 | Flood Control Act- federal government assumed greater costs for flood control measures in the Sacramento Valley |
| 1930 | Central Valley Project-plan to deliver water from the Sacramento River to the San Francisco Bay area and to the southern San Joaquin Valley |
| 1936 | Flood Control Act-enlarged federal funding for flood control projects nationwide and expanded the scope of such projects (massive dams) to provide for additional multiple uses such irrigation, recreation, and electrical power generation. |
| 1937 | Sacramento National Wildlife Refuge-established |
| 1940 | Shasta Dam-located at headwaters of Sacramento Valley providing enormous detention capacity for flood control, irrigation, and power generation |
| 1944 | Sacramento Flood Control Project-90% Complete |
| 1944 | Colusa National Wildlife Refuge-established |
| 1945 | Folsom Dam-located on the American River, this tributary contributes to flooding on the Sacramento River |
| 1962 | Delevan National Wildlife Refuge-established |
| 1965 | Tehama-Colusa Canal-construction initiated |
| 1967 | Oroville Dam-located on the Feather River, this tributary contributes to flooding on the Sacramento River |
| 1979 | Tehama-Colusa Canal-construction completed |

The Gold Rush, which began in 1848, ushered in mass migration to the Sierra foothills (**Table 1-Land Use**). The Sacramento River Valley towns along the eastern boundary of the Colusa Basin Watershed became important supply stops en route to the Sierra gold mines (Kelley 1989). The 1850 Census of Colusa County registered a mere 115 residents (Rogers 1891). Ten years later, the Census estimate for the County was up to 2274 people, and estimated population in 1862 was 4500 (Rogers 1891).

A series of landmark federal and state water resource management legislation was passed between 1850 and 1870 that aimed to provide flood protection, drainage, and irrigation to floodprone regions such as the Colusa Basin Watershed. These included the Arkansas Act in 1850, State Assembly Bill [AB] 54 in 1861, and the Green Act in 1868. Further details about each of these laws are discussed in the *Land-use and Agricultural Cropping Patterns* section of this report. Their net effect was to establish the preconditions necessary to increase the amount of land available for agricultural and urban uses and increases in attendant human population within the Colusa Basin Watershed by converting native habitats such as wetlands and riparian areas.

Following the initial land rush associated with the Green Act, the population of the Sacramento Valley grew more slowly in the early 1900s. The next pulse of regional population increase occurred between 1910 and 1920, as flood control capabilities further improved through the initiation of the Sacramento Flood Control Project (**Table 1-Land Use**). During this time, the total amount of farmland remained fairly constant while populations increased as larger tracts were subdivided. During this time, the average farm size decreased and farmland also became more valuable (Kelley 1989).

### Distribution of Communities and Transportation Systems

Establishment of the earliest towns occurred along the Sacramento River corridor where barges of supplies could be loaded and unloaded (Sedway Cooke Associates 1889). The towns of Colusa, Grimes, and Princeton were among the earliest towns to establish along the river within the Colusa Basin Watershed (Sedway Cooke Associates 1989). The City of Colusa was established in 1850, around the same time the Gold Rush got underway (Kelley 1989). Marysville, across the river, initially grew more prominent due to its better steamboat access to the mines in the Sierra foothills, which meant slower initial growth for the towns on the river's west bank located within the Colusa Basin Watershed (Kelley 1989). When the Sacramento River navigational channel was deepened to Red Bluff in 1853, mining industry traffic passed further up river, passing by the Colusa County towns along the river, directing growth and development in Red Bluff instead (Sedway Cooke Associates 1989). Following the initial boom of gold mining, as agricultural production increased in the 1860s and 1870s, the City of Colusa regained prominence as a shipping port delivering the wheat harvest downriver (Sedway Cooke Associates 1989). Towns such as Williams, Maxwell, and Arbuckle later grew up around the Northern Railroad line during the 1870s and continued to serve as transportation centers for the grain harvest (Sedway Cooke Associates 1989).

### Land-use and Agricultural Cropping Patterns

Farming and grazing activities spread out into the Sacramento Valley as the population of the region increased in response to the Gold Rush, representing the initial transformation of valley bottom grasslands, wetlands, and riparian habitats into a variety of fruit and grain crops (Kelley 1989). The earliest accounts of agricultural development that accompanied the first Euro-American settlements include the arrival of cattle in 1847 and sowing of barley in 1849 (Green 1880). The first settlers farmed the better-drained alluvial soils along the Sacramento River using dryland-farming techniques for wheat and barley (DWR 1990).

Initially, farmers avoided the vast tule marsh of the Colusa Basin lowlands because they did not yet have the technology to drain them or protect them from regular flooding. Therefore, they initially established farms and orchards on the natural levees along the river and higher ground along the foothills where the soils had better drainage and high fertility (Kelley 1989). However, the Arkansas Act of 1850 granted all U.S. Federal lands that were swamp or otherwise flooded to the states so long as proceeds of the sale of these lands were used to drain them to put them into agricultural use (**Table 1-Land Use**, Kelley 1989). Unlike reclamation plans and policies that followed, drainage planning under the Arkansas Act followed natural drainage pathways, and it lifted the acreage limitations that a single party could purchase (Katibah 1981). State AB 54 followed this Act in 1861, which brought the task of coordinating swampland reclamation under state authority rather than individual private enterprises (**Table 1-Land Use**) and established the first swampland reclamation districts (Kelley 1989). Together, these policies initiated a large-scale political process to systematically drain the "swamplands" (a.k.a., tule marshes) that occupied the low basins (such as Colusa Basin) in the Sacramento Valley.

The next piece of legislation that significantly shaped both land use and agricultural cropping patterns in the Colusa Basin Watershed was the Green Act, which was passed in 1868. Will S. Green, the architect and namesake of the Green Act, was one of the most important figures whose actions shaped the history and characteristics of the Colusa Basin Watershed during this period. Green was a Colusa County surveyor in 1857, where he first hatched visions of how the basin lands could be drained and reclaimed for the purpose of agriculture. In 1868, he became a State Assemblyman and from this position introduced the Green Act (**Table 1-Land Use**). According to the Green Act an individual could purchase swamplands for $1 per acre without any limitation on the total number of acres and, provided that they proved it had been drained and cultivated, they would receive their final land title. Then, if the land could be cultivated for 3 years, the purchase price would be returned to the owner (Kelley 1989). On its first day of enactment the Green Act spawned applications for 15,000 ac (Kelley 1989). This began an enormous land rush, and certain entrepreneurs purchased huge tracts of swamplands throughout the Great Valley. Between 1868 and 1871, nearly a million acres, practically all of the swamplands formerly owned by the state passed into private ownership (Kelley 1989). Singular purchases of 100,000 to 250,000 ac were not uncommon. The Green Act dramatically stimulated the purchase and reclamation of wetlands within the Colusa Basin Watershed. For example, L.F. Moulton purchased 30,000 ac in Colusa County for this purpose. In addition to consolidating land ownership, the Green Act also fragmented reclamation districts into numerous small districts that followed property lines, not natural drainage patterns on the landscape. Each reclamation district enacted its flood control measures in a fairly autonomously rather than in a coordinated, valley-wide fashion (Kelley 1989).

In the late 1860s to early 1870s, railroad development opened up access to distant economic markets and increased farmland exports from the region. A number of Colusa County towns sprang up around the Central Pacific, Southern Pacific, and Northern Railway Lines around 1878 including Willows, Williams, Maxwell, and Arbuckle (Rogers 1891). The growing conditions of climate and soil in California's Central Valley, coupled with a few good rainfall years, produced exceptionally large yields of wheat (Kelley 1989). Access to export markets and high productivity initiated sharp growth in wheat growing and increased pressures to drain the remaining wetlands. Whereas wheat growing had previously been constrained to a narrow (5 mi) strip along the Sacramento River prior to 1867, by 1879 it was grown throughout the Colusa Basin Watershed from the Sacramento River to the western foothills (Hall 1975). Wheat production peaked in 1880 (Kelley 1989) and records indicate that 403,008 acres of wheat were planted in Colusa County in 1889 (Rogers 1891).

Irrigation capabilities improved in the 1880s with the initiation of the Glenn-Colusa Canal system to bring Sacramento River water to farmers (**Table 1-Land Use**, DWR 1990). This brought about a shift from summertime dryland-farming to irrigated crop capabilities (DWR 1990).

In the vicinity of the city of Colusa, fruit and nut orchards were established around 1875-1880 (Sedway Cooke Associates 1989). Following the turn of the century, the area around Arbuckle increased almond production significantly, from 150 acres in 1911 to 11,000 acres in 1933 (Sedway Cooke Associates 1989). Almond production was profitable on relatively small parcels compared to grain production; this increase in almond production was accompanied by concurrent subdividing of larger ranches (Sedway Cooke Associates 1989.)

The era around 1913 saw great increases in the conversion of floodprone swamplands to agricultural uses as reclamation districts expanded levees, drained the swamplands, and planted agricultural crops. The State Reclamation Board and the Sacramento River Flood Control Project were both established in 1911, and the Sacramento and San Joaquin Drainage District was established in 1913 (**Table 1-Land Use**, DWR 1990). These flood control initiatives further improved drainage, prevented flooding, and provided irrigation water, increasing the area available for agricultural cultivation (DWR 1990). For example, the surface area of Sacramento Valley lands in some state of reclamation in 1910 was about 300,000 ac and by 1913, 400,000 ac were under some state of reclamation (Kelley 1989).

Railroad construction in the region expanded between 1906-1913 to include lines from Sacramento to Woodland and from Marysville to Colusa (Kelley 1989). River navigation improved after 1913 following deep dredging of the Sacramento River. Commercial traffic on the Sacramento River peaked in 1925 and declined thereafter (Kelley 1989). Increased river and railroad traffic followed increasing agricultural production, and shifts in the types of agricultural commodities occurred at this time. Orchards increased in lieu of field crops as protection from floods increased (Kelley 1989). An example cited from a single landholding illustrates the shift in productivity that occurred in the region at this time: a 54,000 ac holding that produced 35,000 tons of freight per year from field crops prior to 1916 was divided into smaller holdings in orchard production and produced 150,000 tons (Kelley 1989). By 1915, orchards lined both banks of the river and included pears, plums, peaches, cherries, prunes, apricots, and the earliest vineyards (Kelley 1989). Fruit growing has historically been perceived as more conducive to longer-term stewardship for smaller family farms than the relatively shorter-lived boom of wheat production (Kelley 1989).

During the early 1900s, the predominant farm crops in Colusa County were rice and tomatoes (Sedway Cooke Associates 1989). Rice production increased most dramatically between 1911 and 1920 (**Table 2 Land-Use**). In 1911, only 160 ac of rice was grown in the Sacramento Valley; by 1915, 720,000 sacks were produced in the valley, and by 1916, 2.5 million sacks of rice were produced in the valley (Kelley 1989). The earliest accounts of rice growing in the Colusa Basin Watershed are attributed to Spaulding Ranch in 1910 (Hall 1975). Rice cultivation grew quickly on previously unused soils, perhaps due in part to its greater tolerance of alkaline conditions and poorly drained soils (Hall 1975). The productivity and profits of some of the earliest (1917) experiments in growing rice were enormous (Hall 1975); however, subsequent harvests on the same land were significantly lower (despite favorable climatic conditions). This did not deter the rapid spread of rice cultivation in the region, which resulted in nearly all the remaining available land being put into rice production by 1920 (Hall 1975). Eventually, through trial and error of methods of production such as better site selection, rest, and rotation periods, successive yields of rice were made more consistent and the initial expansion in rice growing leveled out (Hall 1975).

**Table 2. Land Use. Rice Acreage 1913-1919.**

| County | 1913 | 1914 | 1915 | 1916 | 1917 | 1918 | 1919 |
|---|---|---|---|---|---|---|---|
| Colusa | 750 | 3000 | 8750 | 16,100 | 19,750 | 28,500 | 39,050 |
| Glenn | 0 | 120 | 500 | 8100 | 16,500 | 30,000 | 34,500 |

Source: (Hall 1975, adapted from Bleyhl 1957)

Great increases in agricultural acreage and shifts toward more valuable crops indicate that agricultural growth in the region has continued to this day. Using Colusa County as an example to illustrate this general historic trend for the whole watershed, in 1939 barley was the largest field crop in Colusa County at 75,000 ac and rice was the second largest at approximately 25,000 ac. while almonds were the largest crop among fruit and nuts at 7,418 ac. (**Table 3-Land Use**). At this time the County commercially produced about 5 different kinds of field crops and about 15 types of fruit, nut, and vine (grape) crops (Colusa County 1939). Barley remained the largest field crop (on an acreage basis) until the late 1950s when rice acreage (58,770 ac) exceeded barley (46,000 ac) as the largest field crop in Colusa County (Colusa County 1960). By 2006, rice acreage in Colusa County had grown to 142,600 ac and tomatoes were the second largest field crop at 18,400 ac. while almonds remained the largest crop among fruit and nut crops at 28,600 ac. In 2006, the County commercially produced about 10 different kinds of field crops and 3 kinds of fruit and nut crops (Colusa County 2006). One factor that contributed to these shifts was the development of the Tehama-Colusa Canal, which was authorized in 1950 and began service in the early 1970s (**Table 3-Land Use**, DWR 1990). The Tehama-Colusa Canal dramatically increased the area of irrigated agricultural lands, particularly along the western foothills of the Colusa Basin Watershed (DWR 1990).

**Table 3. Land Use. Historic Crop Acreage Based on County Crop Reports for the Years Shown.**

| County | Year | Crop Type | Acreage |
|---|---|---|---|
| Colusa | 1939 | Field Crops | 123,651 |
| | 1940 | Field Crops* | 177,077 |
| | 1960 | Field and Vegetable Crops* | 177,390 |
| | 1969 | Field and Vegetable Crops* | 222,000 |
| | 1990 | Field and Vegetable Crops* | 187,440 |
| | 2001 | Field and Vegetable Crops* | 201,042 |
| | 2006 | Field and Vegetable Crops* | 200,255 |
| | | | |
| | 1939 | Fruit, Nut, and Vine Crops | 14,515 |
| | 1940 | Fruit, Nut, and Vine Crops | 13,263 |
| | 1950 | Fruit, Nut, and Vine Crops | 14,452 |
| | 1960 | Fruit and Nut Crops | 13,374 |
| | 1969 | Fruit and Nut Crops | 17,320 |
| | 1990 | Fruit and Nut Crops | 29,300 |
| | 2001 | Fruit and Nut Crops | 34,350 |
| | 2006 | Fruit and Nut Crops | 38,150 |

| County | Year | Crop Type | Acreage |
|---|---|---|---|
| Yolo | 1937 | Field and Vegetable Crops* | 200,020 |
| | 1940 | Field and Vegetable Crops* | 219,130 |
| | 1950 | Field and Vegetable Crops* | 291,202 |
| | 1970 | Field and Vegetable Crops* | 316,680 |
| | 1980 | Field and Vegetable Crops* | 264,348 |
| | 1990 | Field and Vegetable Crops* | 227,181 |
| | 2001 | Field and Vegetable Crops* | 261,125 |
| | 2006 | Field and Vegetable Crops* | 232,773 |
| | | | |
| | 1937 | Fruit and Nut Crops | 18,451 |
| | 1940 | Fruit and Nut Crops | 16,153 |
| | 1950 | Fruit and Nut Crops | 15,819 |
| | 1960 | Fruit and Nut Crops | 16,647 |
| | 1970 | Fruit and Nut Crops | 19,290 |
| | 1980 | Fruit and Nut Crops | 19,827 |
| | 1990 | Fruit and Nut Crops | 19,528 |
| | 2001 | Fruit and Nut Crops | 28,298 |
| | 2006 | Fruit and Nut Crops | 33,144 |
| Glenn | 1940 | Field and Vegetable Crops* | 146,247 |
| | 1950 | Field and Vegetable Crops* | 194,855 |
| | 1960 | Field and Vegetable Crops* | 179,696 |
| | 1970 | Field and Vegetable Crops* | 173,945 |
| | 1980 | Field and Vegetable Crops* | 189,859 |
| | 1990 | Field and Vegetable Crops* | 146,256 |
| | 1999 | Field and Vegetable Crops* | 143,292 |
| | 2001 | Field and Vegetable Crops* | 162,364 |
| | 2006 | Field and Vegetable Crops* | 142,245 |
| | | | |
| | 1940 | Fruit and Nut Crops | 8,891 |
| | 1950 | Fruit and Nut Crops | 9,628 |
| | 1960 | Fruit and Nut Crops | 7,803 |
| | 1970 | Fruit and Nut Crops | 15,167 |
| | 1980 | Fruit and Nut Crops | 22,373 |
| | 1990 | Fruit and Nut Crops | 31,996 |
| | 1999 | Fruit and Nut Crops | 41,353 |
| | 2001 | Fruit and Nut Crops | 52,256 |
| | 2006 | Fruit and Nut Crops | 53,666 |

* Includes alfalfa hay but not pasture.

## EXISTING CONDITIONS

### Scope and Methods

The Land Use and Social Characteristics section of this assessment has relied on existing information available at the time. The general plans for each of the 3 counties within the Colusa

Basin Watershed provided the primary source of information on land use patterns, policies, and plans. However, each of these plans is somewhat dated, and each county is currently revising its general plan. The current Yolo County general plan dates to 1983, with a revised version due out in 2008 (Yolo County Community Development Agency 1983). The Colusa County general plan was adopted in 1989 with a horizon of 20 yrs (to 2010), but its housing element was updated in 2003. The latest version of the Glenn County general plan was completed in 1993 and it was conceived as a 20 yr plan to be renewed in 2012 (QUAD Consultants 1993). It is also currently under revision and projected to be ratified in the latter half of 2008. This revision is intended to guide development and land use in Glenn County until 2027. Land use information from the existing county general plans has been supplemented by more recent surveys (1997, 1998 and 2003) conducted by the DWR. The general plans also contributed some information on population statistics, projections, and economic development; however, more recent demographic data have been incorporated from the 2000 U.S. Census and 2007 Department of Finance [DOF]. Census data are reported for whole counties, while the boundaries of the watershed cross county boundaries. Therefore, all countywide data is provided as an approximation of existing conditions and trends within the Colusa Basin Watershed. These sources, among others, contain a wealth of information about land use and social characteristics in the watershed. Therefore, in keeping with the scope and objectives of this assessment, existing information about land use and social characteristics have been included that bear upon the stakeholder resource issues identified above (flood control, erosion control, agricultural preservation, habitat restoration planning, water quality/quantity, etc.), rather than purporting to be a comprehensive treatment of each subject. For more detailed information about each subject, please refer to the references or appendices provided for each source.

**Watershed Community Characteristics**

**Distribution of Communities and Transportation Systems.** The principal cities in the Colusa Basin Watershed in descending order of population size are Willows (6469), Colusa (5773), and Williams (5255, DOF 2007). Each of these cities is around 2-3 $mi^2$, with the exception of Williams, which is 5.4 $mi^2$ (U.S. Census Bureau 2007). Numerous smaller communities exist within the unincorporated portions of the 3 counties. These include towns such as Maxwell, Arbuckle, Dunnigan, Knights Landing, Princeton, Grimes, and Artois, among others. All of these cities and communities are located along one of the watershed's 4 principal roadways. Willows and Williams are located along Interstate 5, while Colusa is located at the junction of Highways 45 and 20 (**Figure 1-Introduction**). Chico and Woodland are the 2 closest cities with populations greater than 50,000, and Sacramento is the closest city with a population over 100,000. As such, they serve as important links to regional employment and commerce just beyond the boundary of the watershed. The city of Willows is relatively close to Chico (<30 mi). Colusa and Williams are both nearly equidistant between Chico, Woodland, and Sacramento (40-60 mi).

Interstate 5 is the major north-south arterial, with Highways 45 and Old Highway 99W forming secondary north-south arterials. Highway 20 is the principal east-west arterial passing through Williams and Colusa in the center portion of the Colusa Basin Watershed. Highway 162 serves this function in the northern portion of the Colusa Basin Watershed as it passes through Willows.

These 4 major transportation routes, along with county roads, serve to transport the majority of the Colusa Basin Watershed's agricultural and manufacturing products via truck, because river freight is no longer active, and railroad freight carries relatively little volume of local products (Sedway Cooke Associates 1989). In addition to transporting commercial products into and out of the watershed, these 4 arterials also convey large amounts of commercial traffic through the watershed en route to further destinations. Colusa County contains 1067 mi of roadways, half of which are local roads, mostly gravel or dirt surfaced (Sedway Cooke Associates 1989). Local roads convey much of this commercial traffic and consequently have maintenance requirements that exceed local financial resources for repairs (Sedway Cooke Associates 1989).

**Community Characteristics.** The Colusa Basin Watershed spans 3 counties: Glenn, Colusa, and the northeastern portion of Yolo. Among these 3 counties, Yolo County is by far the most populous, followed by Glenn and Colusa, which have similar population densities (**Table 4-Land Use**, DOF 2007). Colusa and Yolo Counties have experienced the highest rates of population growth in the past 7 years (16%), exceeding the statewide rate of growth (11%) during this period (2000-2007, DOF 2007). Glenn County has experienced rates of growth slightly lower than the statewide average (9%, DOF 2007). The highest growth rate among cities within the Colusa Basin Watershed has occurred in Williams, which experienced 43% growth in the past 7 years (DOF 2007, **Table 5-Land Use**). The majority of the Colusa Basin Watershed is in private ownership with a small percentage in public ownership (primarily the Bureau of Land Management [BLM] and U.S. Fish and Wildlife Service [USFWS], **Figure 1-Land Use**). Agricultural production is the predominant industry in the region, and the vast majority of the Colusa Basin Watershed is in rural-agricultural land use, which includes crop production, orchards and vineyards, and grazing land. Three relatively small cities, each containing the largest proportion of the area's population, form the only urban hubs within the Colusa Basin Watershed: Willows, Colusa, and Williams (Sedway Cooke Associates 1989). The remaining population lives on rural homesites and in numerous smaller communities within the unincorporated counties. Preservation of the aesthetic, economic, and environmental aspects of these pastoral communities is a primary value among residents of the region (Yolo County Community Development Agency 1983, Sedway Cooke Associates 1989, and QUAD Consultants 1993). The rural character and requisite land and water resources that support these communities are threatened by population growth, attendant land conversion, urbanization, and changes and intensification in agricultural production. In the absence of comprehensive land use and watershed planning, these changes in community characteristics could potentially have adverse impacts on soil, water, and air resources through increased wind and water erosion, increased stormwater runoff, biological habitat loss/degradation, and transportation inefficiencies.

**Demography and Economy Overview.** The cultural and socioeconomic aspects of the Colusa Basin Watershed are a product of the settlement history and predominant industries of the Colusa Basin Watershed. 60-85% of the land is in agricultural use in Colusa and Yolo counties. Although the average farm or ranch size is 748 ac, most (70%) farms are <500 ac and a small amount (8%) of ranches are very large, >2000 ac (Sedway Cooke Associates 1989).

Agriculture (including grazing and crops without timber revenue) accounts for $791.5 million (2006) in goods from Colusa County and Glenn County; basin-wide totals would be much higher when one factors in that a portion of the Yolo County agricultural economy ($370.1 million in 2006) that occurs within the watershed boundary (USDA 2007, Glenn County Department of Agriculture 2006, Yolo County Department of Agriculture 2006). The Colusa Basin Watershed is the rice growing capital of the state with 225,036 ac in rice production in Colusa County and Glenn County in 2006 (Colusa County Department of Agriculture 2006). Rice production constitutes 19% of Colusa County's acreage and 39% of the County's non-timber agricultural income and it accounts for nearly 10% of Glenn County's acreage and 26% of the County's non-timber agricultural income (Glenn County Department of Agriculture 2006, Colusa County Department of Agriculture 2006). Fruit and nut orchards comprise 38,150 ac, which represents 5% of Colusa County's acreage and 34% of the County's agriculture income (Colusa County Department of Agriculture 2006). Almond orchards comprise 28,600 (75%) of the fruit and nut orchard acreage in Colusa County (Colusa County Department of Agriculture 2006).

Agriculture, forestry, and fishing-related businesses constituted 25% of all businesses in Colusa County. Agriculture and mining were the largest employers in Colusa County. Government, transportation, and public administrtation constitute a significant employment sectors. Retail sales represent approximately 15% of the local businesses (**Table 4-Land Use**, U.S. Census Bureau 2007 and Colusa County Economic Development Corporation 2006). In Yolo County education and social services are the largest employment sectors due to the presence of larger cities and schools in the southern half of the county, which are outside the watershed, yet affect County-level Census figures (U.S. Census Bureau 2007). The economic base and employment sectors of the northern half of Yolo County are probably comparable to the relative proportions shown for Glenn and Colusa counties (**Table 4-Land Use**).

Median household incomes range between $32,000 and $59,000 among the three counties and averages $43,000 with typically three people per household. Eleven (11%) to 14% of people in the Colusa Basin Watershed live below poverty level (U.S. Census Bureau 2007).

The average age of residents of the Colusa Basin Watershed is around 31 yrs old, and proportions of people over the age of 65 are comparable to statewide averages (10%-12%). Most people over the age of 25 have completed high school (60%-80%), while 10%-30% have completed bachelor's degrees or higher (U.S. Census Bureau 2007).

The majority of residents are white (80%-90%) and other races comprise small percentages of the population: 2-3% are American Indian or Alaska Native persons, 2-3% are Asian (in Glenn and Colusa), and less than 1% are Black. Persons of Hispanic or Latino origin comprise 30-50% of the population in the Colusa Basin Watershed, comparable to the statewide average of 35%. Between 20% and 30% of the Colusa Basin Watershed's population is foreign born (U.S. Census Bureau 2007).

**Table 4. Land Use. Demographic Statistics of 3 County Study Area and Local Communities.**
(U.S. Census Bureau 2007, DOF 2007)

| County | Area ($mi^2$) | 2007 Population | 2007 Population Density (per $mi^2$) | % Growth 2000-2007 | 2005 Housing Units | 2000 Households | 2006 Building Permits | 2000 Median Household Income | Le Sec (In 10 |
|---|---|---|---|---|---|---|---|---|---|
| Glenn | 1,314 | 28,915 | 22 | +9% | 10,372 | 9,172 | 168 single-, 1 multi-family | $32,107 | 10, 21 fisl mi edu soc reta ma |
| Colusa | 1,151 | 21,272 | 18.5 | +16% | 7,251 | 6,097 | 99 single-, 0 multi-family | $38,350 | 81 in a fisl 11 anc |
| Yolo | 1,013 | 193,983 | 191 | +16% | 69,106 | 59,375 | 783 single-, 90 multi-family | $44,810 | 82, 22, hea |

**Table 5. Land Use. Demographic Statistics of 3 County Study Area and Local Communities.**
(U.S. Census Bureau 2007, DOF 2007)

| City | 2007 Population | 2000 Population | % Growth 2000-2006 | Median Age | 2005 Median Household Income | Ethnic Composition | Population Density (per mi$^2$) | Educa |
|---|---|---|---|---|---|---|---|---|
| Willows | 6,469 | 6,220 | +4% | 31 | $32,100 | 61% white, 23% Hispanic, 3.6% American Indian, 18% foreign born (9.9 Latin America, 7% Asia) | 2,189 | 70.8% school higher, 9.0% bachelo degree |
| Colusa | 5,773 | 5,402 | +7% | 32 | $41,200 | 52.8% white non-hispanic, 41.7% Hispanic, 23.3% other races, 3.8% 2 or more races, 2.4% American Indian, 0.8% Hawaiian/ Pacific Islander, 0.7% East Indian, 20.7% foreign born (18% Latin American) | 3,461 | 69.6% school higher, 13.6% bachelo degree, gradua degree |

| City | 2007 Population | 2000 Population | % Growth 2000-2006 | Median Age | 2005 Median Household Income | Ethnic Composition | Population Density (per $mi^2$) | Educa |
|---|---|---|---|---|---|---|---|---|
| Williams | 5,255 | 3,670 | +43% | 26.6 | $37,400 | 71.2% Hispanic, 45.5% other race, 24.9% white non-hispanic, 6.3% two or more races, and 2.3% American Indian, 47.5% foreign born (Latin America) | 865 | 43% hi school degree, 5.4% bachelo degrees 1.3% gradua degree |
| Dunnigan | 1,307 | 897 | 8.13% | unavailable | $28,833 | 42% white, 79% Hispanic | 18 | unavai |

**Major Construction Projects Present and Planned.** Information about major recent construction projects is based on a 2004 report from the California Department of Conservation Farmland Mapping and Monitoring Program, since the 2006 report is not yet available. This report is based on the Department of Water Resources [DWR] Land Use survey information coupled with recent aerial photography interpretation, selective field reconnaissance, and public review. Results vary as to their specificity; sometimes the particular project is identified by name and specific location, at other times only a general area is identified, such as occurring somewhere within a given U.S. Geologic Survey [USGS] 7.5 minute quadrangle.

Between 2002 and 2004, irrigated farmland was converted to urban land uses at 7 primary locations in the Colusa Basin Watershed. These included new housing developments such as Horizons in Williams and others around Dunnigan. Expansion of the Colusa Industrial Park accounted for small amounts of conversion of irrigated farmland and additional amounts of grazing land. In Cortina Creek quadrangle, 132 ac of irrigated farmland became a freeway interchange (California Department of Conservation 2004). More information about potential development planned for the Dunnigan area is described below in the Plans and Policies Section concerning the updated Yolo County general plan.

The Colusa Basin Drainage District [CBDD] is currently planning 2 flood water detention facilities: one west of Willows on South Fork Willow Creek to reduce flooding in Willows and one in the Wilson Creek area (CH2MHill 2003). The South Fork Willow Creek Detention Facility is completely designed, has nearly all permits secured and has a bid packet ready for distribution as soon as funding becomes available. The Wilson Creek Detention Facility still requires further study to determine its feasibility. In addition to these two sites, the CBDD has other sites in Glenn and Colusa Counties targeted for remediation measures including, but not limited to detention facilities (Massa 2008).

**Recreational Use.** Hunting, boating, and fishing are among the most popular recreation activities in the Colusa Basin Watershed. The Colusa Sacramento River State Recreation Area includes 60 ac of waterfront near the city of Colusa with a public boat launch and access to fishing. There is a second boat launch location at Knights Landing. Fishing is permitted in the Packer Unit of the Sacramento River National Wildlife Refuge [NWR] at river mile 168-R, just south of Butte City.

Hunting is permitted on portions of the Sacramento NWR complex such as the Delevan, Colusa, and Sacramento River NWRs. Typical game species include quail, deer, dove, ducks, geese, pheasant, turkey, and other waterfowl (coot, moorhen, snipe). Other wildlife related recreation includes wildlife observation and photography (USFWS 2007). In addition, numerous private landholders offer access to duck hunting blinds on their property. Private hunting clubs make use of flooded rice fields in wintertime.

There are 4 nine-hole golf courses within the Colusa Basin Watershed: one in Yolo County (Dunnigan), 2 in Colusa County (Colusa and Arbuckle), and one in Glenn County (Willows). Thunderhill Raceway Park west of Willows is a recreational attraction that brings in revenue for Glenn County and could possibly create growth in the County at a later date (Casey, pers. comm. 2008).

**Land-use Patterns, Zoning, Plans, and Policies (City and County)**

**Overview.** Patterns and policies of land use in the Colusa Basin Watershed directly affect the goals and objectives of this watershed planning process. Growth in population, housing, and commercial development can lead to such changes as loss of agricultural land to urban uses, increases in road density and surface area, and increases in impermeable surfaces within the watershed. Such changes affect watershed hydrology, water quality, soil conservation, and native habitats. The challenge for land use planning is to allow for economic community development and accommodate population growth while protecting valued resources such as water, air, soil, biota, and aesthetics.

Under state law, a county's general plan sets forth the basic policies governing land use (both public and private) in order to guide long-term planning. In doing so, general plans must address the following 7 required elements: Land Use, Housing, Circulation, Natural Resource Conservation, Open Space, Noise, and Safety (Curtin and Talbert 2005). In addition, they sometimes include additional guidance concerning energy, economic development, air quality, or other aspects of the physical environment. Subsequent specific plans provide additional standards for development and actions that follow or support the general plan policies.

The goals of each of the general plans for the 3 counties within the Colusa Basin Watershed consistently place preservation of prime agricultural land as one of their highest priorities (Yolo County Community Development Agency 1993, Sedway Cooke Associates 1989, and QUAD Consultants 1993). One of the main ways the counties aim to achieve this goal is to encourage most new development to occur within or adjacent to existing cities, communities, and major transportation corridors. In order to provide long-term planning direction, each county must try to anticipate population growth, economic growth, and attendant housing or commercial development, and then designate sufficient quantities of land within the general plan around urban areas to accommodate this growth. The General Plans designate broad categories of land use accordingly. Typically, each category has a clearly defined use or list of permitted uses. Subsequent zoning ordinances, zoning maps, and specific plans will define minimum lot sizes, building sizes, and other development standards. Examples of zoning categories that are used to designate land uses in the Colusa Basin Watershed include the following:

- Open space/ public lands
- Foothill agriculture/forestry
- Intensive agriculture
- General agriculture
- Agriculture/residential
- Rural residential
- Suburban residential
- Single family residential
- Multiple family residential
- Local commercial
- Community commercial
- Service commercial
- Highway and visitor service commercial
- Industrial

- Business park
- Public facilities
- Recreation

**Table 6-Land Use** shows the proportions of various land uses in the Colusa Basin Watershed based on DWR data (from 1997 for Yolo County, 1998 for Glenn County, and 2003 for Colusa County). **Appendix 1-Land Use** provides the DWR Standard Land Use Legend, which defines the terms used in **Table 6-Land Use**, and **Figure 2-Land Use** shows the spatial distribution and extent of each of these land use categories.

**Table 6. Land Use. Land Uses in Colusa Basin Watershed.**
(Based on GIS analysis of DWR data, various years 1997-2003).

| Land Use Classification | Acres | % of Watershed |
|---|---|---|
| Native Vegetation | 432,492 | 41.4% |
| Rice | 217,698 | 20.8% |
| Grain and Hay Crops | 73,567 | 7.0% |
| Deciduous Fruits and Nuts | 68,787 | 6.6% |
| Field Crops | 62,976 | 6.0% |
| Truck and Berry Crops | 50,572 | 4.8% |
| Pasture | 37,663 | 3.6% |
| Native Riparian | 33,878 | 3.2% |
| Idle | 16,949 | 1.6% |
| Water | 15,574 | 1.5% |
| Urban Vacant | 9630 | 0.9% |
| Vineyards | 6701 | 0.6% |
| Semi-agricultural | 5105 | 0.5% |
| Urban Industrial | 3707 | 0.4% |
| Urban Residential | 3301 | 0.3% |
| Citrus and Subtropical | 2977 | 0.3% |
| Urban | 1126 | <0.1% |
| Barren | 1010 | <0.1% |
| Urban Commercial | 728 | <0.1% |
| Urban Landscape | 532 | <0.1% |
| Unclassified Land in DWR Land Use Dataset | 472 | <0.1% |
| **Total** | **1,045,445** | **100.0%** |

**Glenn County General Plan.** This example from the Glenn County's General Plan illustrates the potential impact of growth in the Colusa Basin Watershed and subsequent planning process. The 1993 Glenn County General Plan analyzed 3 growth rate scenarios for a 20-yr planning period: high, medium, and low, corresponding to 5%, 3% and 1.5% (QUAD Consultants 1993). The preferred alternative for which they planned was the medium rate, which was projected to increase the population of the county by 21,700 people by 2012 (from 25,300 people to 47,000 people). This scenario would require 4000 additional housing units in the unincorporated county along Interstate 5 and Highway 32 and 9000 more in the 2 main cities (Orland and Willows). It was estimated that 2000 ac of land would be required to accommodate this growth.

Development in the foothills or on prime agricultural land was to be avoided or discouraged as much as possible. Therefore, land use policies and tools such as designating land uses, establishing urban limit lines (growth boundary), zoning ordinances, minimum parcel sizes, and Williamson Act contracts, among others, were applied in order to conserve agricultural land, direct growth and development to the most appropriate locations, and protect shared valuable resources (soil, water, air, and aesthetic values). The planning process resulted in an exhaustive list of policies found within all 7 of the general plan elements (Land Use, Housing, Circulation, Natural Resource Conservation, Open Space, Noise, and Safety) that affect patterns of future development.

Glenn County has developed numerous land use goals, policies, and standards that will continue to affect the condition of the watershed. The plan sets forth goals such as conserving agricultural land, providing housing, protecting surface water quality, and protecting ground water quality and recharge areas. The general plan directs growth towards 6 designated pre-existing development areas along established transporation corridors: Willows, Orland and unincorporated communities of Artois, Butte City, Elk Creek, and Hamilton City (QUAD Consultants 1993). Each area has a delineated Urban Limit Line [ULL] that encourages in-fill development and allows for conversion of existing use (such as agriculture) to urban and residential uses within these designated areas. The ULL is designed to be sufficient to accommodate 20 yrs of projected population growth. Such areas were determined through analysis of soils, flooding potential, growth and development projections, transportation accessibility, extent of public services, and ecologically sensitive areas (e.g., biologically important areas, groundwater recharge zones, steep slopes, **Figures 3-Land Use** and **Figure 4-Land Use**).

The county's policies recognize that two-thirds of the county is croplands and pasture lands that contribute significantly to the local economy and provide open space and wildlife habitat as well. For example, rice fields can serve important functions in wintertime as winter waterfowl habitat, floodwater detention, and groundwater recharge when they are managed for these purposes. Flooding rice fields has also become the preferred alternative for decomposing rice-stubble since 1993 when burning was limited due to air-quality concerns. Since that time, only 25% of rice fields can be burned to control disease or similar purposes.

Glenn County general plan policies limit the amount of rural residential (low density) zoning in order to prevent more widespread conversion of agricultural land. This development pattern is also inefficient for delivering public services, utilities, and transportation. Where conversion is necessary outside of designated ULLs, grazing lands are preferred over prime cropland in order to conserve prime agricultural soils (QUAD Consultants 1993). There is a hierarchy established to direct conversion of agriculture lands to urban use first within ULLs, then within rural residential zones, if there is adequate water for drinking and fire fighting. Important Farmland (**Appendix 2-Land Use**) maps are to be consulted along with appropriate environmental review prior to approval of any development plans (California Department of Conservation 2004). Standards for development also include direction to provide a 300 ft buffer to adjacent agricultural parcels under the Williamson Act contract, which is aimed at clustering building development on parcels (QUAD Consultants 1993).

Section 6.5 of the Glenn County General Plan focuses specifically on watershed protection measures by stipulating development standards pertaining to the protection of watersheds, watercourses, retention of soils, and preservation of riparian habitats that help protect water quality (QUAD Consultants 1993). All new developments in the foothill or mountain areas or adjacent to streams must submit a county approved grading, excavation, and erosion control plan. The following recommended measures should be included in these plans: avoid development on steep slopes, construct fill slopes 2:1 (H:V) or gentler, construct V-ditches above cut or fill slopes to redirect water away from the exposed slope, and revegetate all newly exposed slopes before 15 October. Soil disturbance is to be contained between 1 May and 1 October, and all exposed soil is to be mulched and seeded by 15 October. Straw bale dikes and filter fabric barriers should be placed downstream to act as sediment traps until newly exposed surfaces stabilize. Temporary or permanent sedimentation basins should be constructed as needed according to engineering specifications. Topsoil should be stockpiled and reused. Drainage channels need to be stabilized to prevent erosion, usually by lining with rock. Erosion control measures should be a condition of approval and monitored regularly by the County. The County requires a bond be posted to ensure proper implementation and maintenance of these measures.

In addition to these sediment control measures, watershed protection is also encouraged through the use of a development standard stating that building and development should be setback at least 50 ft from wetlands, riparian habitats, and open space corridors (QUAD Consultants 1993). Water quality protection is further supported by performance standards for dairies pertaining to manure management and livestock densities per each appropriate land use zone.

Glenn County has also mapped restorable wetlands, biologically sensitive areas, groundwater recharge zones, and streamside protection areas (**Figures 3-Land Use**, **Figure 4-Land Use**, **Figure 5-Land Use**). Restorable wetlands are approved by the Board of Supervisors for wetland habitat easement acquisition by the United States Fish and Wildlife Service [USFWS] using Migratory Bird Conservation Funds in accordance with the North American Waterfowl Management Plan and Central Valley Habitat Joint Venture Implementation Plan (QUAD Consultants 1993).

Policies have been enacted that set priorities for groundwater use within Glenn County. Highest priority is given to household and domestic supplies, followed by agricultural use. The third and fourth priorities are industrial/commercial uses and wildlife/conservation uses. The lowest priority is exportation of Glenn County groundwater out of the region reflecting the aim and desire to conserve and maintain local supplies of groundwater (QUAD Consultants 1993).

**Colusa County General Plan.** The Colusa County General Plan sets forth similar goals, objectives and policies as Glenn County while sharing concerns for balancing growth with resource protection. It sets forth the general goal of preserving agricultural land by using the strategies of encouraging compact development close to existing communities. Growth rates in the past have been as high as 58% in the County, which translates to a need for 120 to 150 new housing units per year (Sedway Cooke Associates 1989). Growth and development alternatives were weighed, and the County selected an Interstate 5 Growth Corridor alternative largely based on access to transportation, but also included other considerations such as flooding and capacity

(Sedway Cooke Associates 1989). Future development will be directed toward the junction of Interstate 5 and Highway 20, while aiming to keep the communities in the area distinct. The communities of Williams, Arbuckle, and Maxwell will receive 68% of projected growth. These communities were chosen in part because they had greater capacity to accommodate growth and were less flood-prone than Colusa. Williams has been anticipated to double in population and triple in land area (Sedway Cooke Associates 1989). Williams has exhibited the highest rate of growth from 2000-2006 (29%) among the cities in the Colusa Basin Watershed (**Table 5-Land Use**). Industrial development is to be directed to a corridor between Interstate 5 and Old Highway 99W. **Table 7-Land Use** shows proportions of land use categories in Colusa County at the time of adoption (1989):

**Table 7. Land Use. Land Use Proportions in Colusa County circa 1989.**
(From County General Plan).

| Land Use Designation | Area (ac) | Proportion of County Land (%) |
|---|---|---|
| Cropland | 358,000 | 48.5% |
| Undeveloped Rangeland | 244,800 | 33.2% |
| National Forest | 72,000 | 9.7% |
| Orchards and Vineyards | 38,200 | 5.2% |
| National Wildlife Refuges | 12,000 | 1.6% |
| Undeveloped Bottomlands | 9300 | 1.2% |
| Communities | 2500 | 0.3% |
| Rural Subdivisions | 1200 | 0.2% |
| **Total** | **738,000** | **100%** |

The County used population projections for a 20-year planning period (to 2010) to guide future land uses towards the following categories and proportions (**Table 8-Land Use**). However, the terms that the County General plan uses to classify existing (1989) conditions and future (2010) conditions are not exactly parallel, which does not facilitate easy comparison. Nonetheless, the intent of future growth planning is clear when one attempts to compare the two tables: namely, protect and even increase agricultural acreage, protect resource conservation lands, and direct growth into designated community planning areas rather than into rural subdivisions. Further descriptions of some of the land use classifications used for future planning are included below.

**Table 8. Land Use. Projected Land Use Proportions in Colusa County in 2010.**

| Land Use Designation | Area (ac) | Proportion of County Land (%) |
|---|---|---|
| Agriculture-General | 419,100 | 57% |
| Agriculture-Upland | 183,100 | 25% |
| Resource Conservation | 114,200 | 15% |
| Community Planning Areas | 14,400 | 2% |
| Upland-Transition | 4200 | 0.6% |
| Non-Urban Industrial | 1500 | 0.2% |
| Rural Residential | 1400 | 0.2% |
| Rural Service Center | 100 | <0.1% |
| **Total** | **738,000** | **100%** |

Uses and management of Resource Conservation lands include: 20,000 ac of Bureau of Land Management [BLM] land in the western foothills of the county; 6,000 ac managed by the U.S. Bureau of Reclamation; plus portions of the Sacramento NWR complex; and some private mining, grazing, recreation, and housing uses. Much of the rangeland in the western part of the county is BLM land (Sedway Cooke Associates 1989).

Upland agricultural land consists of minimum lot sizes of 80-160 ac to be used for livestock grazing (primarily cattle and sheep, Sedway Cooke Associates 1989). The County has considered increasing the 80-ac minimum lot size in upland rangeland to discourage subdividing large ranch parcels (Sedway Cooke Associates 1989). General agriculture refers to lands in the valley floor that have had a minimum lot size of 10 ac; however, the County has at times considered increasing this to 20-40 ac minimums. The primary use of general agriculture lands is production of crops, orchards, and vineyards. Upland transition lands are located in the coast range foothills and are potentially available to be converted from existing agricultural uses to other uses, but they are subject to restrictions of 10-80 ac minimum lot sizes and proof of available water supplies to serve proposed development needs (Sedway Cooke Associates 1989).

Community Planning Areas [CPAs] are proposed development nodes along Interstate 5 and in designated communities in the unincorporated county that are currently slated to receive some proportion of projected growth. These areas include the full range of community services and mixture of land uses including commercial, residential, industrial, agricultural, and public lands. Seven communities are designated to receive the majority (75%) of projected urban growth: Colusa, Williams, Arbuckle, Maxwell, Princeton, Grimes, and College City (Sedway Cooke Associates 1989). Non-Urban industrial land refers to industrial land uses within the CPAs, and the Rural Residential designation applies to residential uses within the CPAs as well as a few planned development subdivisions. The Rural Service center designation refers to the central areas of numerous smaller residential settlements in the County.

Sustained natural resource use and conservation are addressed in the Conservation Element of the Colusa County General Plan. Nearly 60% of the land in the County is in agricultural use of some kind. Additional natural resources in Colusa County include some existing and potential mineral and timber resources. The mineral resources include a sand and gravel operation at Sand Creek and Princeton Ranch. Homestake Mining Company owns large holdings in Southwest Colusa County where they have conducted exploration for a potential gold mine development (Sedway Cooke Associates 1989). Natural gas fields exist in the eastern portion of the county near Grimes. Natural gas production has at times contributed significantly to the County's economy and was once highly productive (Sedway Cooke Associates 1989). Natural gas exploration is also underway in the Dunnigan Hills in Yolo County.

**Yolo County General Plan.** Because the current Yolo County general plan dates to 1983, with a revised version due out in winter of 2007-2008, the information described below is somewhat outdated. It is the last set of population growth and development projections and land use planning decisions contained on record. A few preliminary documents are available that describe the present state of the general plan revision process and these contain a number of alternatives that include a range of development scenarios for portions of the County within Coulsa Basin; however, the preferred alternative has not yet been finalized. A few elements of these alternatives are included below in order to lend some more current information about land use planning and development in the southern portion of the Colusa Basin Watershed.

In Yolo County population growth in the 1980s was at 24% with housing growth at 14% for the previous decade, and it was projected to experience 27% growth in the next 20 yr period (to 2000, Yolo County Community Development Agency 1983). Given this growth projection, 30,000 people would be added to the 4 major urban areas (Davis, Winters, Woodland, and West Sacramento). Half of these people (15,000) could go into existing urbanized areas while the other half would go into redeveloped east Yolo County. As a result, 15% of land within the urban use zone would be converted to accommodate this growth (Yolo County Community Development Agency 1983). As with the 2 counties in the northern watershed, 60% of Yolo County soils are high quality agricultural soils and the majority (85%) is in agricultural use (Yolo County Community Development Agency 1983). Most of this agricultural land is pastureland along with acres of wheat, tomatoes, grains, and fruit and nut orchards. Only 6% of the county is urban. Yolo County's largest cities are outside of the Colusa Basin Watershed, but a number of smaller communities such as Dunnigan, Knights Landing, and Zamora are situated within the Colusa Basin Watershed. Yolo County, like Glenn and Colusa counties, opted to make use of prescribed urban boundaries, which allow and encourage infill development into contiguous urban centers.

According to the Sacramento Area Council of Governments, Yolo County's share of regional growth could include more than doubling the population of its 4 cities and unincorporated area during the next 50 yrs (Yolo County 2007). The alternative planning and development scenarios that are currently under consideration in the general plan update process for Yolo County include a wide range of potential changes in the county, with significantly different fates proposed for Dunnigan (Design, Community, & Development 2006). Alternative 1 directs 10% of future growth and development into the unincorporated county, 40% into unincorporated communities, and 60% would occur as rural residential development. Alternative 1 would result in 2695 new housing units in the unincorporated county along with 289 ac of commercial/industrial development (Design, Community, & Development 2006). Alternative 2 directs more growth (85%) into the existing unincorporated communities than Alternative 1, and 94% of new growth would be located in Dunnigan, Esparto, Knights Landing and Madison. This scenario plans for 5525 new residential units and 478 ac of commercial/industrial development (Design, Community, & Development 2006). Alternative 3 directs 70% of new growth into Dunnigan, which could absorb 7000-10,000 new residential units, and 717 ac of new commercial/industrial development would occur in the unincorporated county under Alternative 3 (Design, Community, & Development 2006). Alternative 4 would spread the development of 6978 new residential units evenly among the unincorporated communities, incuding 1051 ac of new commercial/industrial development, which would occur in the unincorporated county. Alternative 4 includes additional restrictions on housing development in rural agricultural areas (Design, Community, & Development 2006). The final preferred alternative is likely to incorporate the most favorable aspects of each of the 4 alternatives described to date (Yolo County 2007). The draft updated general plan and draft Environmental Impact Report [EIR] are scheduled for release in winter 2007-2008.

**Williamson Act Contracts.** Williamson Act contracts are the second principal way that agricultural land is protected from premature or casual conversion to urban land use in the Colusa Basin Watershed. The California Land Conservation Act of 1965 (commonly known as the Williamson Act), allows landowners to voluntarily place restrictions on development and use on agricultural lands in exchange for tax reductions and other incentives (Curtin and Talbert 2005). The Williamson Act was adopted in order to maintain the agricultural economy of the state, to ensure food supplies, to discourage premature or unnecessary conversion of agricultural land to other uses, to discourage noncontiguous urban development patterns, and to preserve open space and aesthetic values of agricultural lands. Lands under this contract are only to be used for agriculture, recreation, or open space uses, and contracts last 10 yrs. In 1998 the state legislature began allowing 20-yr contracts, called Farmland Security Zones. Minimum parcel sizes for contracted lands under the Williamson Act are 10 ac on prime farmland soil and 40 ac on non-prime soils. Cancellation of the contract prior to the end-date requires petitioning and payment of a substantial fee based on full (unrestricted) fair market value of the land. More information about Williamson Act Contracted Lands is included in the following section of this assessment, *Conservation and Agricultural Easements*.

In the Colusa Basin Watershed, 34% of the prime soils are under Williamson Act Contract (144,711 ac) and 14% are in Farmland Security Zone contract (58,952 ac). 61% of non-prime soils in the Colusa Basin Watershed are under Williamson Act contract (301,508 ac) and less than 1% are under Farmland Security Zone contract (309 ac, **Figure 6-Land Use**).

However, Colusa County is unique in the state in that most of the arable land is not under Williamson Act contract (Sedway Cooke Associates 1989). The reason cited for this is that California Proposition 13 limited the financial advantage of Williamson Act contracts. Proposition 13, passed in 1978, significantly curtailed property taxes and their annual rate of increase (Sedway Cooke Associates 1989). The majority (95%) of land in Colusa County that is under Williamson Act contract is foothill-grazing land, with just 5% on the valley floor. This helps prevent rural residential development and subdivision of the western foothill lands.

### Easements (Agricultural, Conservation, etc.)

Conservation easements are voluntary agreements between landowners and public agencies or non-profit organizations that transfer development and usage rights of the land to the agency or non-profit organization in order to promote conservation and protection of natural resource values. The agency or non-profit holds the legally binding agreement while the landowner retains legal ownership of the property. The agreement runs with the land after ownership has changed hands. There is often a financial benefit to the landowner in the form of reduced property taxes and may include additional benefits as well. Agricultural conservation easements specifically restrict use of the land to farming, open space or recreation uses. The Williamson Act contracts (described in the previous section, *Land-use Patterns, Zoning, Plans, and Policies*) function similarly to conservation easements by offering landowners tax relief and other incentives for maintaining the land in agricultural, open space, or recreation uses. However, Williamson Act contracts differ from easements because they are based on contractual law with 10-yr terms and options to renew, whereas conservation easements become part of the title history of the parcel and are perpetual.

In the Colusa Basin Watershed, 3 public agencies hold conservation easements, the Natural Resource Conservation Service [NRCS], USFWS, and the California Department of Fish and Game [DFG]. In addition, The Nature Conservancy protects 418 ac, 300 ac of which are in easements. California State Parks, California Rangeland Trust, and BLM are also active in the Colusa Basin Watershed either owning conservation lands or easements. The California Resources Agency has assembled a spatial dataset of Public, Conservation, and Trust Lands for the California Legacy Project; however, conservation easement data on private lands are not publicly available (CaSIL 2007).

### Soil Class Effectiveness in Regard to Agricultural Preservation

The majority of soils in the Colusa Basin Watershed are considered Important Farmland. 52% of the Colusa Basin Watershed is either prime farmland or farmland of statewide importance (545,960 ac; see **Appendix 2-Land Use**). The 48% that is not prime farmland is principally grazing land in the western foothills (498,262 ac). **Table 9-Land Use** shows the proportion of various soil classes within the Colusa Basin Watershed counties. **Table 10-Land Use** shows acreage totals for soil classes within each county.

### Agricultural Cropping Patterns and Irrigation Practices

The DWR surveys agricultural production, cropping patterns, and irrigation approximately every 7 yrs. Each county's Agricultural Commissioner produces annual Crop and Livestock Reports that summarize the acres of production and gross values of agricultural products. The Farmland Mapping and Monitoring Program [FMMP] of the State Department of Conservation tracks conversion of prime farmland every 2 yrs using aerial photography, field reconnaissance, computer mapping, and public review.

In Glenn County, 2006 gross agricultural production was valued at $369 million dollars. Rice constituted the majority of this amount ($95 million), and almonds were the next largest single crop ($77 million, USDA 2007, **Table 11-Land Use**). Together, rice and almonds comprise 55% of the total crop and livestock value for the County (USDA 2007). Colusa County reported $423 million in gross agricultural production, $165 million of which was from rice and $112 million was from almonds. Colusa County produced 28% of the state's rice production in 2006, the most of any county (USDA 2007). Yolo County reported $370 million in gross agricultural production; tomatoes constituted $77 million of the total.

**Table 9. Land Use. Soil Class Data by Percent for Each of the 3 Counties within the Colusa Basin Waters**

| County | Prime Farmland | Farmland of Statewide Importance | Unique Farmland | Farmland of Local Importance | Total Important Farmland | Grazing Land | Urban, Built-up Land | |
|---|---|---|---|---|---|---|---|---|
| Colusa | 27.2% | 0.3% | 16.9% | 31.4% | **75.8%** | 1.2% | 0.6% | |
| Glenn | 19.2% | 10.4% | 2.0% | 9.3% | **40.8%** | 27.3% | 0.7% | |
| Yolo | 39.7% | 2.8% | 8.1% | 10.2% | **60.8%** | 22.2% | 4.4% | |

**Table 10. Land Use. Soil Class Data for Each of the 3 Counties within the Colusa Basin Watershed in Ac**

| County | Prime Farmland | Farmland of Statewide Importance | Unique Farmland | Farmland of Local Importance | Total Important Farmland | Grazing Land | Urban, Built-up Land | Othe |
|---|---|---|---|---|---|---|---|---|
| Colusa | 201,642 | 2152 | 124,796 | 232,758 | **561,348** | 9151 | 4624 | 163,42 |
| Glenn | 162,670 | 88,374 | 16,589 | 78,721 | **346,354** | 231,716 | 6080 | 259,22 |
| Yolo | 259,637 | 18,123 | 53,157 | 66,619 | **397,536** | 145,227 | 28,511 | 74,35 |

**Table 11. Land Use. Gross Agricultural Production Value of the Top 10 Commodities for Each of the 3 Counties in the Colusa Basin Watershed.**
(USDA 2007).

| Rank | Commodity | Value x 1,000 ($) |
|---|---|---|
| **COLUSA** | | |
| 1. | Rice | 164,596 |
| 2. | Almonds | 111,712 |
| 3. | Processing Tomatoes | 42,427 |
| 4. | English Walnuts | 12,661 |
| 5. | Cattle and Calves | 12,181 |
| 6. | Onion Seed | 9612 |
| 7. | Rice Seed | 8279 |
| 8. | Apiary Pollination Fees | 5301 |
| 9. | Alfalfa Hay | 5051 |
| 10. | Dry Beans | 3833 |
| | **Total** | **375,653** |
| **GLENN** | | |
| 1. | Rice | 94,717 |
| 2. | Almonds | 77,238 |
| 3. | Milk | 42,344 |
| 4. | Walnuts | 30,815 |
| 5. | Dried Plums | 22,130 |
| 6. | Cattle and Calves | 20,227 |
| 7. | Alfalfa Hay | 12,022 |
| 8. | Grapes | 6830 |
| 9. | Pistachios | 5496 |
| 10. | Sunflower Seed | 4730 |
| | **Total** | **316,549** |
| **YOLO** | | |
| 1. | Tomatoes | 77,097 |
| 2. | Alfalfa Hay | 39,368 |
| 3. | Wine Grapes | 38,047 |
| 4. | Almonds | 28,884 |
| 5. | Seed Crops, All | 28,767 |
| 6. | Rice | 23,918 |
| 7. | Walnuts | 18,547 |
| 8. | Organic Crops | 14,498 |
| 9. | Cattle and Calves | 11,556 |
| 10. | Livestock Products | 9117 |
| | **Total** | **289,799** |

Significant conversions of agricultural production were recorded by the FMMP. In 2004, over 1750 ac of irrigated farmland had been converted to wetland (2002-2004) in Colusa County in Moulton Weir, Sanborn Slough, Cortina Creek, and Dunnigan USGS 7.5 quadrangles (California Department of Conservation 2004). Approximately 140 ac and 180 ac of local grazing land were converted to orchards and row crops in the Salt Canyon and Wildwood School quadrangles. Approximately 280 ac in Salt Canyon and 450 ac in Meridian quadrangles were irrigated to establish new orchards where there had been grazing land. In Dunnigan USGS 7.5 quadrangle, 1000 ac of new orchards and irrigated row crops were added in 2004.

Irrigated farmland was sometimes converted to grazing land or non-irrigated grain. This may be due to crop rotations as fields are left fallow. Approximately 138 ac in Stone Valley quadrangle and 322 ac in Princeton quadrangle were converted from irrigated row crops to grazing land due to being fallow for 6 yrs. Approximately 190 ac in Princeton quadrangle were converted to grazing land as old orchards were removed on the Sul Norte Unit of the Sacramento NWR (Princeton quadrangle, California Department of Conservation 2004). Grazing will continue on the Sul Norte Unit of the Sacramento NWR as a management tool for non-native invasive species control.

### U. S. Fish and Wildlife Service Refuges

The Sacramento NWR Complex consists of 5 NWRs and 3 Wildlife Management Areas [WMAs] listed below and shown on **Figure 1-Land Use**.

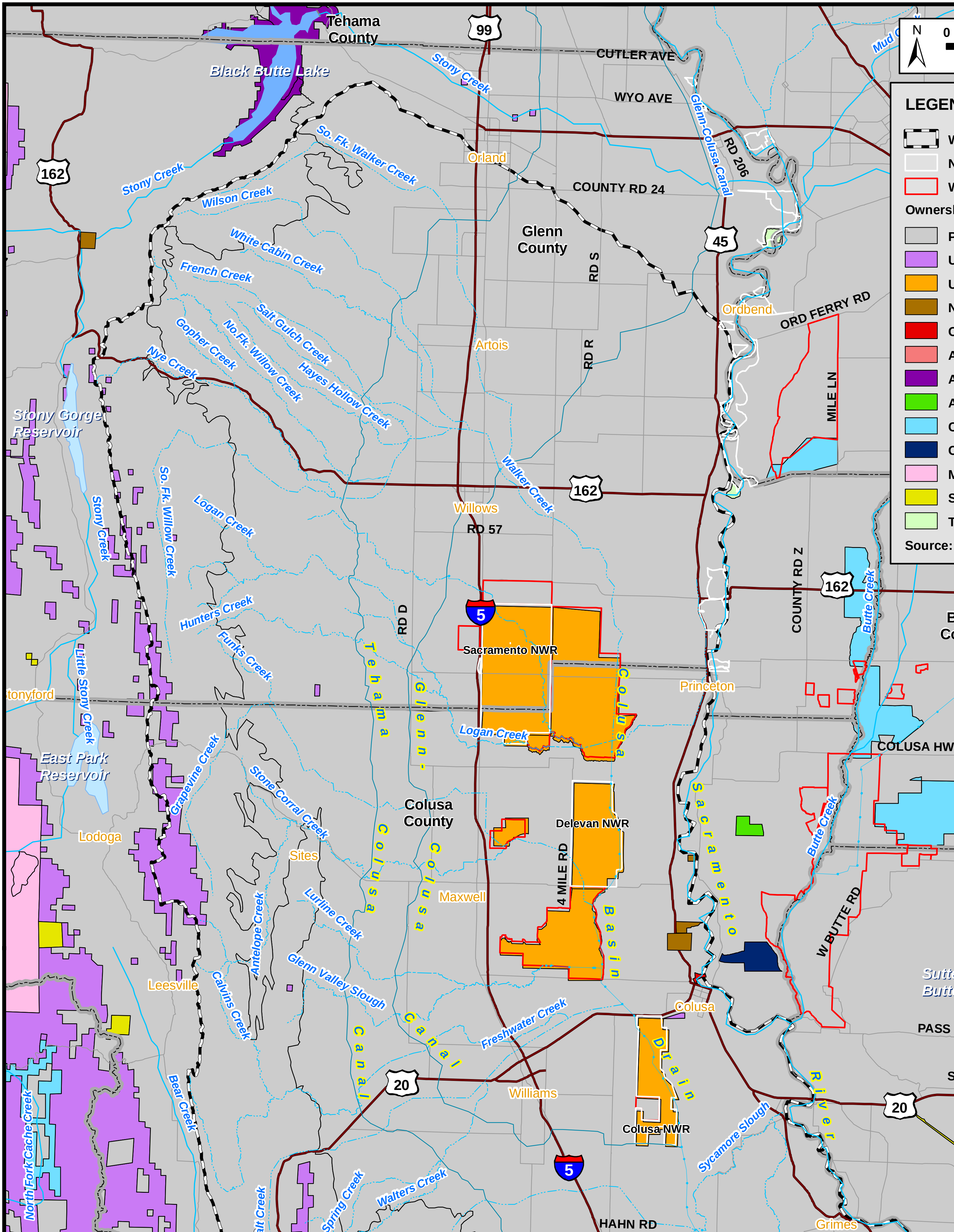
- Delevan NWR
- Colusa NWR
- Sacramento River NWR (consists of many units)
- Sacramento NWR
- Sutter NWR
- Butte Sink WMA

These refuges comprise 35,000 ac of wetlands and upland habitats. The USFWS holds 30,000 ac of conservation easements in the complex (USFWS 2007). The Delevan, Colusa, and Sacramento NWRs in the Colusa Basin Watershed comprise 12,000 ac, which is 15% of the State's total NWR land (Sedway Cooke Associates 1989). The Sacramento NWR Complex serves as resting and feeding areas for approximately half the migratory birds on the Pacific Flyway. Migratory birds rear in Alaska and the Canadian Arctic in summer, then winter in the Sacramento Valley. Ducks start to arrive in August and continue to arrive through October; most depart around February and March (USFWS 2007). Although primarily managed for migratory waterfowl, the refuges provide habitat to shorebirds, raptors, and numerous other wildlife species.

The refuges include at least 6 main habitat types: Seasonal Marshes, Permanent Ponds, Riparian Woodlands, Watergrasses, Uplands, and Vernal Pools (USFWS 2007). Typical plant species in Seasonal Marshes include emergent herbaceous vegetation such as cattail, hardstem bulrush, alkali bulrush, swamp timothy, and smartweed. Permanent Ponds support some emergent herbaceous vegetation such as cattail and roundstem bulrush as well as aquatic species such as sago pondweed. Riparian areas consist of larger, woody trees and shrubs such as cottonwood, valley oak, sycamore, willows, box elders, elderberry, and wild rose. Watergrass habitat includes flood tolerant grass and forb species such as smartweed, Bermuda grass, and jointgrass; while Uplands in the refuges mostly contain annual grasslands. Vernal Pool habitats are unique wetlands that are wet for only a short duration in the springtime. These habitats include spring wildflowers such as goldfields, downingia, and popcorn flowers (see Section *Biotic Habitats* below for more detailed descriptions of habitats in the Colusa Basin Watershed as a whole, including those that occur in the NWRs).

The NWRs and WMAs are managed to maintain the health and distribution of these habitats for the benefit of plants and animals and for human enjoyment and recreation. Seasonal marshes are drained in late spring/summer to encourage plant growth, and then flooded in fall thus replacing some of the historic flooding that occurred when the Sacramento River routinely flooded the Colusa Basin (USFWS 2007). Today the refuges receive a limited amount of water from the Bureau of Reclamation's Central Valley Project canals to support this management activity (USFWS 2007). Prescribed discing, burning, mowing, and pond excavation are employed to maintain patch diversity and productivity of the habitats. For example, Permanent Ponds may be drained every 3-5 yrs and burned to limit plant growth to maintain open water habitat.

Research and planning activities feed back into adaptive management of the refuge complex. Currently research and monitoring occurs during bi-monthly waterfowl surveys, and there are active research projects examining avian flu (USFWS 2007). The USFWS began a Comprehensive Conservation Planning [CCP] process in 2005 for Delevan, Colusa, Sacramento, and Sutter NWRs. The CCP is a 15-yr plan consisting of goals and strategies for refuge management in accordance with the 1997 NWR System Improvement Act. The final CCP for the Sacramento River NWR was completed in July 2005 (USFWS 2007).



Tehama County
Black Butte Lake
Stony Creek
Wilson Creek
So. Fk. Walker Creek
White Cabin Creek
French Creek
Salt Gulch Creek
Gopher Creek
No.Fk. Willow Creek
Hayes Hollow Creek
Nye Creek
Stony Gorge Reservoir
So. Fk. Willow Creek
Logan Creek
Hunters Creek
Funk's Creek
Little Stony Creek
East Park Reservoir
Grapevine Creek
Stone Corral Creek
Lodoga
Sites
Lurline Creek
Antelope Creek
Glenn Valley Slough
Calvins Creek
Leesville
Bear Creek
North Fork Cache Creek
Spring Creek
Walters Creek
CUTLER AVE
WYO AVE
Orland
COUNTY RD 24
Glenn County
RD S
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Glenn-Colusa Canal
RD 206
Ordbend
ORD FERRY RD
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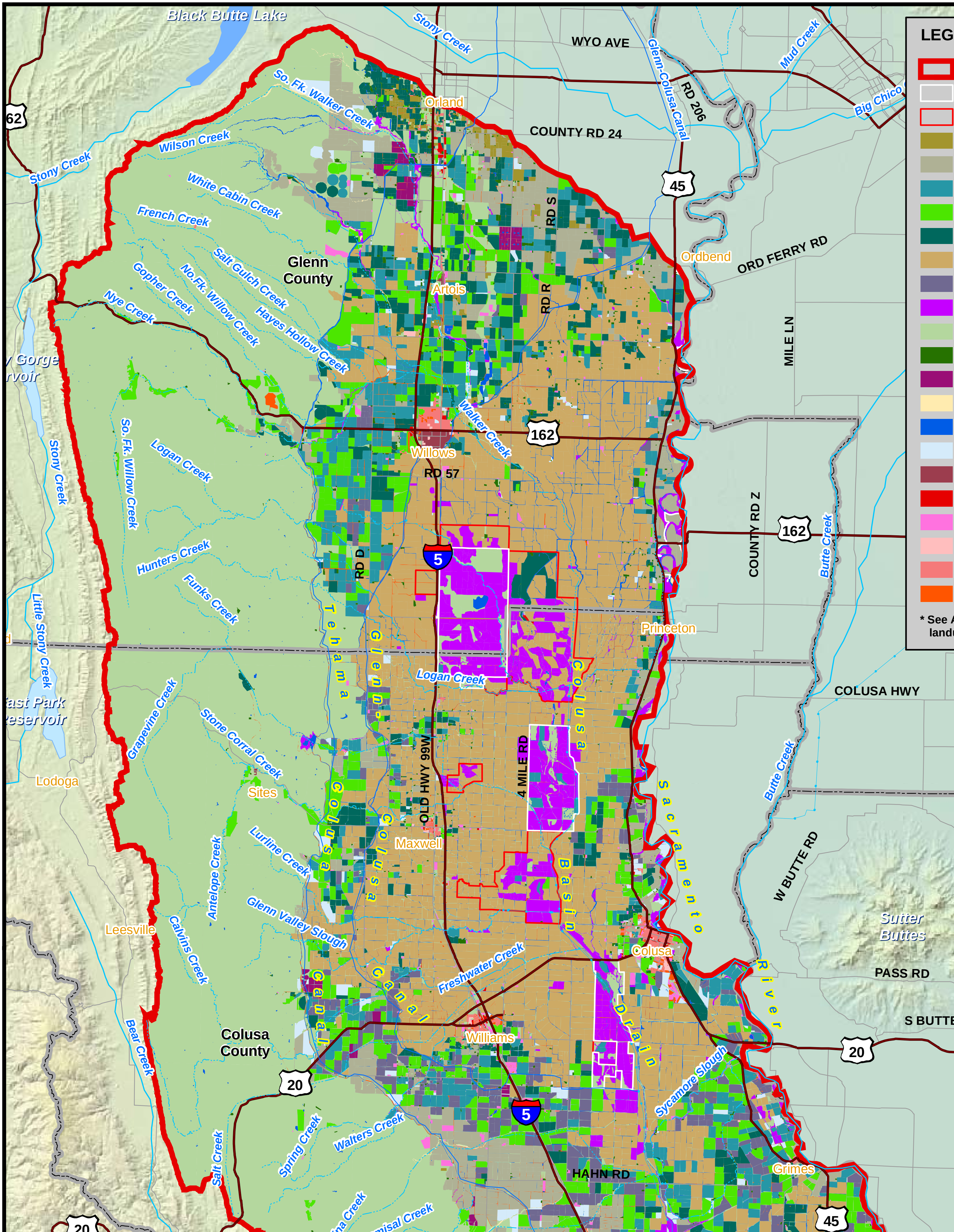

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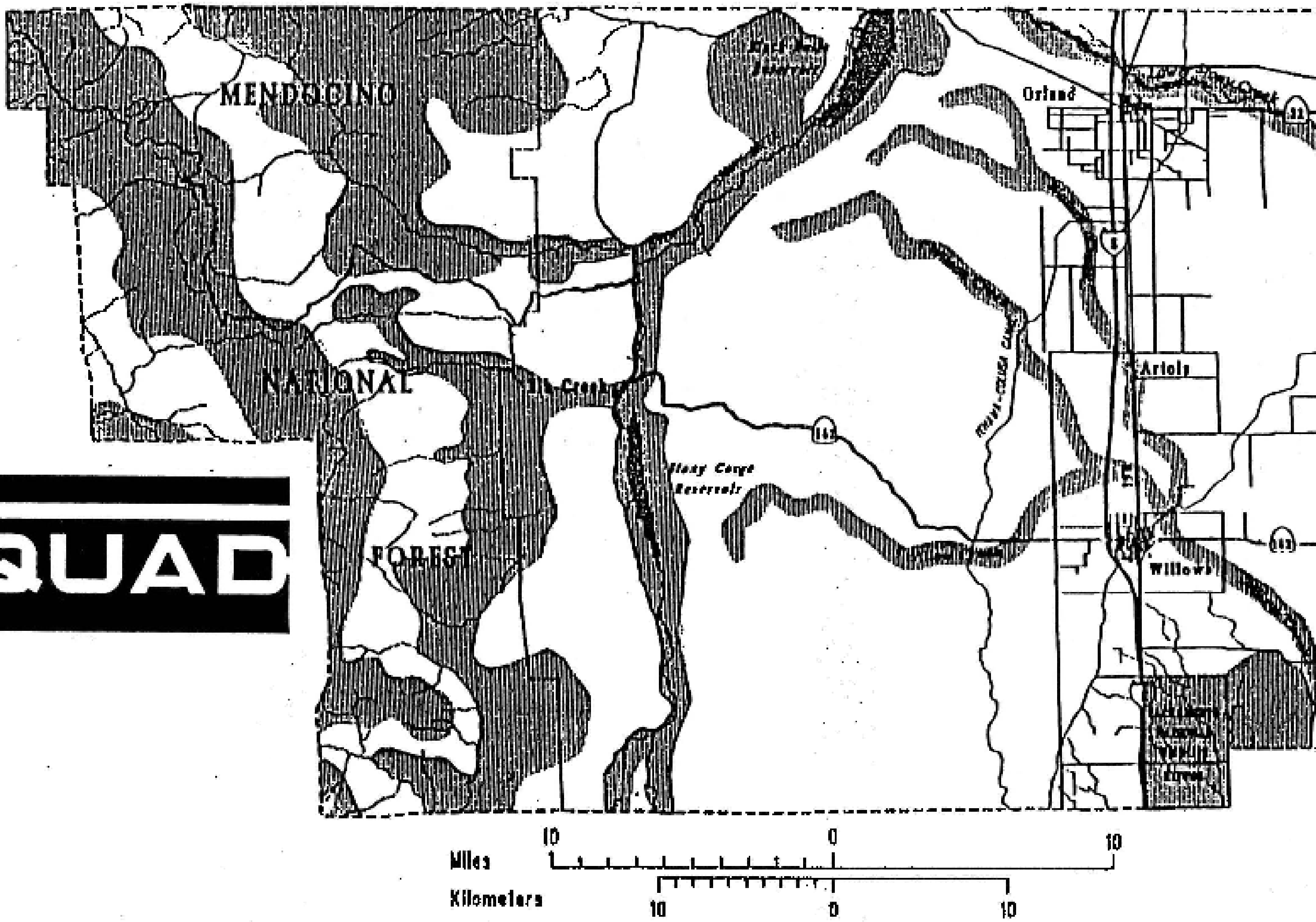


QUAD

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

**Colusa Basin Watershed Assessment: Biologically Significant Areas**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 3 - Land Use |
|---|---|---|
| SM | N:\Projects\2850-01\Figures\April 2008 | |

**Source: Quad Consult**
**Volume 1 Policy Plan**
**Inc. and Dowling Asso**
**of Supervisors.**

**Note: Figure clarity is**
**the above source. Plea**
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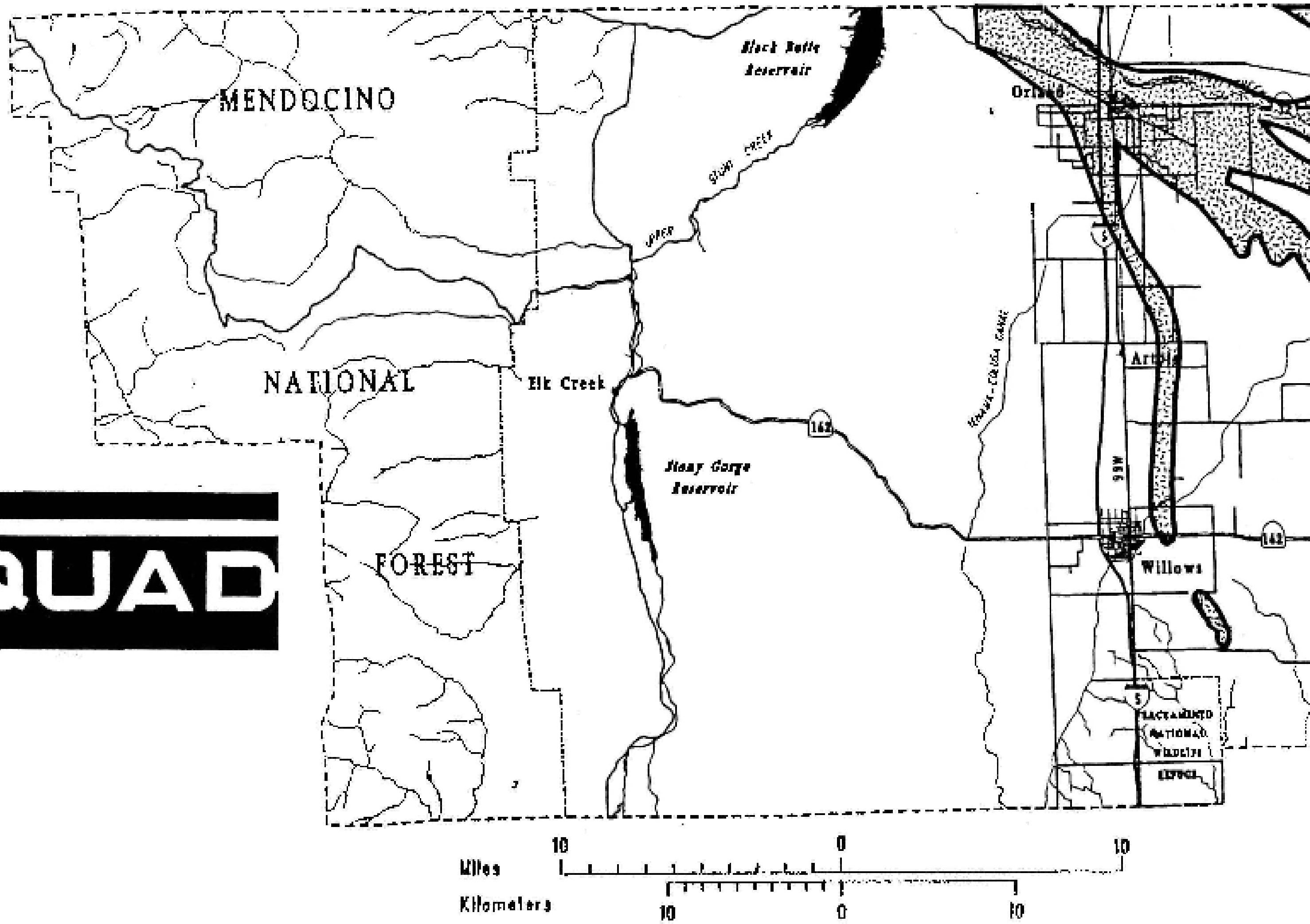


QUAD

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

**Colusa Basin Watershed Assessment: Groundwater Recharge Zones**

| | | |
|---|---|---|
| Proj No. 2850-01 | Date Dec. 2008 | Figure 4 - Land Use |

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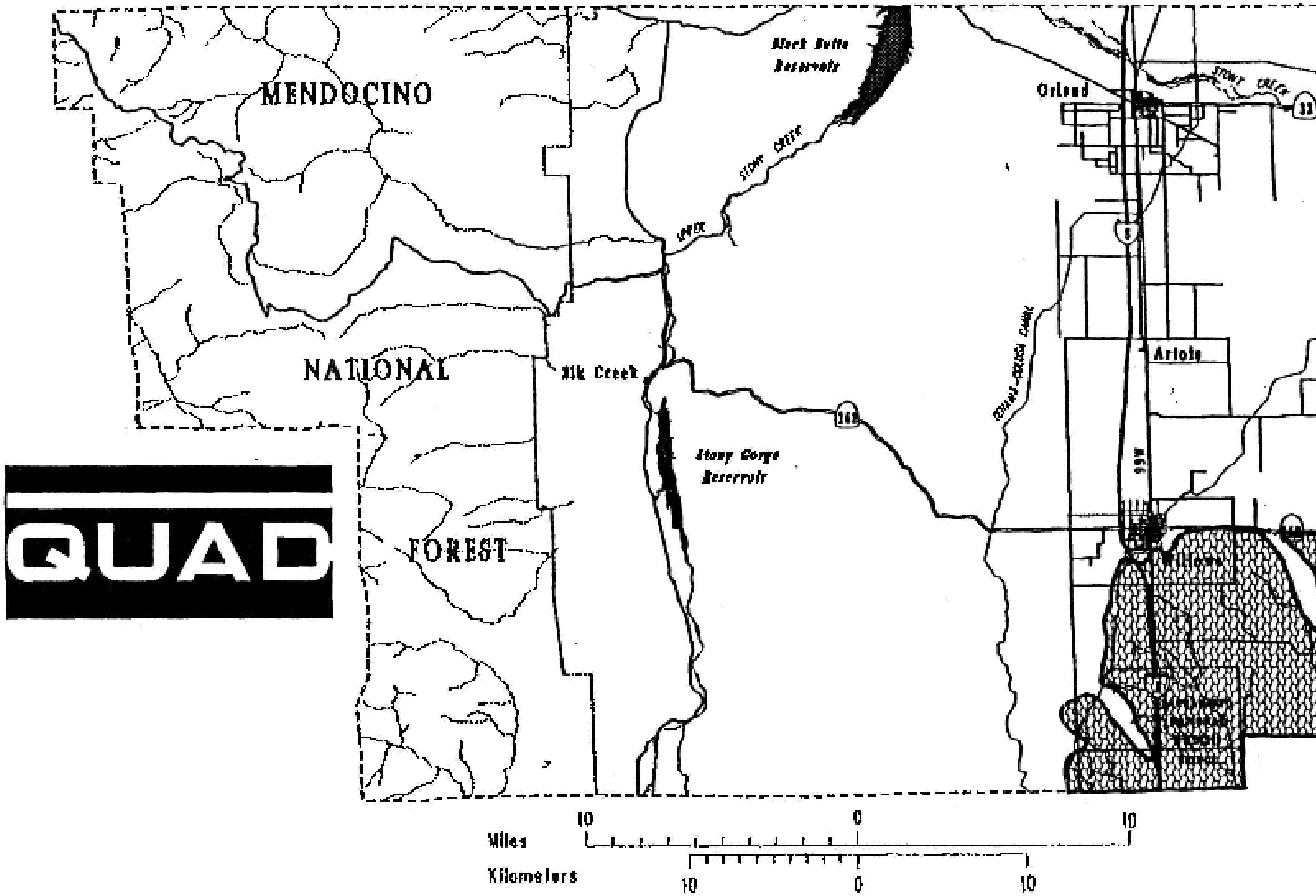
**Source: Quad Consul**
**Volume 1 Policy Plan**
**Inc. and Dowling Ass**
**of Supervisors.**

**Note: Figure clarity is**
**the above source. Plea**




**H. T. HARVEY & ASSOCIATES**
*ECOLOGICAL CONSULTANTS*

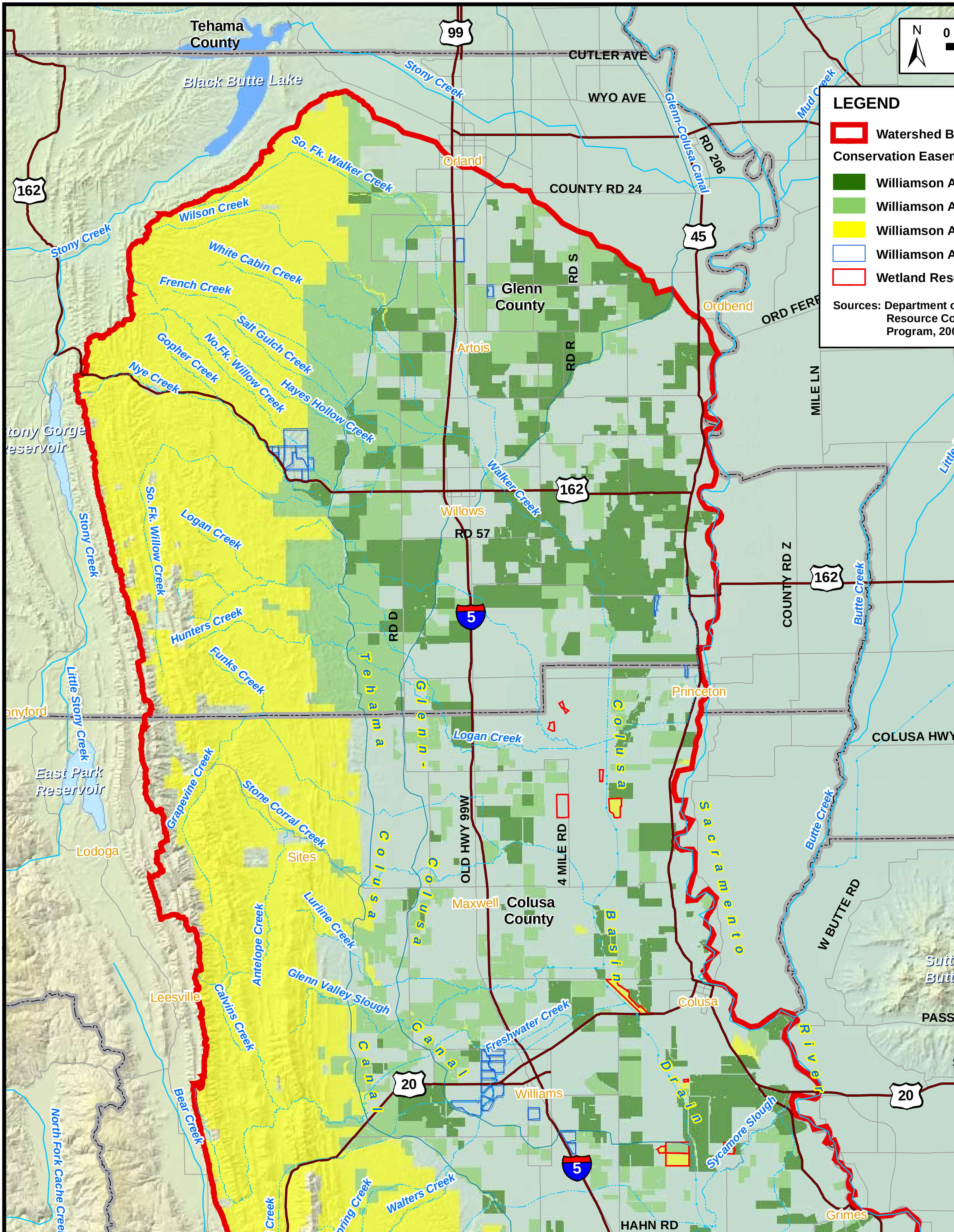
**Colusa Basin Watershed Assessment: Potentially Restorable Wetlands**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 5 - Land Use |
|---|---|---|

| SM | N:\Projects\2850-01\Figures\April 2008 |
|---|---|

**Source: Quad Consult**
**Volume 1 Policy Plan**
**Inc. and Dowling Asso**
**of Supervisors.**

**Note: Figure clarity is**
**the above source. Plea**



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Gopher Creek
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Hayes Hollow Creek
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# GEOLOGY

## GEOLOGIC SETTING OF THE COLUSA BASIN WATERSHED

The Colusa Basin Watershed lies entirely within the Great Valley geologic province, an area that includes the present Sacramento Valley and its fringe of foothills underlain by the valley's older sedimentary bedrock, bordered by the Coast Range, Klamath, Cascade, and Sierra Nevada mountains. The Great Valley province is characterized by broadly warped bedrock, a sequence of marine sedimentary rocks known as the Great Valley Sequence, which formed when a Cretaceous sea filled the Sacramento Valley (Bailey and Jones 1973). Broad warping of the Cretaceous marine sedimentary bedrock layers uplifted and tilted them along the Watershed boundary and lowered them along the valley centerline, giving rise to the foothills along the western edge of the Colusa Basin Watershed **(Figure 1-Geology)**. Note that 'Cretaceous marine sedimentary bedrock' and 'Cretaceous bedrock' are used interchangeably with 'Great Valley Sequence' in this assessment.

Erosional dissection of the uplifted foothills by Tertiary and Quaternary streams poured sediment into the sinking valley, forming a sequence of older alluvial rocks that flank the foothills, which in-turn have been uplifted and dissected by still younger streams. Holocene streams in more or less the same positions continue to dissect the Cretaceous foothills and the older alluvial deposits and pour sediment onto the flat valley floor. There is some evidence reviewed below suggesting that the Colusa Basin Watershed divide extended farther to the west during the Tertiary than it does presently, as would help explain the massive depositional volume and particular lithology of the Tertiary Tehama Formation. Holocene streams form contemporary alluvial fans that grade into the wide band of valley flat and basin lands (the Colusa Basin) which formed on the aggrading Sacramento River floodplain (Bryan 1923, Helley and Harwood 1985).

The geology section of this assessment at times refers to geologic Formations and patterns extending beyond the boundaries of the Colusa Basin Watershed, as needed to appropriately explain the geology of the watershed itself.

### Generalized Geologic Section

**Figure 2-Geology** shows a generalized geologic section across the Colusa Basin Watershed near Grimes (DWR 1962). The section shows the Coast Range foothills forming the drainage divide on the west and the overlying Tehama Formation forming a dissected "western terrace," flanking the foothills composed of the older alluvial deposits, primarily of Tertiary Tehama Formation. Downstream from the western terrace, there are smoothly sloping alluvial fans composed of mostly unconsolidated Pleistocene and Holocene alluvial deposits which grade into the basin flat lands of the Colusa Basin confined between the alluvial fans to the west and the natural levees and floodplain deposits of the Sacramento River to the east. The dashed line depicts the interfingering of the generally coarser alluvium delivered by the foothill streams and the finer-grained floodplain alluvium deposited by the Sacramento River as the valley has aggraded over time. According to this generalized section, the alluvial deposits of the Sacramento River are about 100 ft thick. Bryan (1923) estimated they were as much 300-400 ft thick, and Helley and

# GEOLOGY

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Harwood (1985) estimated they were as much as 390 ft thick along the central axis of the Sacramento Valley.

As reflected by this generalized geologic cross section, explaining the surficial geology of the Colusa Basin Watershed requires that emphasis be given to the processes of fluvial dissection of the uplifted bedrock and the resulting deposition of alluvium of various ages, including subsequent uplift and dissection of the older alluvial rocks. This approach is warranted because the streams that deposited the older alluvial rocks, including the Tehama Formation, are more or less the same streams that are presently depositing younger alluvium on the smoothly sloping active alluvial fan surfaces (Helley and Harwood 1985). Of particular interest is the evolution of the drainage areas of the individual foothill watersheds by fluvial dissection, which has been influenced strongly by the particular physical character of the underlying bedrock. The present state of the underlying bedrock influences the hydrology and sediment yields of the foothill watersheds. The geology of the individual landforms shown in the geologic section is described in more detail below.

### Coast Range Foothills

The western drainage divide of the Colusa Basin Watershed is mostly formed by higher, more erosion resistant ridges of the Great Valley Sequence exposed in the Coast Range foothills. This uplifted, warped, and tilted sequence of Cretaceous marine sedimentary bedrock includes layers of sandstone, sandy shale, and conglomerate rocks**.** Where they form the western drainage divide, the Coast Range foothills are distinctive in their parallel ridge-and-valley topography and the resulting rectilinearly trellised drainage networks. This is the result of the more resistant sandstones and conglomerates forming ridges while the intervening, less resistant shales have been worn down more completely by erosion, forming long narrow valleys. Oblique air photos plainly reveal this pattern in the steeply dipping sedimentary strata **(Figure Geology-3).** On this subject, Bryan (1923) observed:

> The larger ranges and valleys of the Coast Ranges owe their relief in large part to faulting. In detail the topography is due to the relative resistance of the rocks to weathering. The sandstones and conglomerates form ridges, and the shales form valleys. As the rocks have been tilted to high angles, the ridges generally trend in the same direction, and most of the valleys are narrow.
>
> The lowest hills are unforested and grass covered; the higher ones are covered by only a scanty growth of low trees. The linear ridges with their steep slopes make a sharp contrast with the adjacent red lands and low plains.
>
> From Stony Creek to Williams the trend of the ridges is slightly west of north. Toward the west each succeeding ridge rises higher above the blanket of alluvium on the lowest ridges and the intervening valleys become in general narrower and higher. The lower ridges have somewhat smooth crests except where streams have cut sharp V-shaped notches. These crests indicate an old plain of erosion on which the alluvium was laid down. This plain has been deformed and plunges under the valley fill on the east and rises into the mountains on the west, where it is lost in a tangle of serrate ridges.

> South of Williams the ridges trend southeastward. They follow the western margin of the plateau of alluvium thrown up by the Hungry Hollow fault and the fringe of alluvium of similar origin south of Esparto.

The largest of the higher elevation isolated foothill valleys show as buff-colored islands of recent alluvium (Qal) within the green-colored Cretaceous rocks nearer the western edge of the watershed **(Figure Geology-4)**: Squaw flat in the upper watershed of Logan Creek, a large valley flat in the upper watershed of Funks Creek, the northern portion of the Antelope Valley in the upper watershed of Stone Corral Creek, and the southern portion of the Antelope Valley in the upper watershed of Freshwater Creek. Narrower alluvium-filled valleys lie along the trellised stream network cut into the softer shale rocks throughout the foothills area, as is revealed by larger scale geologic maps (e.g., Helley and Harwood 1985). In places, the streams have also cut directly across the grain of the cretaceous rocks, especially in the northwest part of the watershed, where, for example, Nye Creek cuts southeasterly.

### Tertiary Tehama Formation

Resting on the Cretaceous bedrock of the Great Valley Sequence, with marked unconformity, is the Tehama Formation of Tertiary age **(Figure 2-Geology)**. The Tehama Formation (Tte) is composed of compacted pale-green, gray, and tan sandstone and siltstone with lenses of crossbedded pebble and conglomerate (Helley and Harwood 1985). According to Helley and Harwood (1985), the Tehama Formation is composed of alluvium derived from dissection of the marine sedimentary bedrocks of the Great Valley Sequence in the Coast Range foothills and deposited by more or less the same streams that dissect the Tehama Formation today. However, local workers have more recently observed that most of the Tehama Formation deposits came from the Franciscan Formation west of the current watershed divide, and therefore that a different drainage network existed in the past Watershed (Jack Alderson, Colusa County NRCS Agricultural Engineer, pers. comm., July 2008). Today, the drainage networks to the north (Stony Creek) and south (Cache Creek) of the Colusa Basin Watershed extend into the Franciscan Formation west of the Colusa Basin Watershed, probably having captured those drainage areas from the Colusa Basin Watershed.

First, local workers observed that red chert, from pebble size to cobble size, is very common in channels eroding the Tehama Formation and as lag material on Tehama Formation uplands, but red chert is absent or rare in channels eroding the Great Valley Sequence. Red chert can be found in the Great Valley Sequence foothills where conglomerates are exposed, but these exposed conglomerates are not at all common. The distribution of rock types for some deposits within the watershed.are given in California Division of Mines Bulletin 180 (1961). For example, for Salt Creek (draining near Arbuckle): Graywacke 84%, vein quartz 4%, chert 7%, greenstone 4%, and limestone 1%. And for Sand Creek: Graywacke 60%, greenstone 17%, chert 12%, vein quartz 10%, and carbonate nodules 1%. California Division of Mines Bulletin 180 (1961) does not contain data for a creek draining only the Great Valley Sequence, but it is commonly observed that only the greywacke is common in the Great Valley Sequence.

Second, the volume of the Tehama Formation is large compared to the Cretaceous marine sediments exposed in the foothills of the Colusa Basin Watershed. Some part of the volume may have been carried down from the north, but in general it is hard to imagine that the small modern streams draining the foothills could have deposited the entire volume of the Tehama Formation. The Tehama Formation is ~3.3 million years before present [mybp] and overlying Red Bluff deposits are 0.45 to 1.1 mybp (Helley and Harwood, 1985). Moores (2008) dates the beginning of the tilting of the Great Valley Sequence rocks at one to three mybp. It is quite possible that Tehama Formation deposits were laid down before the Colusa Basin Watershed drainage divide came to its present position, and there was a long period of deposition that might have included significant changes in stream courses. Olmstead and Davis (1961) describe the deposition of the Tehama Formation:

> On the west side of the Sacramento Valley fluviatile deposition continued throughout the Pliocene and possibly into the early Pleistocene. The streams continually shifted across broad, low flood plains, and the deposition of predominantly fine-grained materials (Tehama Formation) characterized the latter part of the epoch.
>
> During this time of deposition, the Sacramento Valley was more extensive than it is now. The western margin of the valley was as much as 20 miles west of the present edge west of Red Bluff, and the northern end of the valley was near Redding. The axis of the trough was several miles west of its present position.

Third, no geologic studies were located during the preparation of this assessment stating specifically that the Tehama Formation deposits were derived only from the Franciscan. Instead, it is generally believed that the Tehama Formation deposits come from the Coast Ranges and the Klamath Mountains. The Colusa Basin Watershed is far south of the Klamaths. The Coast Ranges certainly encompasses the Franciscan Formation deposits lying to the west of the Colusa Basin Watershed which were probably uplifted before the uplift of the western edge of the Great Valley Sequence. However, to date, the tectonic history of the west side of the valley has not been clearly documented.

The Putah Tuff and Nomlaki Tuff beds lie near the base of the Tehama Formation, respectively in or near the southern and northern portion of the watershed, putting the maximum age of the Tehama Formation near that of the tuff beds – about 3.3 to 3.4 million years. The maximum thickness of the Tehama Formation is about 2000 ft near the Sacramento River. Its thickness generally decreases where it has been uplifted higher and been more deeply dissected along the foothill front **(Figure 1-Geology)**. Because the underlying Cretaceous marine sedimentary rocks of the Great Valley Sequence are not groundwater-bearing, the base of the Tehama Formation is also the base of fresh groundwater in the entire Sacramento Valley.

The amount of the Tehama Formation that is exposed along the mountain front varies markedly in the Colusa Basin Watershed. The variation in the extent of the exposure between the Cretaceous bedrock foothills to the west and the younger alluvium to the east likely has a strong influence on the character of the streams that dissect it, including the amounts, lithology, and size distribution of sediment they historically and presently pour onto the alluvial fans. Northwest of Willows, the Tehama Formation retains the form of a broad alluvial fan underlying most of the upper watershed areas of Walker Creek, Wilson Creek, White Cabin Creek, Sheep Corral Creek, and to a lesser extent also French Creek, Salt Gulch Creek, and Hayes Hollow Creek. The Tehama Formation comprises nearly the entire pink-colored area mapped at the 1:250,000 scale by Jennings and Strand (1960) as upper Pliocene non-marine rocks (Puc) and reproduced in

**Figure 4-Geology.** To the south of this outcropping, due west of Willows, Nye Creek and South Fork Willow Creek are dissected entirely in Cretaceous bedrock, the Tehama Formation being absent.

West-southwest of Willows, North Fork Logan Creek has its headwaters in a relatively narrow remnant of the upper Pliocene non-marine rocks (thus presumably Tehama Formation) flanking the foothills, its small drainage area evidently giving it insufficient power to more completely dissect it (**Figure 4-Geology**). However, a closer examination of more detailed geology maps indicates that this is not a remnant of the Tehama Formation but instead one of numerous scattered remnants of the Pleistocene Red Bluff Formation. Producing later maps at a 1:62,500 scale, Helley and Harwood (1985) did not show the Tehama Formation present at North Fork Logan Creek. In fact, the topography in the vicinity is distinctly that of the Cretaceous bedrock, with its west of north trending parallel ridges transitioning directly to the smoothly sloping alluvial fans on the east. Helley and Harwood (1985) instead showed that scattered outcroppings of the Red Bluff (Qrb) lie in the area circumscribed by Jennings and Strand (1960) as upper Pliocene non-marine rocks (Puc).

### Pleistocene Red Bluff Formation

According to Helley and Harwood (1985), the Red Bluff (Qrb) is:

> . . . a thin veneer of distinctive, highly weathered bright-red gravels beveling and overlying the Tehama, Tuscan, and Laguna Formations. In this study we interpret the Red Bluff Formation as a sedimentary cover on a pediment surface and therefore suggest that it formed in response to a fixed base level caused by impeded or closed drainages of the Sacramento Valley. The Red Bluff pediment is overlain by the Rockland ash bed (0.45 m.y. old) (Meyer and others, 1980) and in turn overlies the basalt of Deer Creek (1.08+/-0.16 m.y.). Therefore, the pediment must have formed sometime within that 630,000-yr interval.
>
> The Red Bluff is best preserved in the northern part of the valley from Redding to the south of Orland Buttes on the west and south to Chico on the east; it also occurs along the southwest side of the valley where its pediment character is less clear. The scattered cappings of the Arroyo Seco Gravel of Piper and others (1939) and Shlemon (1967) in the Sacramento area and also the half dozen or so scattered gravel remnants south of Woodland between Cache and Putah Creeks may actually be Red Bluff. The Red Bluff is deformed by the Dunnigan Hills anticline, a doubly plunging fold west of Arbuckle, and it unconformably overlies the Tehama on a structural high south of Woodland that may be a continuation of that fold. The Red Bluff also unconformably overlies the Tehama in intermittent patches along the western valley between Winters and the mouth of Cache Creek.

Helley and Harwood (1985) give the Red Bluff Formation a maximum age of 1.08 million years, while the Pliocene epoch is generally designated as covering the period of geologic time from 1.8 to 5 million years ago. It appears that Jennings and Strand (1960) included the Red Bluff Formation with the Tehama Formation in the upper Pliocene non-marine rocks (Puc), possibly before the maximum age of the Red Bluff was determined by later studies. Indeed, more recent mapping compiled by the 1:250,000 scale USGS map series, such as the Sacramento Sheet (Wagner et al. 1981) shown in the southeast corner of the Colusa Basin Watershed in **Figure 4-Geology**, divides the Tertiary Tehama Formation (Tt) and Quaternary Red Bluff (Qrb). The

1:250,000 scale Ukiah Sheet covering most of the Colusa Basin Watershed has not been updated since 1960.

Detailed cross-inspection of the 1:250,000 and 1:62,500 scale maps seem to confirm that Jennings and Strand (1960) did include the Red Bluff Formation with the Tehama Formation in the upper Pliocene non-marine rocks (Puc), such that everywhere **Figure 4-Geology** shows (Puc) flanking the foothills in central part of the Colusa Basin Watershed – between South Fork Willow Creek and Cortina Creek – it designates scattered remnants of the Pleistocene Red Bluff Formation, not the Tertiary Tehama Formation.

The Tehama Formation is not exposed along the foothill front where North Fork Logan Creek, Hunters Creek, Funks Creek, Stone Corral Creek, Lurline Creek, Glen Valley Slough, Manor Slough, Freshwater Creek, and Salt Creek debouch onto the valley flat. In places **Figure 4-Geology** shows the Tehama Formation incompletely dissected by some of the smaller intervening drainages (Baker Slough, and some of the numerous other unnamed streams). Again, where Helley and Harwood's (1985) 1:62,500 scale geology maps overlap the foothill front in this area, they do not show outcroppings of the Tehama Formation.

The Tehama Formation begins to rise up strikingly from the younger, smoothly sloping alluvial fan deposits to form prominent deeply dissected foothills beginning west-southwest of Williams and south of Freshwater and Salt Creeks, notably in the same range of latitudes where the parallel sandstone, shale, and conglomerate ridges of the Cretaceous bedrock change from a west of north alignment to a southeast alignment.

Spring Creek, or Spring Valley Creek as it is sometimes labeled, has its upper watershed in the Cretaceous bedrock and dissects the Tehama Formation before passing onto the alluvial fans southwest of Williams **(Figure 4-Geology)**. Upstream from the Tehama Formation, Spring Creek first traverses Spring Valley, a broad and irregularly shaped isolated valley that appears, like the much larger Capay Valley to the south, to lie within a downfaulted block of Cretaceous rocks. The smaller upper watershed area of Walters Creek is underlain almost entirely by the Tehama Formation.

The majority of the Cortina Creek upper watershed is underlain by the Tehama Formation, with the highest elevation reaches draining Cretaceous bedrock forming Cortina Ridge. The entire upper watershed areas of Chamisal Creek and Sand Creek are dissected in Tehama Formation rocks. That the upper reaches of Sand Creek have not incised into the Cretaceous bedrock underlying the Tehama Formation may be partly due to downfaulting in the general vicinity of Capay Valley to the south **(Figure 1-Geology)**. These foothill streams are said to produce more abundant gravel-sized sediment than other foothill streams in the watershed. The upper watersheds of Whiskey Creek and Elk Creek are entirely underlain by the Tehama Formation.

To the south, a ridge of Cretaceous bedrock begins again to form the western divide of the Colusa Basin Watershed, such that the highest elevations of the watersheds of Salt Creek, Petroleum Creek, Buckeye Creek, Mushoak Creek, and Oat Creek drain Cretaceous bedrock, but the majority of these upper watershed areas are underlain by the Tehama Formation. To the southeast, the smaller Dunnigan Creek and Bird Creek upper watersheds are underlain entirely by Tehama Formation rocks.

Farther to the south, near Zamora, the western divide of the Colusa Basin Watershed is formed again by the Tehama Formation, where Zamora Creek, Willow Spring Creek, and Smith Creek deeply dissect the Tehama Formation. The higher uplift and deeper dissection of the Tehama Formation in this area have created a distinctive topography. The greater relief has led the area to be uniquely characterized as "hills": the Dunnigan Hills and Hungry Hollow Hills **(Figure 5-Geology).** The bright red gravels of the Red Bluff Formation are exposed in the headwater areas of Willow Springs Creek and Smith Creek.

Bryan (1923) dubbed exposures of the Tehama Formation, and possibly some of the other older alluvium surrounding the Sacramento Valley, as the "red lands" although the geologic description of Helley and Harwood (1985) indicates their pale green, gray, and tan color. Bryan (1923) observed:

> On both sides of the valley, lying just above its flat interior parts and below the rugged foothills of the adjacent mountain, are broad belts, gently undulating and in places even hilly, which are here designated as red lands. They are variously known as "high plains," "valley plains," or simply "plains." Where much broken they are called hill, as Montezuma Hills and Hungry Hollow Hills. The name red lands is used because these belts have a somewhat red soil except between Red Bluff and Chico, and even here, where all the soils are brown because of their derivation from the Tuscan tuff, the soil of the red lands is more reddish than that of the low plains.
>
> The red lands are composed of alluvium laid down by the streams after the adjacent mountains were uplifted. This alluvium, which is called the older alluvium, has also been uplifted and is now being dissected by the streams. The red lands are therefore deformed and eroded alluvial slopes, whose character depends on their original form, the nature of the deformation and later erosion.
>
> After the mountains were uplifted debris from them was deposited in the valleys, first at a rapidly increasing and then at a gradually decreasing rate. Fluctuation in the volumes of the streams produced differences in the rate, but on the whole the streams carried so much water that they swept the bulk of the material far out toward the center of the valley and dropped only small amounts immediately adjacent to the mountains. This appears to have been the method of distribution of the older alluvium, for in most places it is thin – less than 50 feet thick along the border of the valley and probably nowhere more than 400 feet except, perhaps, in the vicinity of Oroville.

Bryan (1923) further observed:

> The red lands form belts of hilly or gently undulating country that extend along both sides of the Sacramento Valley, and in most places they have a general slope toward the axis of the valley. These belts were once almost as smooth and regular as the lower parts of the valley at the present time. They were constructed by the streams that flowed from the mountains into the valley and there deposited most of their burden of gravel, sand, and silt, building up these marginal belts until they formed smooth plains that sloped gently from the borders of the mountains toward the middle of the valley. These plains were then raised by warping and faulting of the earth's crust

and were subsequently eroded by the same streams that built them, thus acquiring most of their present irregularities. They are hilliest and most sharply contrasted to the rest of the valley where the uplift has been most pronounced and the erosion has consequently been most active, as in the Hungry Hollow and Montezuma hills; they are gently undulating and most indefinite in outline where the uplift has consisted of only slight regional warping, as in the vicinity of Sacramento.

**Variation in the Amount that the Tehama Formation is Exposed along the Foothill Front.** The variation is mostly explained by differences in the amount of uplift and the curvature of warping of the Great Valley Sequence and their effect on the altitude and dip of the Tehama Formation where it may be exposed above the Cretaceous bedrock along the foothill front. Prior to the majority of the subject deformation, the Tehama Formation is believed to have formed a gradually sloping plain that may have been in places as little as 50 ft thick near the mountain front. Therefore, its ultimate exposed width would be significantly reduced if its surface were to steeply dip toward the valley as the result of severe curvature by warping. Severe warping appears to be the explanation for why the Tehama Formation is absent between Willows and Williams. By way of contrast, the amount of uplift and warping shown by **Figure 1-Geology** in the southern portion of the watershed is such that the Tehama Formation was uplifted to a relatively higher altitude but with relatively less warping, giving rise to the relatively flat, plateau-like, and deeply dissected Tehama Formation surfaces west and southwest of Dunnigan and Zamora.

The most severely dissected Cretaceous bedrock occurs only in the same part of the watershed and completely bordering the absence of Tehama Formation rocks. Notice in **Figure 4-Geology** that generally north of Cortina Ridge, the upper (younger) Cretaceous bedrock (Ku) is consistently and significantly more deeply dissected than the lower (older) Cretaceous bedrock (Kl); the latter forms the steeper ridges along the western drainage divide. The older Cretaceous bedrock is presumably more erosion resistant than the younger bedrock. Cortina Ridge, also younger bedrock, has a similar altitude and steepness to the older bedrock, which may be due in part to the faulting in the vicinity of Cortina Ridge having (1) thrown up the younger bedrock to a higher elevation, (2) thrown up a relatively shallowly warped Tehama Formation in front of it protecting it from dissection wrought by base level changes occurring on the valley floor, and (3) situating the drainage divide on Cortina Ridge where thereby limited drainage areas would reduce local denudation rate.

On the subject of the distribution of the Tehama Formation, Bryan (1923) observed:

> "The movements that elevated the red lands and exposed them to erosion were of three well-defined types. The uplift on the east side of the valley from Red Bluff to Chico took place along a monoclinal flexure, which affected not only the older alluvium but also the underlying Tuscan tuff. This movement resulted in the uplift of the alluvium in a narrow belt from the Iron Canyon to the Rio de los Berrendos and in a broader belt from that stream southward to Chico. On the opposite side of the valley the alluvium was uplifted on the western limb of a broad synclinal warp of slight curvature, which affected this portion of the valley. The amount of uplift was about 50 feet near the river but increased to 200 or 300 feet or more near the Klamath Mountains, 25 miles west. As a result, the older alluvium was uplifted in a belt about 12 miles wide. From Orland southward to Williams a similar uplift took place but with a greater curvature, so that the outcrop of the older alluvium forms only a fringe along the foothills that decreases in width southward as the older alluvium plunges beneath the younger alluvium with increasing dip. On

> the east side of the valley from Chico to Mokelumne River, the uplift consisted of warping similar to that between Red Bluff and Williams. The amount and curvature of the warping were not the same in different localities, and in consequence there is considerable variation both in elevation and in slope toward the center of the valley throughout the area. From Williams southward to Vacaville there was uplift along two nearly parallel normal faults, with the upthrow on the mountain side. Of these the Hungry Hollow fault is by far the longer and more pronounced." (emphasis added).

Further, Bryan (1923) observed:

> "From Stony Creek south to Williams the red lands occupy very small areas flanking the foothills of the mountains. Near Willows they are 2 to 3 miles wide and rise from 100 to 200 feet above the adjacent streams. They have a greatly dissected surface that slopes abruptly from the foothills to the low plains. From Willows south toward Williams the red lands decrease in width and altitude and finally are represented simply by patches of gravelly soil at the base of the foothills.
>
> The most extensive area of red lands on the west side begins at Williams and extends southeastward to Cache Creek. The southern part is called the Hungry Hollow Hills, and this name is sometimes used for the whole area as far north as Williams. It consists of a plateau from 100 to 450 feet above sea level composed of flat-lying soft alluvial materials and volcanic ash. It is bounded on the northeast by a remarkably straight and uniform escarpment (See Pl. IX, B.) In the southern part they have thoroughly dissected the plateau so that it now consists of a series of hills and valleys with remarkably steep slopes, yet each hill rises to the common level of the plateau surface. Farther north considerable tracts of the original flat-topped plateau remain. Here that altitude is great enough to assure a considerable rainfall, and a sparse forest of oak and manzanita covers the hills. The southern section, or Hungry Hollow Hills, has always been treeless and is at present wholly devoted to the growing of grain. South of Cache Creek the plateau dies out in a series of isolated rounded knolls, which rise above the low plain and may be distinguished at considerable distances by their reddish color."

Note that Pl. IX, B is reproduced in this assessment as **Figure 5-Geology.**

### Older and Younger Alluvium

Having been deposited from about 3.3 million years before present [ybp] to about 1.8 million ybp, the Tertiary Tehama Formation comprises the thickest and oldest alluvial deposits in the Colusa Basin Watershed. Since its deposition, it has been uplifted and deformed, variably consolidated, and greatly dissected and filled by Quaternary streams with the result that its present geomorphic position is that of a bluff, plateau, or low foothills, with even the oldest Quaternary floodplains lying far below its upper surfaces. Commonly, references to the older alluvium of the Colusa Basin Watershed exclude the Tertiary Tehama Formation and include only the Pleistocene alluvial deposits. Younger alluvium refers only to Holocene alluvium, which is younger than about 10,000 years old.

The unconformably and patchily overlying Red Bluff Formation is thought to be as old as 1.08 million ybp. The subsequent better preserved Pleistocene alluvial deposits (the Riverbank Formation and Modesto Formation) have been formed in separate intervals from about as early as 450,000 ybp to about 12,000 ybp. The older alluvium is differentiated from the younger alluvium in that, by the passage of time, it is now uplifted and dissected, thereby forming distinct terraces in the foothill valleys and abandoned channel ridges on the alluvial fans. The oldest Pleistocene alluvium is also considerably weathered and more consolidated, approaching semiconsolidated, while the youngest Pleistocene alluvial deposits are unconsolidated and show minimal weathering.

High near-vertical stream banks are the result of modern stream channels impinging on consolidated alluvium that may create a more perceived than real need for bank armoring or mechanical stabilization. Stream restoration techniques used elsewhere that rely on vegetation establishment on the freshly graded *in situ* bank material may be unsuccessful where the native bank material is semiconsolidated. Although the older, more consolidated Riverbank age alluvium is generally elevated and separated from the modern stream channels by inset, unconsolidated deposits of the Modesto and younger Holocene terrace and floodplain deposits, detailed examination of Helley and Harwood's (1985) 1:62,500 scale geologic maps shows that the Modesto and Holocene alluvium only discontinuously flank the modern stream channels. Modern stream channels impinge on Tehama, Red Bluff, and Riverbank Formation rocks at places throughout the Colusa Basin Watershed, mainly within foothill valleys and along upper fan surfaces and contacts of coalescing alluvial fans.

**Bryan's Geologic-geomorphic Provinces.** Bryan (1923) prepared a comprehensive and field-intensive groundwater resources appraisal of the entire Sacramento Valley, and in so doing, synthesized much information about geology and geomorphology of the Colusa Basin Watershed. Bryan himself conducted about 12 months of field work between September 1912 and September 1914. A work crew operated during that entire period, carrying field equipment and provisions with a team of horses and a wagon and making camp along the road each night, to cover the entire area. Bryan's early work expounded on a wide range of subjects of general interest to this assessment, most notably the evolution of the alluvial landforms forming the alluvial fans and flat basin lands, an understanding of which was needed at the time to explain the complicated subsurface structure of various groundwater-bearing and -producing alluvium which underlies the Sacramento Valley, a complex of alluvium then being rather blindly sampled by well drillers. Bryan (1923) divided the Sacramento Valley into 5 geologic-geomorphic landform-types or provinces, the first 4 of which occur in the Colusa Basin Watershed: the red lands, the low plains, the river lands, the flood basins, and the island country.

As discussed above, Bryan's red lands include the Tehama Formation and probably some or all of the older alluvium, in so far as Bryan's low plains include only the "smoothly sloping" part of the alluvial fans (1923):

> The low plains lie in general between the red lands and the river lands, but in some places, where the red lands are absent, they extend to the mountains. They are somewhat lower than the red lands and are nearly level except for very gentle slopes toward the axis of the valley. These plains were built by the streams that enter the valley from the mountain borders and that have dissected the intervening red lands. They owe their remarkable smoothness to the fact that they are still in process of construction, as is fully demonstrated by frequent floods that spread over them and leave behind deposits of silt.

Bryan's river lands comprise only the flat basin lands created by the net depositional influence of the Sacramento River. It follows then that Bryan's low plains include only the active portion of alluvial fan surfaces, and the dissected alluvial fan surfaces along the foothill front are included in Bryan's red lands, not the low plains. Bryan's distinction between the red lands and the low plains is a geomorphic distinction: the division between dissected uplands which are geomorphically terraces (the red lands) and the still active alluvial fan surfaces (the low plains) downstream. **Figure 2-Geology** shows that DWR (1962) appeared to make the same distinction, probably including the dissected Pleistocene alluvium on the upper alluvial fan surfaces with the Tehama Formation as the generally dissected "western terrace." Later investigators, including Helley and Harwood (1985) recognized that the term "low plains" might not apply to nearly the entire fan surface, distinguishing instead between the upper (proximal) fan surfaces and lower (distal) fan surfaces, noting: "…fans whose distal ends grade to low plains and basins."

## Geologic Description of the Alluvial Units

In light of the geologic subtleties illustrated by the above discussion, geologic descriptions of the individual alluvial units will be given before describing the valley terrace and alluvial fan landforms underlain by the older and younger alluvium. A general geologic description has been given above for the Tehama (Tte) and Red Bluff (Qrb) Formations. Helley and Harwood (1985) give the following descriptions for the other surficial alluvial deposits in the Sacramento Valley including the Colusa Basin Watershed:

Qsc stream channel deposits (Holocene) – Deposits of open, active stream channels without permanent vegetation. These deposits are being transported under modern hydrologic conditions; consequently they are light tan and gray, unweathered, and usually in contact with modern surface waters. Our mapping merely limits the right and left bank boundaries of the active stream channel. Morphology within the deposits is constantly changing. Thickness may reach 25 m on the Sacramento River or be less than a few centimeters in bedrock canyons.

Qa alluvium (Holocene) – Unweathered gravel, sand, and silt deposited by present-day stream and river systems that drain the Coast Ranges, Klamath Mountains, and Sierra Nevada. Differentiated from older stream-channel deposits (Qao and Qal) by position in modern stream channels. The deposits form levees along the main course of the Sacramento River, and broad alluvial fans of low surface relief along the western and southwestern side of the valley. Because of high organic content the levee deposits are darker gray than the alluvium flanking the channels on the smaller streams. Thickness varies from a few centimeters to 10 m.

Qo overbank deposits (Holocene) – Sand, silt, and minor lenses of gravel deposited by floods and during high water stages; form low terraces adjacent to present-day alluvial stream channels; coincident with tan and gray organic-rich sediments (Qm), which generally mark high-water trimlines of historic floodwaters. Probably do not exceed 3 meters in maximum thickness.

Qao alluvial and overbank deposits, undivided (Holocene) – Consists of units Qa and Qo.

Qal alluvial deposits, undivided (Holocene and Pleistocene) – Undivided gravel, sand, and silt; this unit generally taken from previous mapping.

Older Alluvium (Pleistocene) – A general description of the older alluvium applies to the Pleistocene Modesto, Riverbank, Turlock Lake, and Red Bluff formations. Mainly forms fans and terraces whose distal ends grade to low plains and basins and whose proximal ends grade to colluvium along the foothills surrounding the valley. Consists of tan, brown, gray, black, and red gravels, silts, and clays that lithologically reflect the local source areas. The youngest of these deposits are unconsolidated and show minimal weathering, while the oldest display maximal weathering and are semiconsolidated. Soil profiles were used to help differentiate members. The upper Pleistocene older alluvium is incised into the older Quaternary and upper Tertiary deposits. Thickness ranges from zero to as much as 120 m in the central part of the valley. The stream systems that deposited the older alluvium are essentially those that flow today as all deposits border modern streams. The youngest deposits lie only a few meters above present stream channels and may even be overtopped by infrequent flooding. The oldest Pleistocene alluvial surface lies tens of meters above modern floodplains. Consists of:

Modesto Formation – The youngest unit comprising the Pleistocene alluvium consists of distinct alluvial terraces and some alluvial fans and abandoned channel ridges. The unit forms the lowest deposits lying topographically above the Holocene deposits along streams and in valleys. It consists of tan and light-gray gravely sand, silt, and clay except where derived from volcanic rocks of the Tuscan Formation; it then is distinctly red and black with minor brown clasts. The Modesto was deposited by streams still existing today because the deposits, for he most part, border existing streams. An exception is the abandoned channel filled with deposits belonging to the upper member of the Modesto on the south side of the alluvial fan of Stony Creek. Divided into:

Qmu Upper Member – Unconsolidated, unweathered gravel, sand, silt, and clay. The upper member forms terraces that are topographically the lowest of the two Modesto terraces. It also forms alluvial fans along the east side of the Sacramento Valley from Red Bluff to Oroville. Soils at the top of the upper member have A/C horizon profiles, but unlike the lower member they lack argillic B horizons. Deposits belonging to the upper member of the Modesto are only a few meters thick and generally form a thin veneer deposited on older alluvial deposits. Original surficial fluvial morphology is usually preserved and gives relief of 1 or 2 m. $C^{14}$ age determinations on plant remains from the upper member at Tulare Lake suggest that the unit is between 12,000 and 26,000 yr old (Brian Atwater, oral commun., 1982). Thus the deposition of the upper member of the Modesto Formation appears to correspond with the Tioga glaciation in the Sierra Nevada (Birkeland and others, 1976)

Qml Lower Member – Unconsolidated, slightly weathered gravel, sand, silt, and clay. The lower member forms terraces that are topographically a few meters higher than those of the upper member. It forms alluvial fans along the main channel of the Sacramento River and Feather River and large levees bordering the Sacramento River from Stony Creek to Sutter Buttes. Upstream from Stony Creek the lower member of the Modesto is preserved as scattered terrace remnants. Alluvium of the lower member of the Modesto surrounds the Dunnigan Hills and borders Cache Creek near Esparto. Soils developed on the lower member contain an argillic B horizon, which is marked by a noticeable increase in clay content and a distinct red color. Its surface fluvial morphology is remarkably smooth and displays little relief. The unit is much more extensive than the upper member and probably represents a longer period of deposition. The lower member of the Modesto unit is the youngest deposit from which we have evidence of fault displacement. Conspicuous linear-edged terraces composed of the lower member are found just south of

Orland Buttes and may be a reflection of the Willow fault zone. The lower member deposited along the northeast fan of the Dunnigan Hills may also reflect fault displacement.

Marchand and Allwardt (1981) gave an age for the lower member as probably Altonean (early and middle Wisconsonian) based on an open-system uranium series minimum age of 29,407+/-2,027 yr on bone from basin deposits of the lower member of the Modesto. A radiocarbon age on wood from a depth of 15-16 m in basin deposits of the lower member was 42,400+/-1,000 yr B.P. (Marchand and Allwardt, 1981, p. 57). They speculated that this may be the older age limit of the lower member. Since the dates were from flood-basin deposits where deposition may have continued long after terrace deposition ceased, the ages may be too young.

Riverbank Formation – Weathered reddish gravel, sand, and silt forming clearly recognizable alluvial terraces and fans. Riverbank alluvium is distinctly older than the Modesto and can be differentiated by (1) its geomorphic position in terraces topographically above the terraces of Modesto age and (2) the degree of post-depositional soil-profile development. The Riverbank displays thicker argillic B horizons with a consistent shift in hue from 10 YR to 7.5 YR and even some 5 YR hues (Munsell color notations). We have divided the Riverbank into two informal members in contrast to the northeastern San Joaquin Valley where Marchand and Allwardt (1981, p. 36) recognized three members. Based on soil-profile development, we tentatively correlate the two members of Riverbank in the Sacramento Valley with the upper two members in the San Joaquin Valley as described by Marchand and Allwardt (1981). The main distinction between the two areas is lithology: the Riverbank of the San Joaquin Valley is predominantly arkosic alluvium while that of the Sacramento Valley contains more mafic igneous rock fragments. Consequently, Riverbank deposits in the Sacramento Valley tend toward stronger soil-profile development for deposits of the same age. Both members of the Riverbank in the Sacramento Valley are lithologically very similar, but the upper member is more widespread and less dissected.

The upper member is prominent in the northwestern part of the Sacramento Valley from Red Bluff to Chico, but it does occur around the western half of the Sutter Buttes. However, both members form a dominant part of the landscape from Oroville south to the delta along the east side of the valley. Their asymmetrical distribution, widespread extent in the northwest and southeast, and absence in the southwest may reflect broad, slow, and relatively aseismic tectonic movement of the valley. Deposits of both Riverbank members are well preserved on the Stony Creek fan and along Cottonwood Creek and the Sacramento River near Anderson.

The Riverbank alluvium is older than the Modesto alluvium but younger than the Red Bluff Formation. Since the Red Bluff is overlain by the Rockland ash bed (0.45 m.y.), the Riverbank, which is cut and filled below the Red Bluff, can be no older than the ash bed and is probably much younger. Considering the degree of erosional dissection of the Riverbank and strong soil-profile development, it must be at least twice as old as the older Modesto age of about 50,000 yr. Marchand and Allwardt (1981 p. 41) placed the Riverbank of the San Joaquin Valley between 130,000 and 450,000 yr B.P. They used several lines of evidence including uranium-trend dating on soils (Rosholt, 1978), which gave the younger limit, while the older limit was based on stratigraphic evidence. The Riverbank in the San Joaquin Valley occupies the stratigraphic interval between the Modesto above and Turlock Lake Formation below. The upper part of the Turlock Lake contains the Friant Pumice Member (600,000 yr old). The Riverbank in the San Joaquin Valley must be considerably younger since a period of erosion and soil formation occurred between its deposition and that of the Turlock Lake. Divided into:

Qru Upper Member – Unconsolidated but compact, dark-brown to red alluvium composed of gravel, sand, silt, and with minor clay. Topographically forms the lower of the two Riverbank terraces; forms dissected alluvial fans on the northwest and southeast sides of the Sacramento Valley with distinct and now abandoned distributary channels cut into the lower member and older deposits. The Riverbank members generally are separated vertically by about 3 m, but the lower member of the Modesto may be more than 5 m lower in elevation. The upper member, while smoother than the more dissected lower member, displays more relief than the lower member of the Modesto.

Qrl Lower Member – Red semiconsolidated gravel, sand, and silt. Comprises the higher of the two Riverbank terraces and remnants of dissected alluvial fans. This terrace is cut and backfilled into the Red Bluff and older alluvial deposits. Its surface is much more dissected than the upper member with several meters of local relief. Where eroded it also displays much stronger, almost maximal soil profiles with hues approaching a maximum of 2.5 YR. Like the upper member, the lower member is best preserved in the northwestern and southeastern parts of the valley; the most extensive exposures are in and around the city of Sacramento. Most of the alluvium of the lower member near Sacramento is very arkosic, and it was probably derived from the western slopes of the Sierra Nevada and deposited by the American River. The modern Sacramento River impinges on the alluvial fan comprising the lower member of the Riverbank and appears to be cannibalizing it.

### Valley Terraces

We reviewed the maps of Helley and Harwood (1985) and applied basic geomorphic reasoning to make the following observations regarding valley terraces and alluvial fans present in the Colusa Basin Watershed. Early Pleistocene streams dissected the Cretaceous bedrock or the Tertiary Tehama Formation to create increasingly deep and wide alluvial-filled valleys in the foothills. Due to influences of climatic variation, tectonism, and base-level change, later Pleistocene streams downcut in the early Pleistocene alluvium, leaving the older alluvium perched high above the new inset floodplains. This process was repeated several times: the Red Bluff was dissected and backfilled to create the lower Riverbank Formation; the lower Riverbank dissected and backfilled to create the upper Riverbank; the upper Riverbank dissected and backfilled to create the lower Modesto; the lower Modesto dissected and backfilled to create the upper Modesto; and the upper Modesto cut and filled to create the Holocene alluvium deposits, of which there may be an upper and lower unit.

An idealized cross-valley geologic section in the foothills of the Colusa Basin Watershed would show preserved remnants of each of the older alluvial units, each with the characteristic amounts of relief. Such an idealized foothill valley geologic section does not exist anywhere in the watershed: at any given location, the individual units were deposited to various thicknesses and only partially preserved, if at all, during the subsequent phase of dissection and backfilling. Lateral migration of Pleistocene streams would have removed part or all of individual units if and where they were present near the streams; the foothill valleys are generally too narrow to sustain the effects of erosion by lateral migrating streams. Although modern foothill valley streams appear to be migrating laterally only very slowly, where they impinge on Tehama Formation and various age Pleistocene alluvial terrace rocks they illustrate a process of downcutting and erosion that has taken place for more than a million years.

**Fanhead Terraces.** More completely preserved sequences of the Pleistocene alluvial deposits generally occur where the foothill valleys widen at their outlet and valley confinement gives way to broad Pleistocene alluvial fan deposits. A well preserved sequence exists at the Pleistocene fan apex of Cortina Creek, where a cross-section under the double overhead power lines traverses the upper and lower members of the Riverbank and Modesto Formations to the north of the creek. Dissection of the Pleistocene fan apexes created terraces at the head of the fan, and translated the active fan apex to a lower elevation on the fan surface some distance downstream from the foothill front. This process of "fanhead entrenchment" had the effect of reducing the frequency of overflow and sedimentation on the upper elevations of the alluvial fan.

**Alluvial Fans.** Lying downstream from the dissected Pleistocene alluvial rocks are the modern alluvial fans which form Bryan's characteristic smoothly-sloping "low plains" between the foothill front and the flat basin lands. As the early Pleistocene streams dissected the Cretaceous bedrock or the Tertiary Tehama Formation to create increasingly deep and wide alluvial-filled valleys in the foothills, they delivered sediment onto the smoothly sloped alluvial fan surfaces radiating from the fan apex; the location and elevation where the streams left confinement of the mountain front allowed the streams to freely migrate across the broad convex-shaped alluvial fan surfaces. The alluvial fans are thus underlain by the older and younger alluvial deposits, with the older deposits generally buried by the younger deposits, or preserved in places where overflow of the older deposits is prevented by the fan channels becoming incised.

The subsurface geologic structure of alluvial fans is complicated by the manner of sediment deposition on the fan surface: the main channel(s) emanating from the fan apex deposit(s) natural sediment levees on either side, producing low linear deposits of gravel and sand along the shallow channels. Overbank flows are common because of the generally heavy sediment loads and shallow channels and gradually reducing channel slopes moving down fan. Sand- and silt-laden overbank flows pour over the sand and gravel banks and deposit over broader areas on the fan surface. Natural levees of multiple active and abandoned channels interweave on the fan, and in places, have the effect of collecting silt-laden sheetflow, creating linear lenses of silty and clay deposits between levees.

**Alluvial Fan Dissection.** The zone of sediment deposition on the alluvial fan shifts over time so that one part of the fan may contain much of the older deposits and another much of the younger deposits. The presence or absence of older alluvium on the alluvial fan surface can be taken as an indication of how recently there has been active migration of fan channels across its surface, and thus as a means to date the onset of channel incision, where present. The Petroleum Creek alluvial fan surface, for example, is underlain almost entirely by lower Modesto alluvium, as its main channel has incised near the southern edge of the alluvial fan apex and along the southern boundary of the upper (proximal) fan surface, along the contact with the Little Buckeye Creek fan. Petroleum Creek probably begin incising about 30,000 years ago, a younger age for the lower Modesto fan surface.

The exposure of the lower Modesto in numerous places near Arbuckle may be the result of similar onset of channel incision of Elk Creek and Salt Creek on both the upper and lower (distal) fan surfaces. Also, fan surfaces of Buckeye Creek, Bird Creek, and Oat Creek are primarily underlain by upper and lower Modesto deposits indicating a general lack of Holocene aggradation. The majority of the fan surfaces of the smaller creeks dissecting the Dunnigan Hills to the south (e.g., Zamora Creek, Willow Spring Creek, Smith Creek) are covered with Holocene sediments, but some of this recent deposition may be due to the reservoir effect of the Colusa Basin, as their elevations are near or below the minimum elevation of the Cache Creek Slough channel ridge (Knights Landing Ridge).

In contrast, to the north, the alluvial fans of Sand Creek, Cortina Creek, and Spring Valley Creek have incised their channels in their Holocene surfaces, indicating more recent main channel incision. All 3 fan surfaces are well developed and generally smoothly sloping, with virtually their entire surface areas covered with Holocene alluvium and lesser exposures of the upper Modesto Formation (12,000-26,000 ybp). These fans show numerous abandoned channel ridges comprising deposits of Holocene alluvium, but their modern channels lack distinctive ridges, being incised to varying degrees within their recently active fan surfaces. According to 5-ft and 10-ft contour interval topography from 1949 air photos, the active channels of North Branch and South Branch Sand Creek lack distinctive channel ridges and are about 2-4 ft incised in the active fan surface. The Cortina Creek active channel also lacks channel ridges, being incised as much as 22 ft near the Holocene fan apex and generally about 5-7 ft downstream. The Spring Creek fan, being rather poorly developed and dominated by the better developed Cortina Creek fan, is entirely covered by Holocene basin deposits. The active channel of Spring Creek does not have distinct channel ridges, being incised as much as 20 ft into its upper Riverbank fanhead terraces and 10 ft within its Holocene fan apex downstream.

This pattern of generally well developed and preserved Pleistocene and Holocene alluvial fans and older to more recent fan channel incision observed in the southern part of the watershed contrasts with the weaker or absent alluvial fan development in the center part of the watershed, generally between Williams and Willows.

Five-ft contour interval topography from 1949 air photos shows that Freshwater Creek flowed within an approximately 8-ft-high channel ridge downstream to near the Glenn-Colusa Canal, its ridge height diminishing with distance downstream to about 4 ft until Freshwater Creek was channelized beginning about 1 mi upstream from the Interstate 5 freeway. According to the same data, Manor Slough and Glenn Valley Slough, with their relatively minor drainage areas, did not have channel ridges, instead exhibiting small but classically shaped alluvial fans with their channels cut about 5-ft-deep in the fan surfaces. To the north, Lurline Creek showed an absence of channel ridges and alluvial fan shaped deposits. Stone Corral Creek showed extensive older and younger alluvial deposits only in places resembling alluvial fan topography, dominated more by irregular meandering network of channel ridge deposits. Five-ft contour interval topographic maps made in 1904 show Stone Corral Creek having produced 10-ft-high channel ridges just downstream from the edge of the foothills, part of the stream that was channelized by the time modern topographic maps were produced, mostly based on the 1949 air photos.

Bryan (1923) observed:

> On the west side of the Sacramento Valley, from Willows southward to the Montezuma Hills (Pl. IV), there are many intermittent streams that issue from the foothills or red lands, loaded mainly with fine silt. These streams have built topographic features that differ markedly from those properly called fans. The channel of each stream is paralleled by raised banks that are essentially natural levees and that are built of sediment dropped by the water as it overflows in time of flood. These raised banks attain a height of 3 to 20 feet above the bottom of the channel, according to the size of the stream. The gentle outward slopes vary in width becoming narrower downstream and according to the size of the stream may attain a width ranging from 500 yards to 3 miles.
>
> It is the habit of these streams, however, not merely to build up their banks but also by deposition gradually to raise their beds, the tendency being to flatten the gradients. Bed and banks together thus gain in elevation until in the course of time they form a double-crested ridge that stands 10 to 25 feet above the lowland on each side. Owing to the gentleness of their outer slopes such ridges are not conspicuous topographic features; some of them, indeed, are so inconspicuous that the eye scarcely perceives them, and leveling by means of accurate instruments is necessary to indicate their presence. In time of flood, however, when the lowland on neither side is inundated, their double crests often remain emergent above the water for long distances and resemble sinuous causeways or dikes. A casual inspection of the map (Pl. XI) shows that most of the farmhouses in this region are located at or near the crests of channel ridges.
>
> Occasionally during floods the stream breaks one of its raised banks. A part or all of the water rushing through the gap and down the slope of the natural levee forms a new divergent channel, which in time is built up like the old one. The abandoned channel below the point of diversion then remains with its raised banks as a low, perhaps, partly disconnected double-crested ridge. Diversions of this kind may occur at several points along the course of the stream, and thus there arises a system or irregularly forking ridges.
>
> The ridges described are not inherently different from those produced on a larger scale by certain aggrading rivers such as the Mississippi and the Sacramento. They have, however, not been recognized as likely to occur as features of intermittent or small streams. Only slight attention has been given to them by physiographers, but features of this type in Sulphur Spring Valley, Ariz., have been described. It is tentatively proposed to call them “channel ridges...
>
> …A traveler going north or south through the western part of Sacramento Valley crosses a large number of these channel ridges. Some still contain the beds of intermittent streams; others are abandoned and permanently dry. They are especially numerous and well developed along the west side of the Yolo Basin. Indeed, the low plains of this region are so largely made up of branching and interlacing channel ridges that they form a distinct type of alluvial slope which may be called a channel-ridged plain.

The Cache Creek Slough channel ridge (Knights Landing Ridge) rises about 20 ft above the Colusa Basin floor to the north and the Yolo Basin to the south (**Figure 6-Geology**).

The older alluvium of the lower Riverbank begins to be widely exposed within the older fan and channel ridge deposits of Stone Corral Creek in the wider vicinity of Maxwell, where Stone Corral Creek was incised about 8 ft in lower Riverbank deposits according to 1949 air photo data.

These exposed, wide areas of the older lower Riverbank fan surfaces suggest that there may have been widespread fan dissection in this area beginning approximately 300,000 years ago, followed by a long-term aggradation phase as the downcut channel valleys backfilled with fine-grained sediments pouring out of the Cretaceous bedrock foothills as general base-level rose with the aggrading Sacramento River floodplain deposits in the Colusa Basin.

The area of poorly or irregular developed Holocene fans between Williams and Willows just discussed coincides perfectly with the area of Tehama Formation absence and adjacent deeply dissected Cretaceous bedrock discussed earlier. Tehama Formation absence is explained by it being more steeply dipped because of stronger curvature by severe warping of the bedrock underlying the Great Valley Province. The resulting narrower band of Tehama Formation would have been more quickly dissected, allowing for the Cretaceous bedrock presently forming the foothills to the west to be more deeply dissected as well. In this area, the Cretaceous bedrock is dissected down to the general elevation of the low plains bordering the valley, such that the average fanhead elevation of the foothill streams from Funks Creek to Freshwater Creek is about 200 ft. This contrasts with fans to the south, where the wider band of uplifted Tehama Formation is present. Spring Creek and Cortina Creek Holocene fanheads are only at about 200 ft elevation, but the Sand Creek fanhead rises to 240 ft, and fanheads to the south rise to more than 300 ft.

The pattern of Pleistocene fan apex elevations can be discerned from the elevation of preserved Riverbank fan terrace deposits with their surfaces preserving Pleistocene fan channels, where present. Spring Creek, Cortina Creek, and Sand Creek apexes once stood at elevations of 240 ft, 380 ft, and 400 ft, respectively. To the south, Petroleum Creek and Buckeye Creek fan apexes once stood at elevations near or above 500 ft. In contrast, there appears to be no geologic evidence of the foothill streams between Williams and Willows having had fan apexes substantially higher than 200 ft, at least not during the latter half of the Pleistocene. There are, however, patchy remnants of the late Pliocene or early Pleistocene Red Bluff Formation unconformably overlying the dissected Cretaceous bedrock and Tehama Formation in the northwest part of the watershed, some with elevations of about 400 ft. This pattern of deeply dissected fan apex elevations where the Tehama Formation is absent between Williams and Willows has been explained by the steeper dip of the Tehama Formation in the area caused by more severe warping. It seems also true that there is a north-south gradient in the altitude to which the Tehama Formation was uplifted that also helps explain its absence there.

Where a wider, higher uplifted band of Tehama Formation rocks is absent along the foothill front, it does not serve as an dissection "buffer" between the valley flat and the softer shale rocks of the Cretaceous bedrock. Where the Tehama Formation is absent, there is more rapid erosion of the weaker shale within the Cretaceous bedrock sequence, yielding more silt- and clay-sized sediment. High loads of fine-grained sediment, possibly also relatively devoid of sand and gravel, probably help explain the dominant mode of sediment deposition by migrating, meandering channels leaving prominent channel ridge deposits.

According to 10-ft contour interval topography from 1949 air photos, Funks Creek is incised about 8 ft within Holocene basin deposits about 2 mi upstream from the Glenn-Colusa Canal, and then within 1 mi from the canal forms a meandering channel ridge that rises to about 12 ft in height above the surrounding lower Riverbank alluvium (**Figure 7-Geology**). These meandering channel ridges are more similar to delta deposits than alluvial fan deposits, again suggesting that rising base-level of the Colusa Basin has affected late Pleistocene and recent alluvial deposition in the central and north-central part of the watershed.

Still farther to the north, near Hunters Creek and Logan Creek and within the broader vicinity of Willows, exposures of lower Riverbank Formation (approximately 300,000 to 450,000 yrs old) become even more common. This appears consistent with the above hypothesis, suggesting that the late Pleistocene streams may have incised into these Riverbank age fans, then aggraded more recently as base-level (Colusa Basin) rose with the Sacramento River bed.

## Colusa Basin

Bryan (1923) summarized the general physiography of the Colusa Basin as follows:

> Colusa Basin lies on the west side of the Sacramento River and extends from the southern part of the Stony Creek fan southward to Knights Landing (Pl. III). The basin is divided into two parts by a ridge constructed by a distributary of the river called Sycamore Slough.
>
> The upper part of Colusa Basin, north of this slough, is approximately 35 miles long and from 1 to 6 miles wide. Along the river it is rather sharply bounded by the slope of the natural levee, but on the west side it has many indentations due to the irregularities of the low plains. The small streams that have built up the low plains in this region have formed channel ridges of light loamy soil which extend out across the clay and adobe soils of the basin. Along this boundary line ground water escapes to the surface and evaporates producing alkaline conditions in the soil. On account of the alkali the western part of the Colusa Basin is marked by large areas of salt grass and low land covered with mounds. This part is known as the "goose lands" and in addition to being subject to occasional overflow is almost worthless for ordinary cultivation unless effective drainage works are constructed. Like other areas of heavy soil in the basins it is now largely used for growing rice.
>
> The lower part of the Colusa Basin has an upper portion called Mormon Basin between Sycamore Slough and a similar ridge known as Dry Slough. The waters of the two distributary channels have built up levees of fertile soil which are in marked contrast to the other parts of the basin. As they are slightly higher than the surrounding country, they are not often overflowed, and consequently they are the sites of prosperous farms. The widest portion of the Colusa Basin is south of Dry Slough. Here alkali is confined rather closely to the western border, between the flood basin and the low plains, but the central area is so subject to overflow that until completion of the reclamation works now being built it will have little value for agriculture. Colusa Basin is separated from the upper end of Yolo Basin by a ridge from one-fourth to 1 mile wide and about 20 feet high, called Knights Landing Ridge. This ridge has a medial groove known as Cache Creek Slough. The slough is evidently an ancient distributary of Cache Creek, and the ridge is a typical channel ridge.
>
> The Upper part of the Colusa Basin is filled by overflow from the river at numerous points where levees are weak and bay back water from overflow below Colusa. The lower part of the Colusa Basin is filled by overflow from the river, largely below Kirkville, and by the very considerable volume of water from the minor tributary streams. At times of very high water it overflows the Knights Landing Ridge, and the permanent reclamation of this basin can therefore be accomplished only by a canal cut through the ridge.

Note that Plate III is reproduced in this report as **Figure 8-Geology**. Also note that the Colusa Basin is within Bryan's river lands geologic-geomorphic province. Bryan's "island country" does not occur in the Colusa Basin Watershed, rather it lies along the lower part of the Sacramento-San Joaquin Delta and consists of (1923):

> . . . numerous tracts of land each of which is surrounded by branching channels of the river. The natural levees of these channels slope away from the channels toward the center of the islands. Thus each island has a saucer-shaped surface and under natural conditions is swampy near the center.

Bryan's description of the natural Sacramento-San Joaquin Delta geomorphology reveals some consistencies with that of the Colusa Basin, a floodplain complex with multiple basins enclosed by an interlaced network of aggrading distributary channel ridges.

Beginning near the mouth of Stony Creek, the Sacramento River natural levee is relatively coarser-grained (Qml) and higher and prevents Sacramento River flood flows from entering the Colusa Basin until it dissipates and dives under the younger lower natural levees beginning about 7 mi north of Colusa. Prior to the completion of early ad-hoc levee improvements culminating in the coordinated Sacramento River Flood Control Project, the Sacramento River routinely overflowed to the west through this low point and entered the Upper Colusa Basin, where it joined with other floodwaters from the southern part of the Stony Creek fan surface and from the foothill streams north of Arbuckle.

Sacramento River flood waters entered the lower Colusa Basin via natural distributary channels (sloughs) and other low or weak points in the natural levee (crevasses) downstream from the high point where the City of Colusa is established. About 7 mi downstream from Colusa, across the river from Meridian in Sutter County, Sacramento River floodwaters routinely passed into possibly the largest distributary slough channel, Sycamore Slough. As Bryan notes, the elevated loamy channel ridge deposits of Sycamore Slough physically separate the upper and lower Colusa Basins. Sycamore Slough ran southwest to near the current alignment of the Colusa Basin Drain, probably impinging on distal facies of the coalescing fans of Sand Creek, Salt Creek, and Elk Creek due north of College City, creating a narrows for floodwaters to drain from the upper basin to the lower basin. Hydrologically disconnected remnants of the original channel remain along its former alignment. Sycamore Slough passed through the lower Colusa Basin, again probably impinging periodically on the distal alluvial fan deposits of Petroleum Creek, Buckeye Creek, and the Dunnigan Hills streams near Zamora before discharging to the Sacramento River immediately upstream from the Knights Landing Ridge. Free gravity drainage was prevented by the junction of the Sacramento River natural levee and the Knights Landing Ridge, both rising about 20 ft above the adjacent flat basin lands (**Figure 6-Geology**). Therefore, under pre-development conditions, drainage from the downstream end of Sycamore Slough to the Sacramento River was governed by spillover then seepage through these 20-ft-high natural levees.

It is generally not known whether or not Sycamore Slough was a continuous channel from near Meridian to Knights Landing. However, relatively detailed 1925 topographic maps suggest that Sycamore Slough was nearly a continuous channel except for an approximately 1-mi-long section within the 15-ft contour elevation about 8.5 mi upstream from Knights Landing (**Figure 9-Geology).** One interpretation of a circa 1840s land grant map of the Lands of Jimeno near Colusa also suggests that Sycamore Slough terminated in a densely vegetated wider basin area in at least one location, probably so densely vegetated with 15-ft-high tules as to be unnavigable (**Figure 10-Geology**). Other workers have suggested that Dry Slough may be the channel that the land grant maps shows terminating in dense vegetation. Sycamore Slough was mapped in detail in 1925, suggesting that its navigability was probably improved by vegetation removal or burning.

Sacramento River flood flows also routinely entered the lower Colusa Basin via numerous other distributary slough channels, including Dry Creek Slough and Corbiere Slough, which also originated near Meridian and deposited loamy channel ridge deposits parallel to and about 4-5 mi east of Sycamore Slough in the upstream end of the lower Colusa Basin. Byers Slough, Tule Slough, and Wilkins Slough, among others, also transported sandy alluvium into the lower basin (**Figure 9-Geology**). Slough channels typically flowed southwesterly such that their elevated channel ridge deposits in places coalesced with Sycamore Slough deposits and in this way created smaller basins within the larger Colusa Basin. Mormon Basin and Munson Basin are 2 such smaller sub-basins created upstream from where Dry Creek Slough deposits and Byers Slough deposits coalesced with those of Sycamore Slough. These sub-basins would have been fed with silt- and clay-laden overflow from the slough channels, thereby resulting in the basin deposits, which are as much as 200 ft thick in the center part of the basin.

Other sources of flood waters to the lower Colusa Basin include general overtopping of the Sacramento River natural levee, contributions of foothill streams south of Arbuckle, and down valley drainage of upper basin floodwaters.

Helley and Harwood (1985) mapped all of the natural levee deposits of the Sacramento River and its distributary slough channels downstream from Colusa as young alluvium (Holocene) (Qa). They gave the following geologic descriptions of basin soils present in the Colusa Basin:

Qb basin deposits, undivided (Holocene) – Fine-grained silt and clay derived from the same sources as modern alluvium. The dark-gray to black deposits are the distal facies of Unit Qa. The undivided basin deposits provide rich and valuable farmland especially for rice production in the Sacramento Valley. This unit covers much of the valley in the southern half of map area. Thickness varies from 1 to 2 m along the valley perimeter to as much as 60 m in the center of the valley.

Qm marsh deposits (Holocene) – Fine-grained, very organic rich marsh deposits; differentiated from the undivided basin deposits (Qb) by generally being under water.

It can be surmised that the fine-grained Sacramento River floodplain deposits (Qa) and basin deposits (Qb) interfinger with the distal alluvial fan deposits of the foothill streams where present (e.g., see **Figure 2-Geology).** In places, basin deposits (Qb) have clearly buried parts of the distal fan surfaces, and vice-versa.

Helley and Harwood (1985) also mapped basin deposits (Qb) at elevations as high as 220 ft or more making contact with proximal fan surfaces in the southern part of the watershed and with dissected Cretaceous bedrock in the much-discussed region of absent of well-developed alluvial fans and Tehama Formation rocks between Williams and Willows. These are not deposits of the Colusa Basin, which are characteristically deep where they interfinger with relatively coarse foothill alluvium, but instead are shallow 3-6 ft thick deposits of fine-grained sediment from foothill streams. Therefore, the boundary of basin deposits does not correspond to the boundary of the valley flat or the Colusa Basin. Topographic maps and soil unit maps can be used to better identify the boundary, the latter distinguishing between the frequently flooded basin soils from the less frequently flooded basin soils lying along the basin rim.

Sacramento River floodplain deposits (Qa) from Sycamore Slough have also buried basin deposits (Qb) in places (Jack Alderson, Colusa County NRCS Agricultural Engineer, pers. comm., July 2008). For example, auger holes and larger excavations show this occurred in several places along the upper reaches of Sycamore Slough from 500 to 2500 ft from the old channel. The Qa deposits are silt loams, fine sandy loams, and even fine sand lying over silty clay Qb deposits at depths from 3 ft to 9 ft. The 1948 soil survey described and mapped the soils adjacent to the slough beautifully. They were mapped as the Sycamore series. Variants were Sycamore loam, very shallow, over Marvin clay; Sycamore fine sand, shallow, over Mormon clay; Sycamore loam, moderately deep, over Marvin clay.

## CASE STUDY: NORTH BRANCH SAND CREEK

Geologic sections were taken of North Branch Sand Creek at representative foothill valley, Pleistocene and Holocene fan apex, and distal fan surface locations, using topographic data from 1:24,000 scale 20-ft and 5-ft contour interval USGS topographic maps made from 1949 air photos and 1:62,500 scale surficial geology maps of Helley and Harwood (1985). A geologic profile was also made from these sources taken on a line through the centerline of the creek from the lower foothill valley area to its channelized termination at the Colusa Basin Drain. The longitudinal section was extended across the Colusa Basin to the Sacramento River along an arbitrarily chosen latitude (39° 5 min) near the historical outlet of the creek. This section latitude is the same as the generalized geologic section taken by DWR (1962) near Grimes shown in **Figure 2-Geology**.

The upper watershed of North Branch Sand Creek is entirely underlain by Tertiary alluvial deposits of the Tehama Formation, rising to a maximum elevation of 1709 ft near the Colusa-Yolo County line where its drainage divide is common with that of the Colusa Basin Watershed. Above an elevation of approximately 720 ft, the steep upper tributary streams are dissected entirely in Tehama Formation deposits. Below approximately 720 ft, the East Fork and mainstem streams cut into alluvial terraces of the late Pliocene or early Pleistocene Red Bluff Formation. East Fork North Branch Sand Creek is incised in the Red Bluff terrace. Mainstem North Branch Sand Creek has dissected the Red Bluff valley fill and deposited alluvium of the upper Riverbank Formation; Sand Creek Road winds back and forth on this surface fording the channel in places. Downstream from the confluence of the mainstem and East Fork, near elevation 600 ft, North Branch Sand Creek flows to the east-northeast over Holocene sand, gravel, and cobble stream channel deposits (Qsc) which in places contact both valley walls where they are as much as 1000 ft wide containing sand, gravel, and cobbles. Here the channel is meandering and locally braided and impinges on Tehama Formation deposits of the valley wall at outside meander bends. Terraces of the upper Riverbank give way downstream to terraces of the lower Modesto, which are relatively near in elevation to the stream, generally within 1.1 yds of modern point bar floodplain deposits and possibly overtopped in places by infrequent floods. **Figure 11-Geology** shows that the channel is wide and shallow upstream from Sand Creek Road crossing and meets grade with the crossing pavement. The channel bed drops abruptly about 15 vertical ft on the downstream side of the crossing which has been recently reinforced with grouted rip-rap; subsequent downcutting is currently undermining the toe of the grout apron. **Figure 12-Geology** shows the channel downstream from Sand Creek Road, where it appears to be about 15 ft incised in the lower Modesto terrace deposits forming the right bank. Gravel bars are well-preserved on the lower Modesto terrace surface here. The location of the Sand Creek Road crossing is shown at left in the longitudinal bed elevation profile of the downstream remainder of North Branch Sand Creek (**Figure 13-Geology**). In parts of that down-cut section, the channel flows on grooved clays with minimal gravel deposits. Grooved clays with minimal gravel deposits also occur in a topographically similar reach of Salt Creek (Jack Alderson, Colusa County NRCS Agricultural Engineer, pers. comm.., July 2008).

A cross-valley geologic section taken at the outside meander bend approximately 1000 ft downstream from Sand Creek Road crossing shows that the portion of lower Modesto terrace deposit nearer the stream channel has dissected 20 vertical ft, such that it is about 12 ft above the 1949 stream bed at the section (**Figure 14-Geology**). Because the headcut is 15 ft deep at the road crossing and appears similarly incised downstream at and near the cross-section, it follows that there has probably been 3 additional ft of downcutting at this section since 1949.

The 1904 USGS topographic map of the vicinity indicates that the thalweg bed elevation was then 458 ft above sea level (457 ft, National Geodetic Vertical Datum [NGVD]29) and the top of bank elevation was 460 ft above sea level (459 ft NGVD29). The 1904 top of bank elevation matches the 1949 top of bank elevation. It is plausible that the bed elevation was only 3 ft lower than the top of bank elevation at this location because that is the same amount of dissection in the lower Modesto surfaces upstream from the road crossing today. Therefore, it appears that the bed downcut at this cross-section from 457 ft in 1904, to 447 ft in 1954, continuing to 444 ft in 2007. This also seems partly verified by the 1904 topographic map which shows a former alignment of Sand Creek Road fording back and forth across North Branch Sand Creek downstream from the section.

**Figure 15-Geology** shows a geologic section taken across the semiconsolidated lower Riverbank Formation (Qrl) alluvial fan apex, indicating that the lower Riverbank deposits have been dissected by about 60 vertical ft in the past approximately 300,000 years. Most of the lower Riverbank terrace has been dissected on the south side of the fan apex, preserving much of the northerly unit, such that the approximately 300,000 year old abandoned fan channels on its surface are plainly visible in circa 1993-1999 1:24,000 air photos and in the 20-ft contour interval topographic data (**Figure 18-Geology**).

Remnants of the younger upper Riverbank (Qru) deposits are also preserved along the southern side of the cross-section, with Holocene dissection centered mid-section. Small remnants of the lower Modesto (Qml) unit are preserved here, rising only a few ft above the stream channel deposits (Qsc).

**Figure 16-Geology** shows a geologic section taken across the apparent Holocene alluvial fan apex of North Branch Sand Creek. North Branch Sand Creek is only shallowly incised in the upper Modesto (Qmu) and Holocene (Qa) alluvium forming the fan surface here and exhibits a anastomosing or distributary channel form (**Figure 18-Geology**). Fine-grained basin deposits (Qb) lie to the north of the channel where they are confined in the overbank area between the channel and the ridge of upper Modesto alluvium. Fine-grained basin deposits (Qb) lie over a wide area to the north of the Modesto ridge. South Branch Sand Creek to the south has a smaller drainage area. Its channel is somewhat more deeply cut in the lower Modesto (Qml) alluvium and there are limited Holocene alluvial deposits of the South Branch flanking the channel here; they begin at and below the Holocene fan apex of the South Branch about ¼ mile farther down fan.

**Figure 17-Geology** shows a geologic section taken across the fan near the downstream end of the distal fan channel section of North Branch Sand Creek. Here North Branch Sand Creek is still shallowly incised in the upper Modesto (Qmu) Formation which is only partly covered by younger alluvium (Qa and Qb). There are numerous abandoned channels of North Branch and South Branch Sand Creek in this vicinity (**Figure 19-Geology**).

**Figure 13-Geology** shows the elevation profile and geologic section taken across the Colusa Basin near where North Branch Sand Creek discharges onto the valley flat. **Figure 20-Geology** shows details from the topographic, geology, and soils maps of this vicinity.

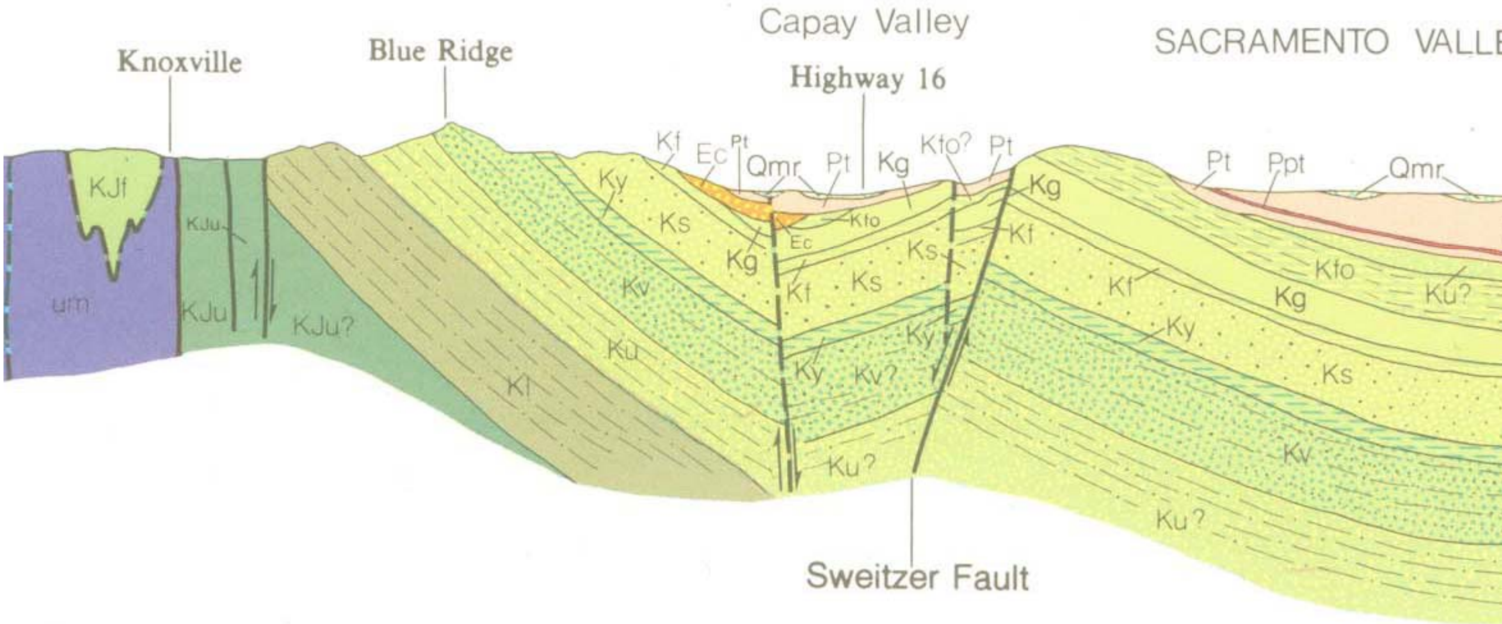



Figure 1-Geology. Eastern portion of the geological section through th
1:250,000 scale geologic map showing the geologic structure underlyi
Basin Watershed. Please see corresponding legend in Figure 4c-Geolo

**Figure 2-Geology. General Geologic Section through the Colusa Basin Wat
Grimes (adapted from DWR 1962).**

Figure 3-Geology. Oblique aerial photo of the dissected Coast Range Foothills in the central portion of the Colusa Basin Watershed. Glenn Valley Slough is in the foreground (adapted from DWR 1962).

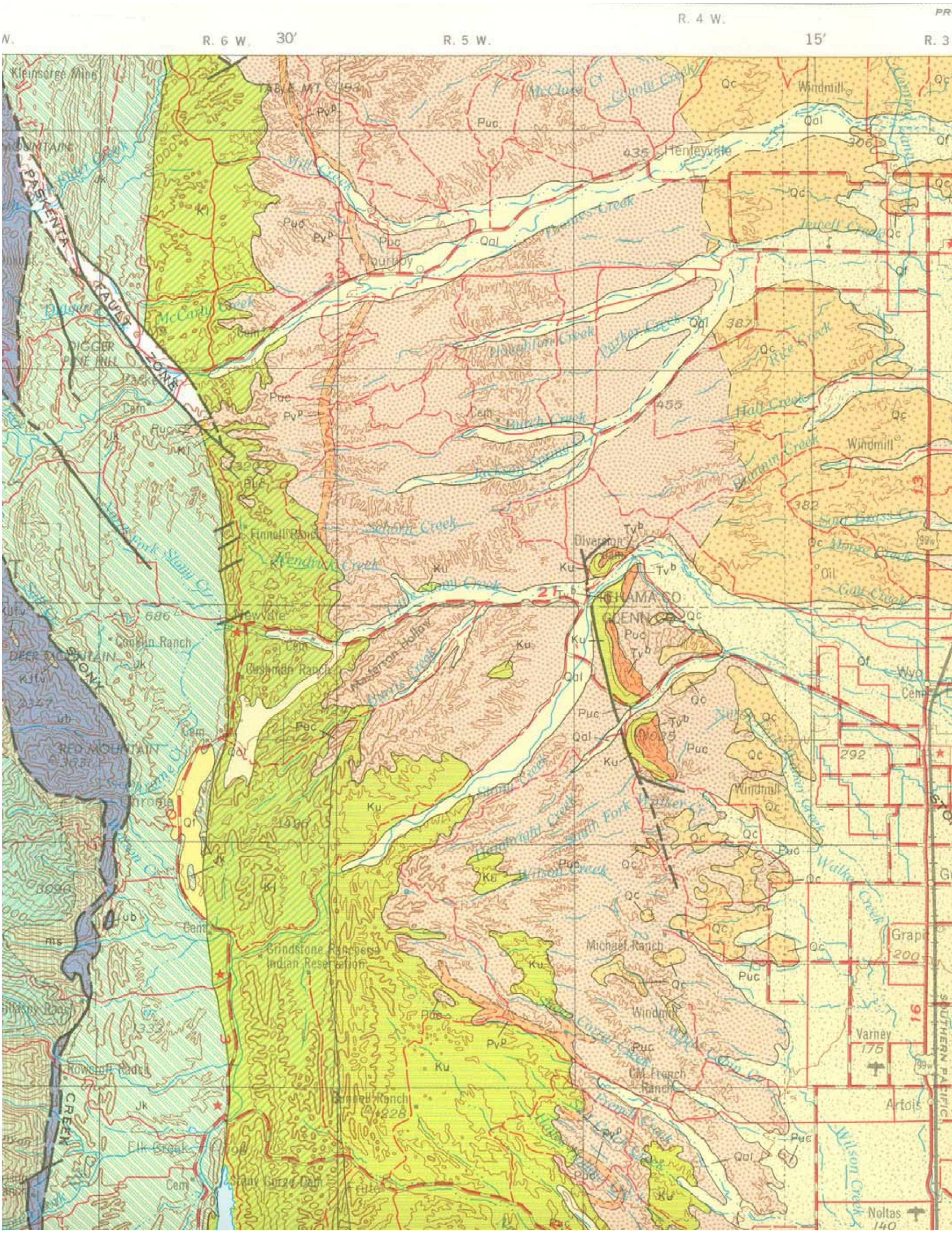



**Figure 4a.1-Geology. Excerpts of the 1:250,000 geologic maps cover**
**1960)**

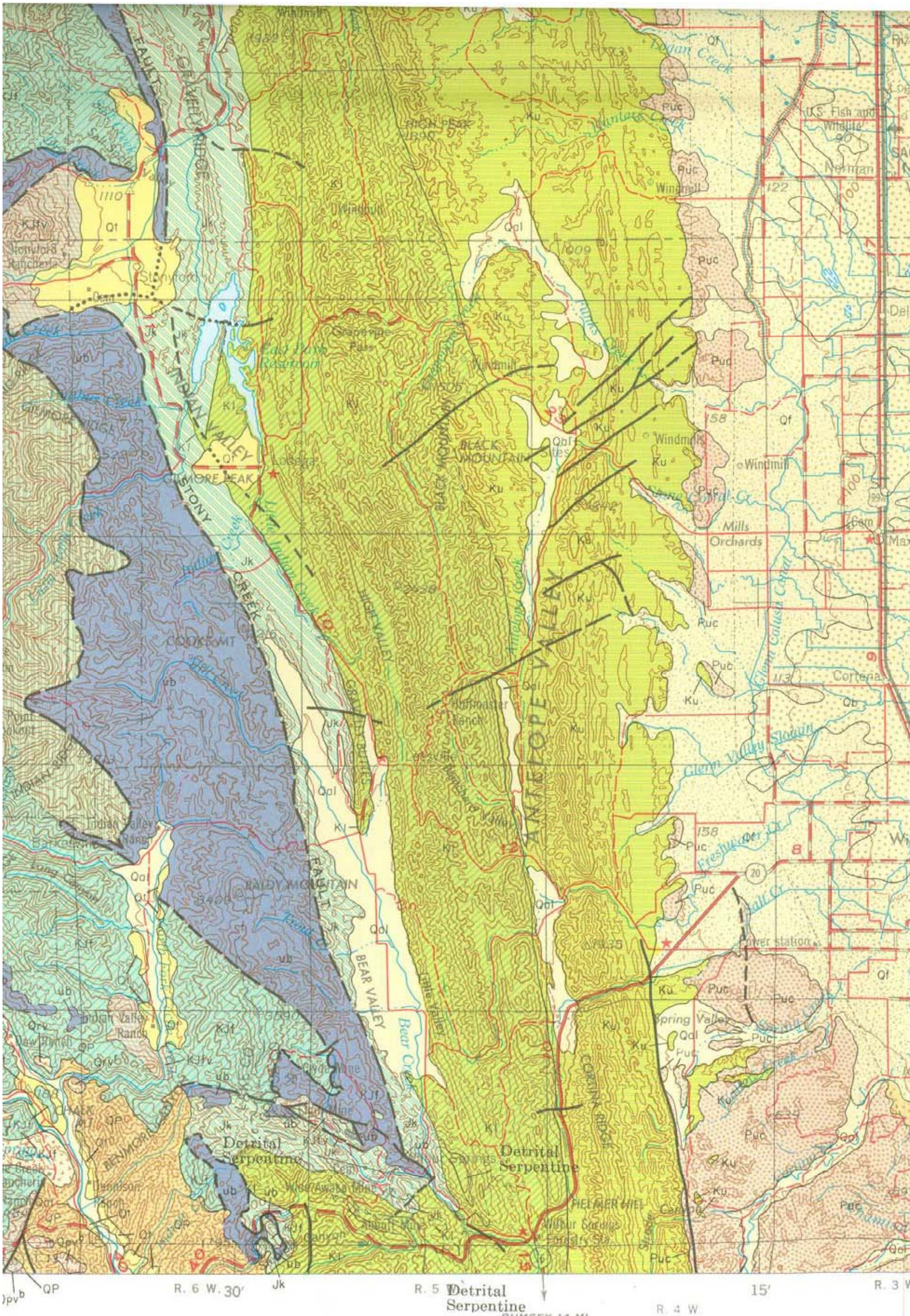
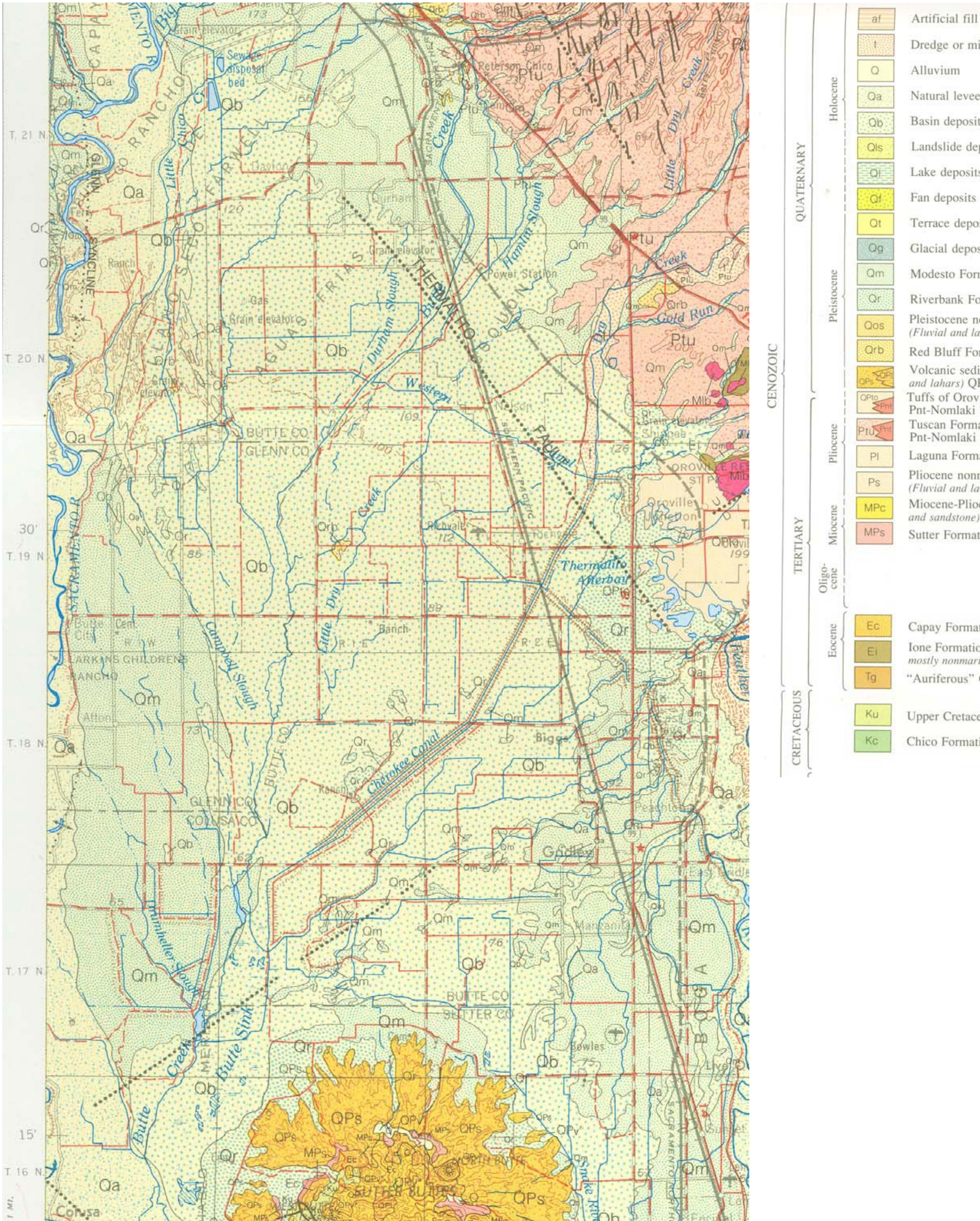



**Figure 4a.2-Geology. Excerpts of the 1:250,000 geologic maps co**
**1960)**



QUATERNARY
Holocene
Pleistocene
CENOZOIC
TERTIARY
Pliocene
Miocene
Oligo-cene
Eocene
CRETACEOUS
af Artificial fill
t Dredge or mi
Q Alluvium
Qa Natural levee
Qb Basin deposit
Qls Landslide dep
Ql Lake deposits
Qf Fan deposits
Qt Terrace depo
Qg Glacial depos
Qm Modesto For
Qr Riverbank Fo
Qos Pleistocene n
(Fluvial and la
Qrb Red Bluff For
QPs Volcanic sedi
and lahars) Q
QPto Tuffs of Orov
Pnt-Nomlaki
Ptu Tuscan Forma
Pnt-Nomlaki
Pl Laguna Form
Ps Pliocene non
(Fluvial and la
MPc Miocene-Plio
and sandstone)
MPs Sutter Format
Ec Capay Forma
Ei Ione Formatio
mostly nonmar
Tg "Auriferous"
Ku Upper Cretace
Kc Chico Format
T. 21 N.
T. 20 N.
30'
T. 19 N.
T. 18 N.
T. 17 N.
15'
T. 16 N.
SACRAMENTO
THERMALITO
FAULT
BUTTE CO
GLENN CO
COLUSA CO
SUTTER CO
Butte Sink
Cherokee Canal
Campbell Slough
Durham Slough
Little Chico Cr
Little Dry Creek
Hamlin Slough
Western Canal
Thermalito Afterbay
Butte Creek
Gold Run
Biggs
Gridley
Durham
Richvale
Oroville
Colusa
SUTTER BUTTES
NORTH BUTTE
Peterson Chico
Power Station
Grain elevator
Sewage disposal bed
R. 1 E.
R. 2 E.
SOUTHERN PACIFIC

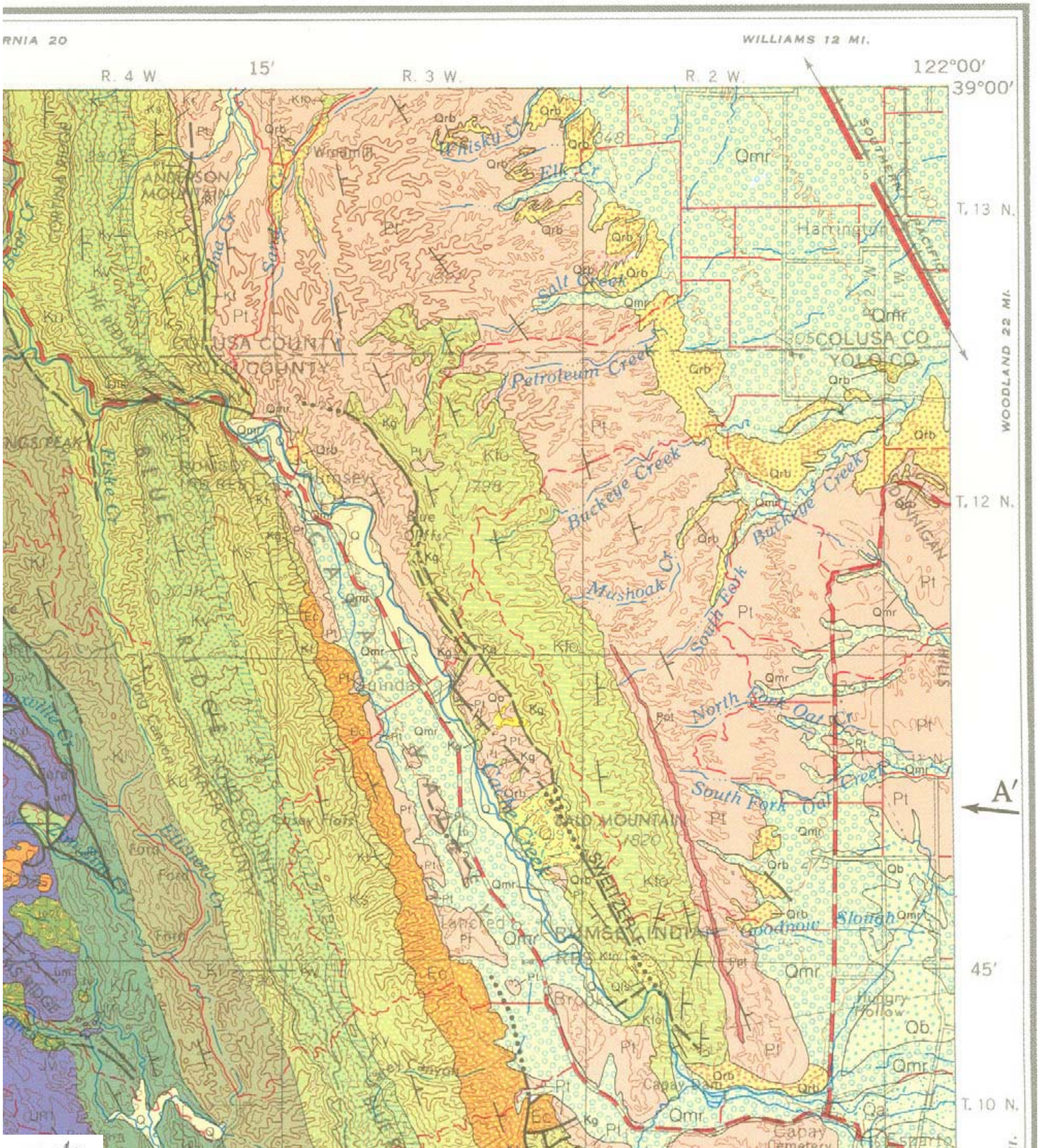
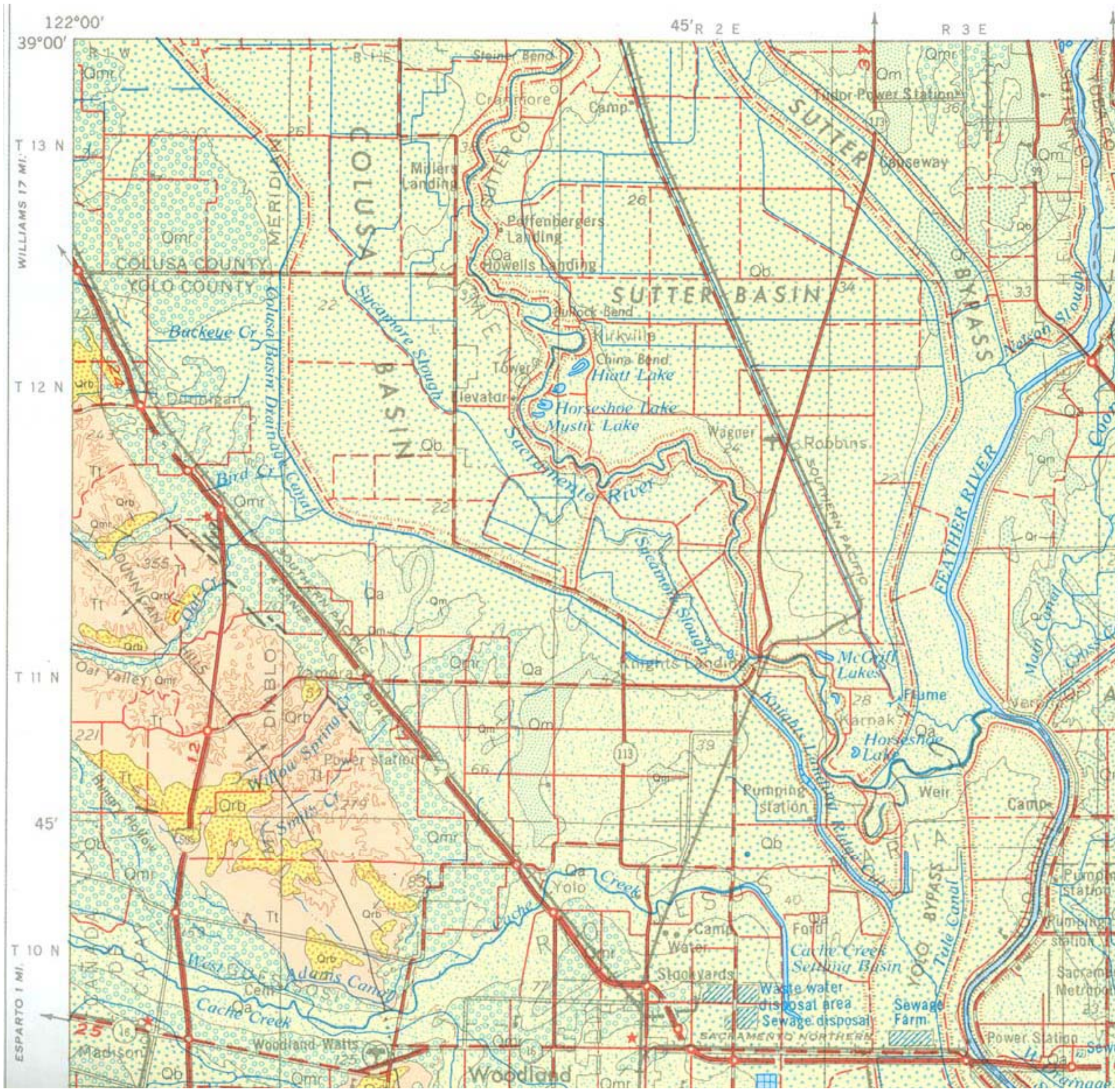
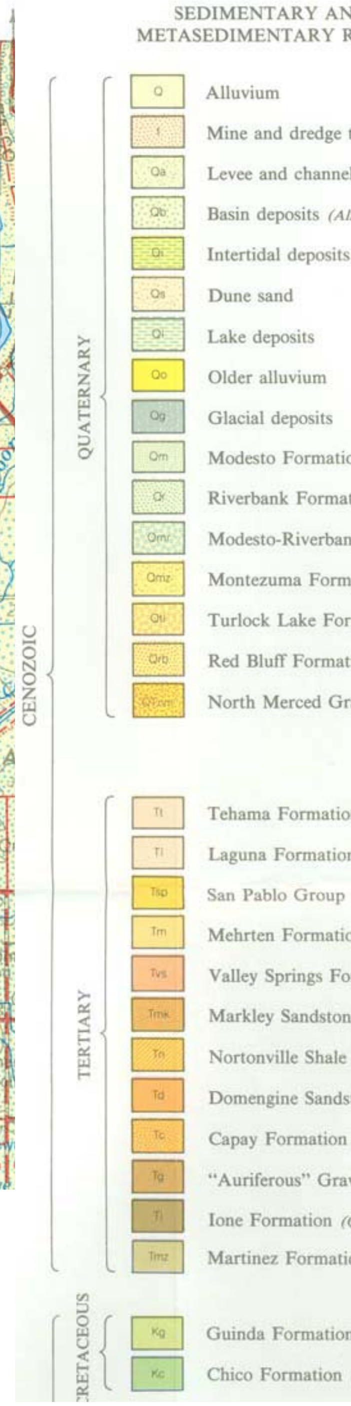


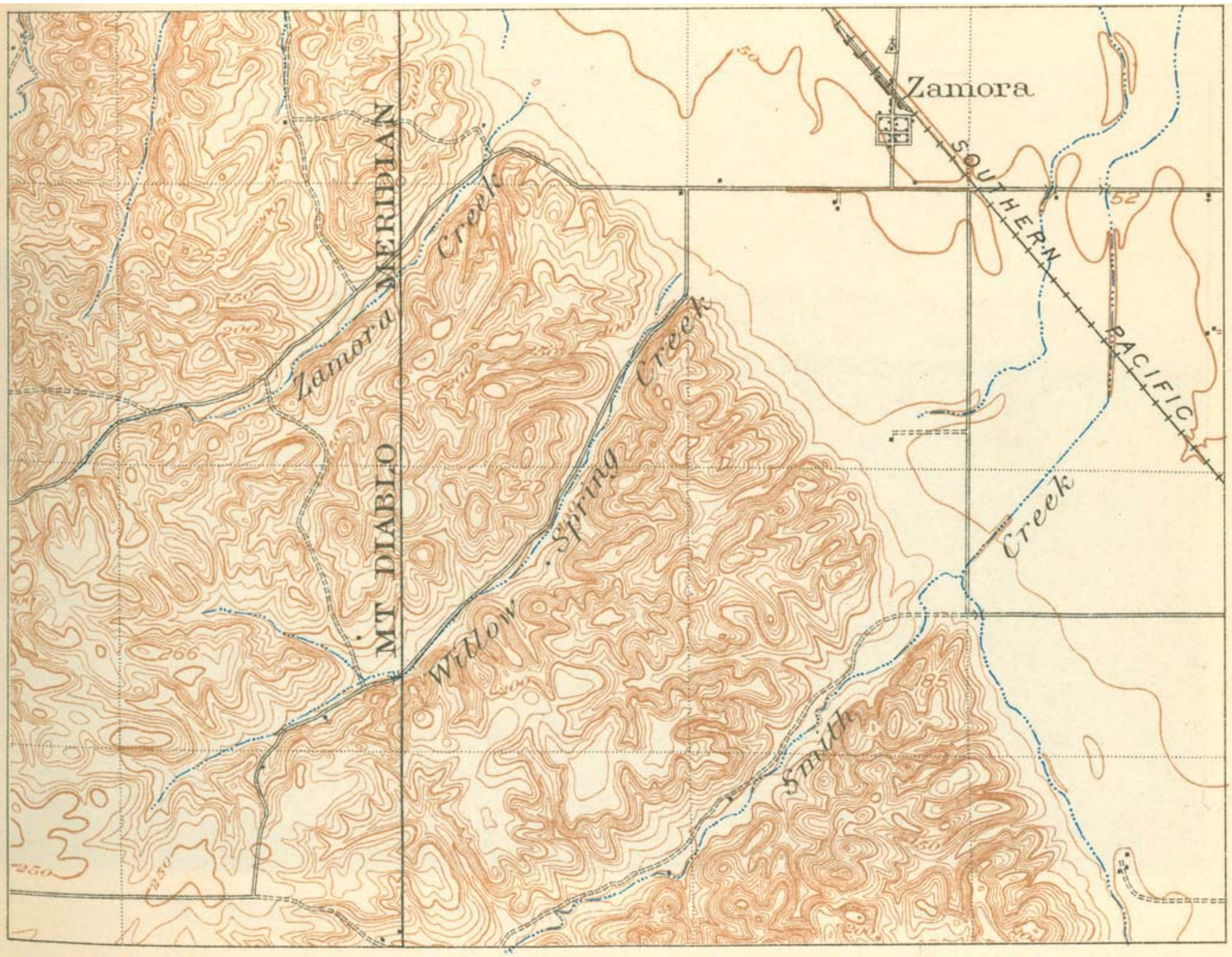

**Figure 4c-Geology. Excerpts of the 1:250,000 geologic maps covering portions of the Colusa Basin Watershed.**






geomorph

**Figure 4d-Geology. Excerpts of the 1:250,000 geologic maps covering portions of the Colusa Basin Watershed. (Source: Wagner and Bortugno, 1982)**




*B.* **MAP OF VICINITY OF ZAMORA, CALIF.**

**Showing escarpment of Hungry Hollow Hills, position of streams cutting the escarpment, dissection of the plateau, and channel-ridged plain at foot of hills.**

0 ½ 1 2 Miles

Contour interval 10 feet.

ENGRAVED AND PRINTED BY THE U.S. GEOLOGICAL SURVEY

**Figure 5-Geology. 1907 topographic map of Zamora, California area showing escarpment of the Hungry Hollow Hills, position of streams cutting the escarpment, dissection of the plateau, and channel-ridged plain at the foot of the hills (adapted from Bryan 1923).**

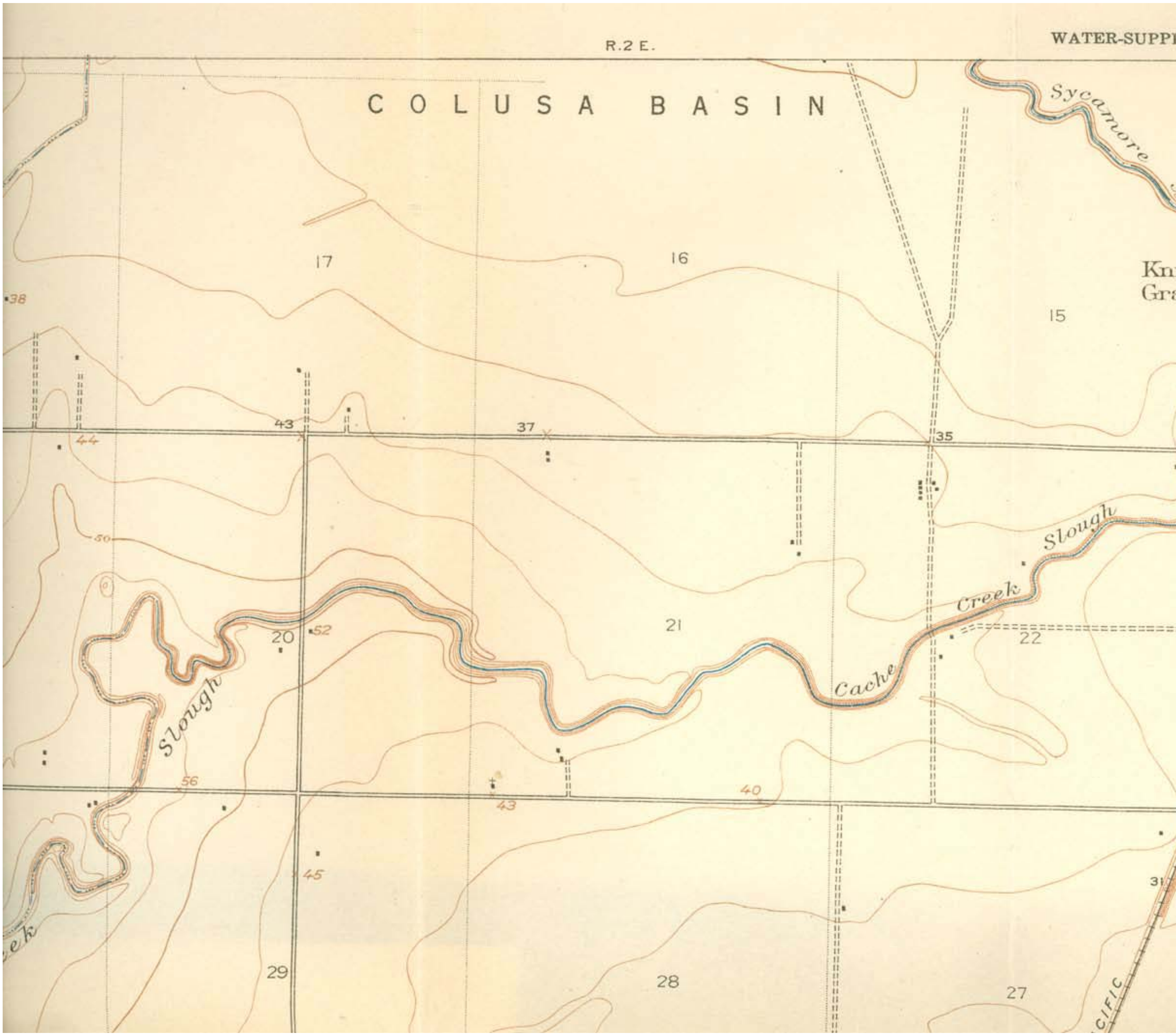



**Figure 6-Geology. Map showing the channel ridge of Cache Creek Slough (Kn Ridge) and the division between the Colusa and Yolo Basins (adapted from**

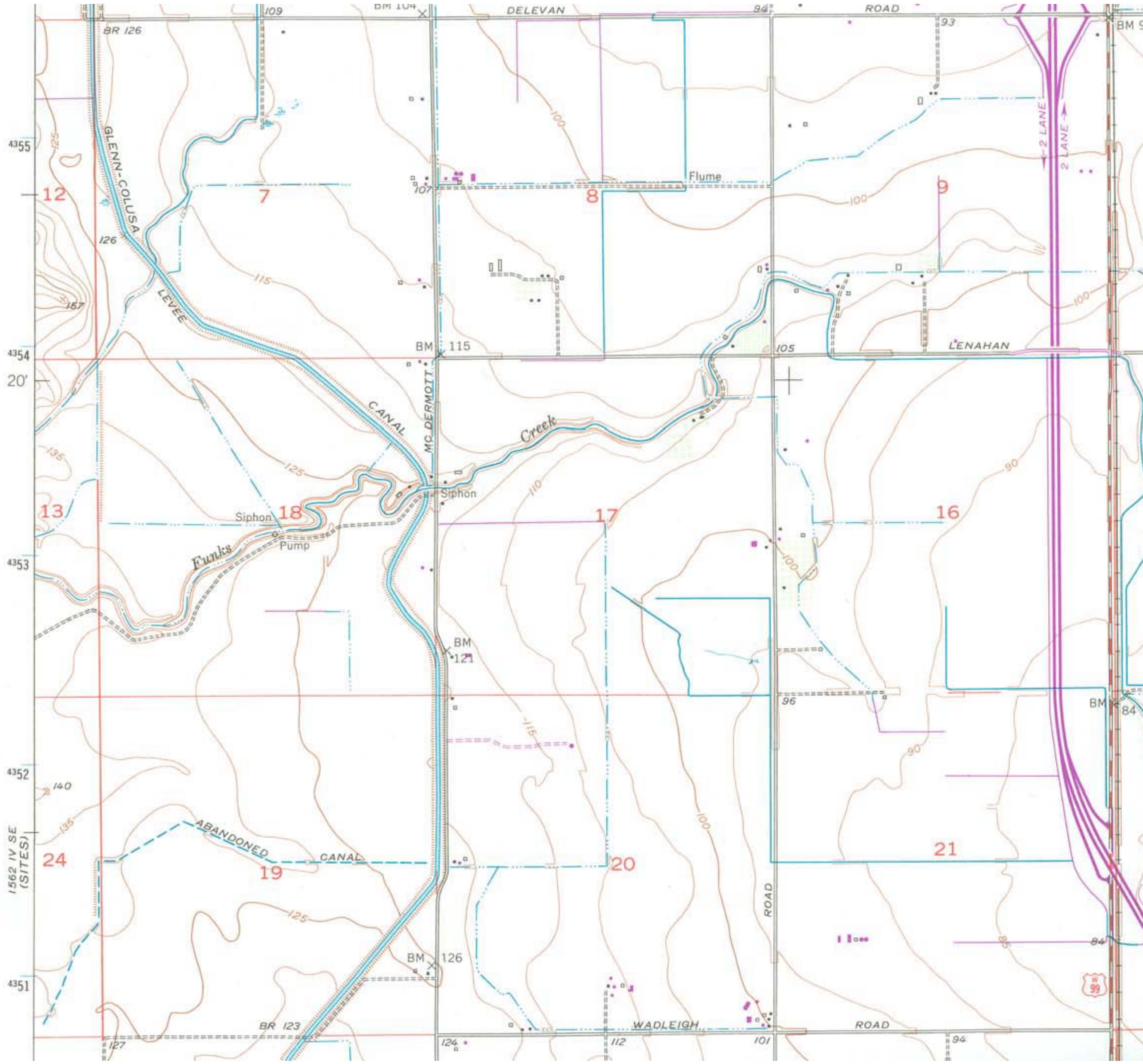
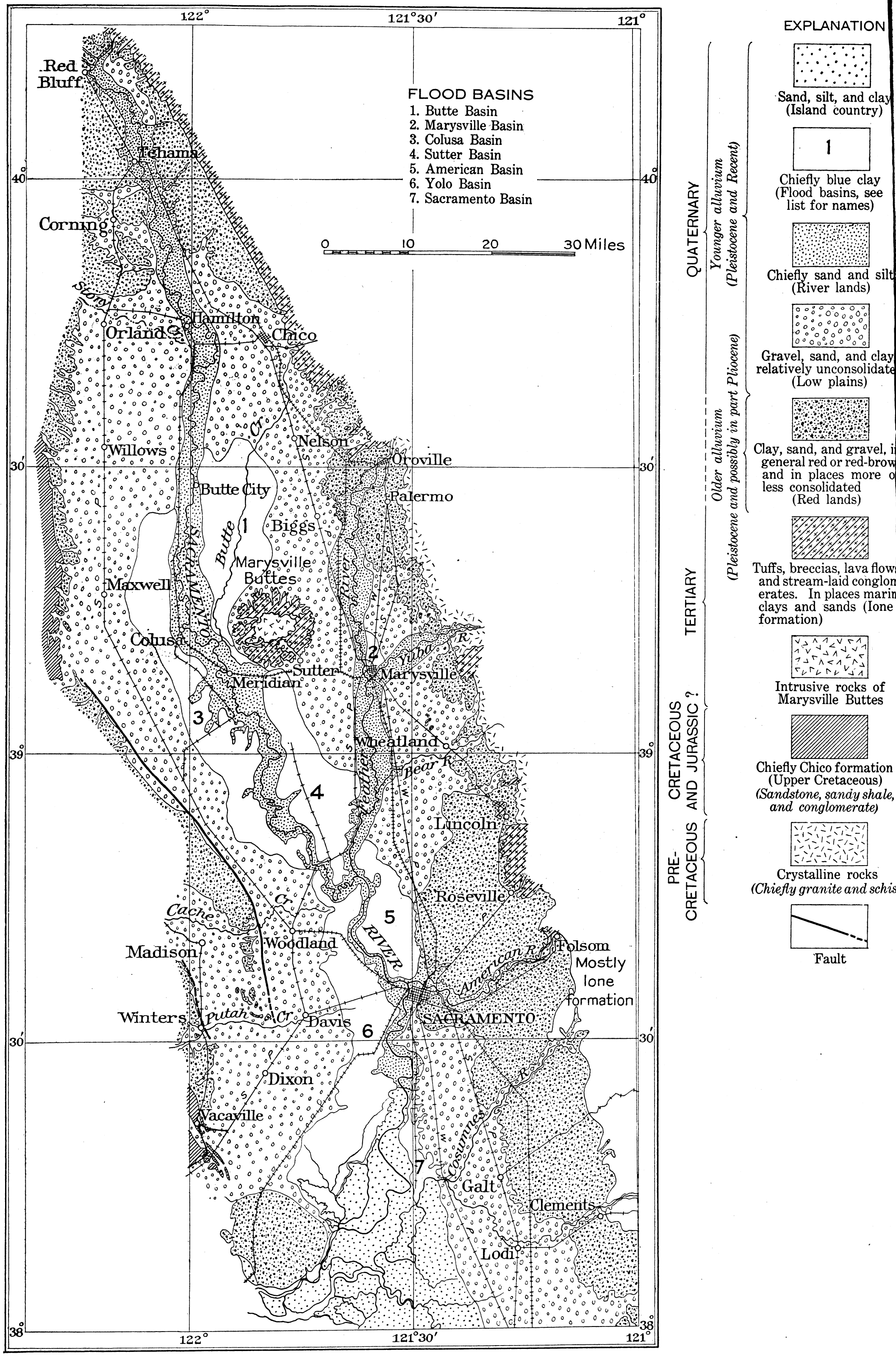



**Figure 7-Geology. Five-foot contour interval 1949 topographic map showin**
**12-ft-high channel ridge of Funks Creek. The channel ridge deposit overlie**
**alluvial deposits of the lower Riverbank Formation.**




MAP OF SACRAMENTO VALLEY, SHOWING GEOLOGY, PHYSIOGRAPHY, AND LOCATION OF FLOOD BASINS.

**Figure 8-Geology. Map of Sacramento River showing geologic and physiographic context of the Colusa Basin Watershed (adapted from Bryan 1923).**


Figure 9a-Geology. Detail of upper part of Lower Colusa Basin reprod


Figure 9b-Geology. Detail of lower part of Lower Colusa Basin reproduced from 1925 to


Figure 10-Geology. Detail reproduced from the ca. 1840s Land Grant Map for L

Figure 11-Geology. Photo looking approx. southwesterly upstream to Sand Cre
Road Crossing. The channel is only a few feet incised in Holocene terrace depo
2007.

Figure 12-Geology. Photo looking approx. north-northeasterly downstream to
Sand Creek Road Crossing. Bed is incised approx. 15 ft into Holocene terrace c
6, 2007.

**Figure 13-Geology. North Branch**
**Longitudinal Bed Elevation Profile and Ground**
(source: 20- and 5-ft contour interval 7

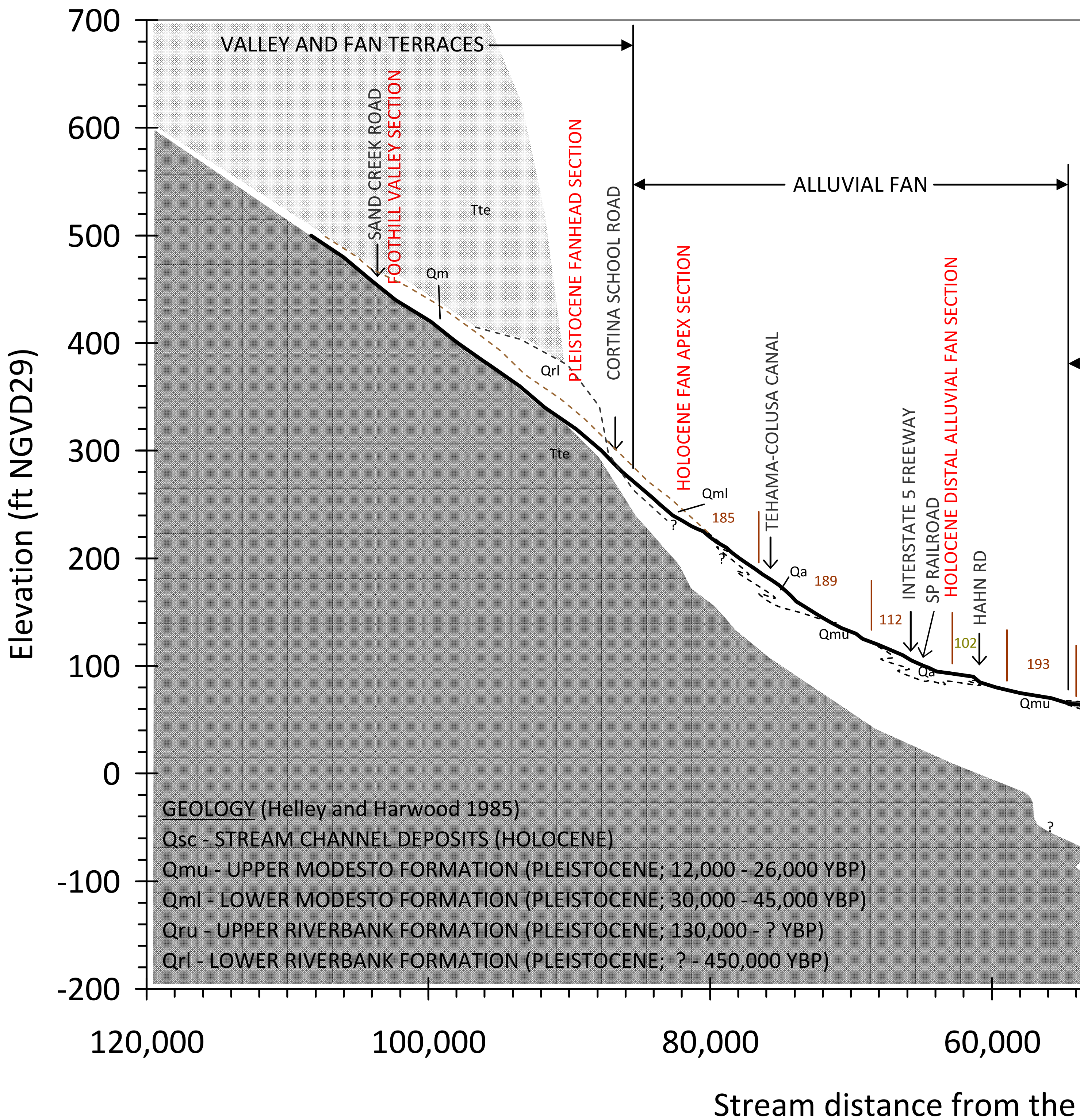


**Figure 14-Geology. North Branch Sand Creek**
**Foothill Valley Cross-Section**
approximately 1,000 ft downstream from Sand Creek Road Crossing
(source: 20-ft contour interval USGS quadrangle, 1949 air photo revision)

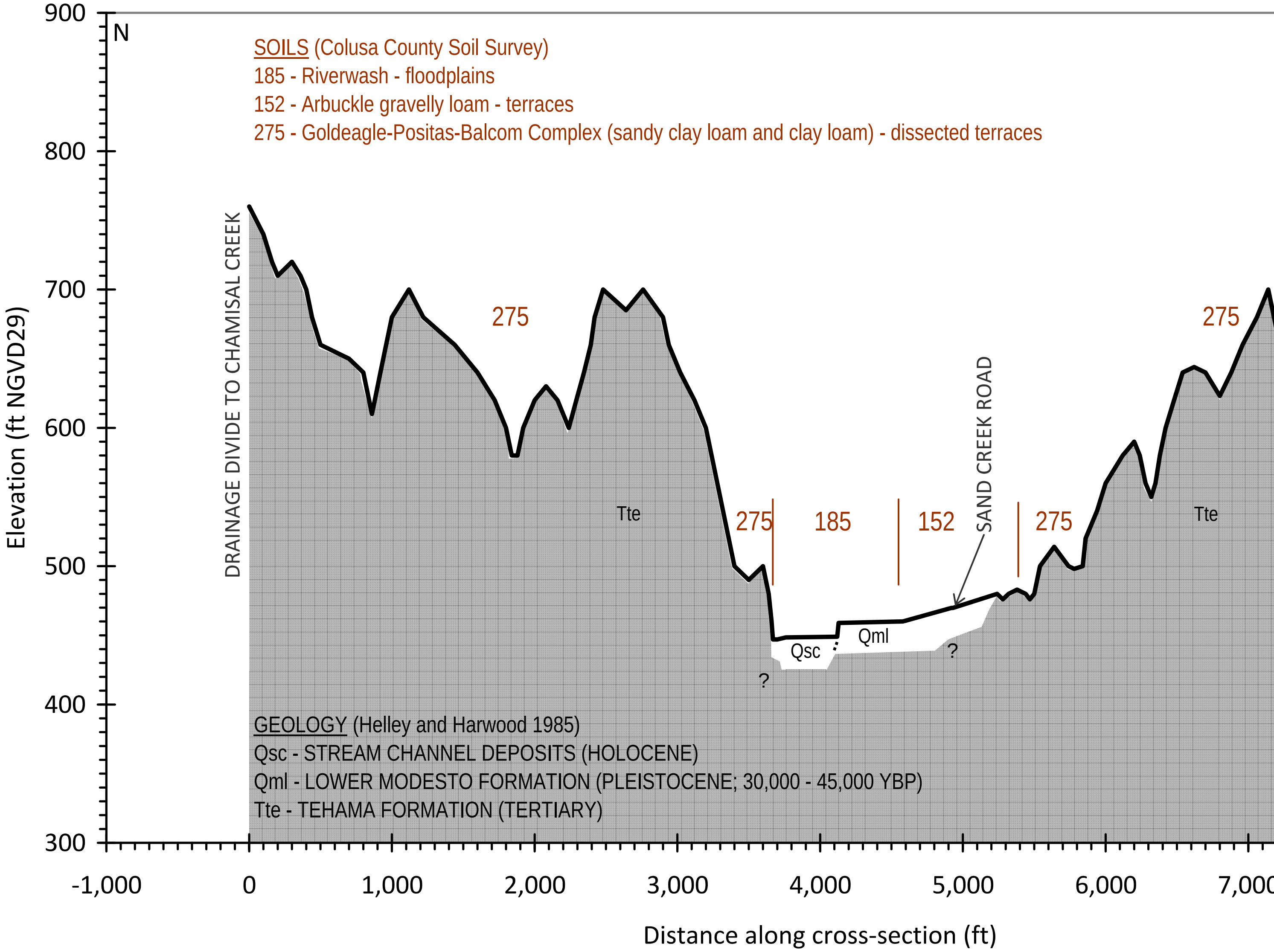


**Figure 15-Geology. North Branch Sand Creek**
**Pleistocene Alluvial Fanhead Cross-Section**

approximately 2,800 ft upstream from Cortina School Road Crossing
(source: 20-ft contour interval USGS quadrangle, 1949 air photo revision)

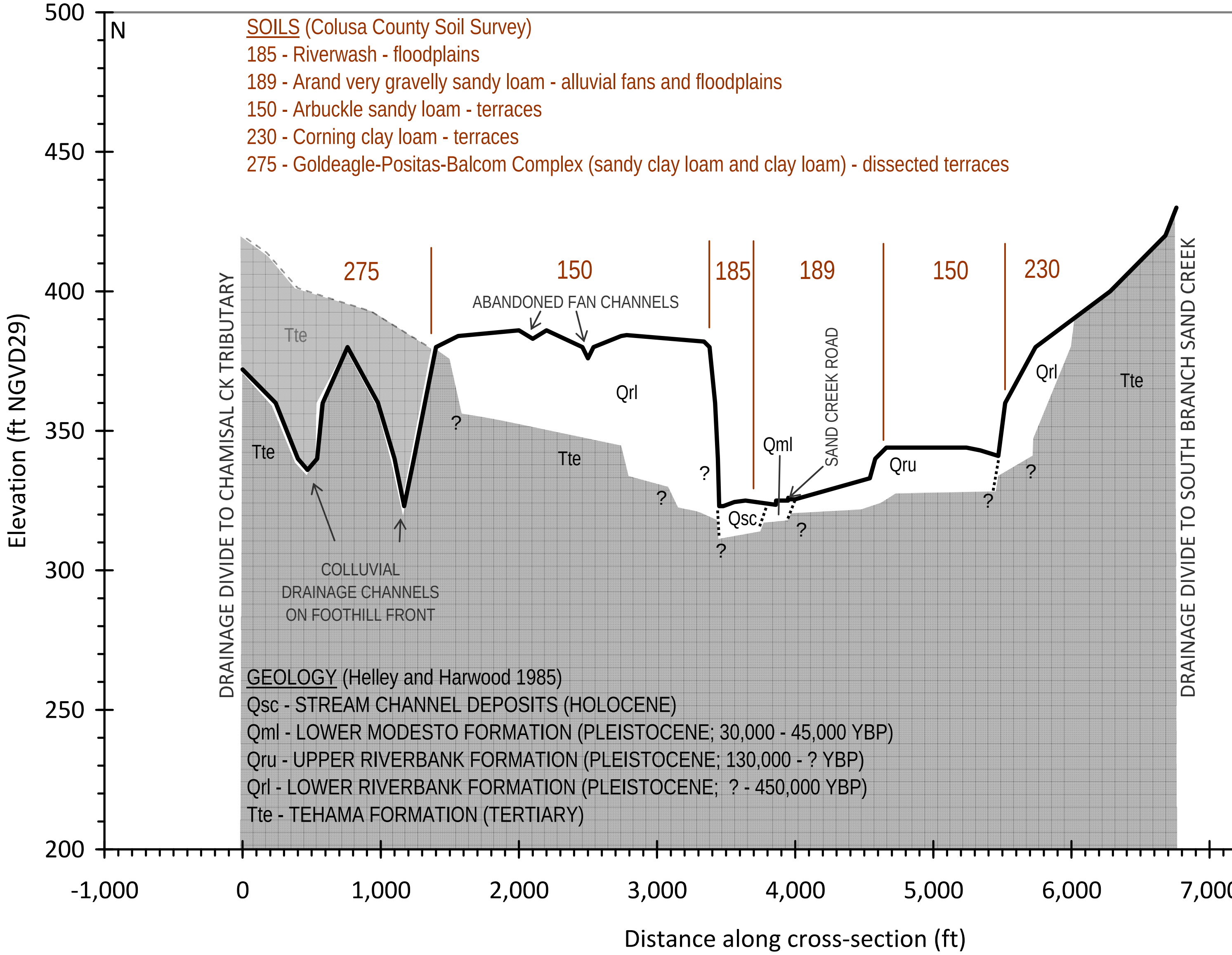


**Figure 16-Geology. North Branch Sand Creek**
**Holocene Alluvial Fan Apex Cross-Section**
approximately 4,300 ft downstream from Cortina School Road Crossing
(source: 5-ft contour interval USGS quadrangle, 1952 topography with 1949 air photo revision)

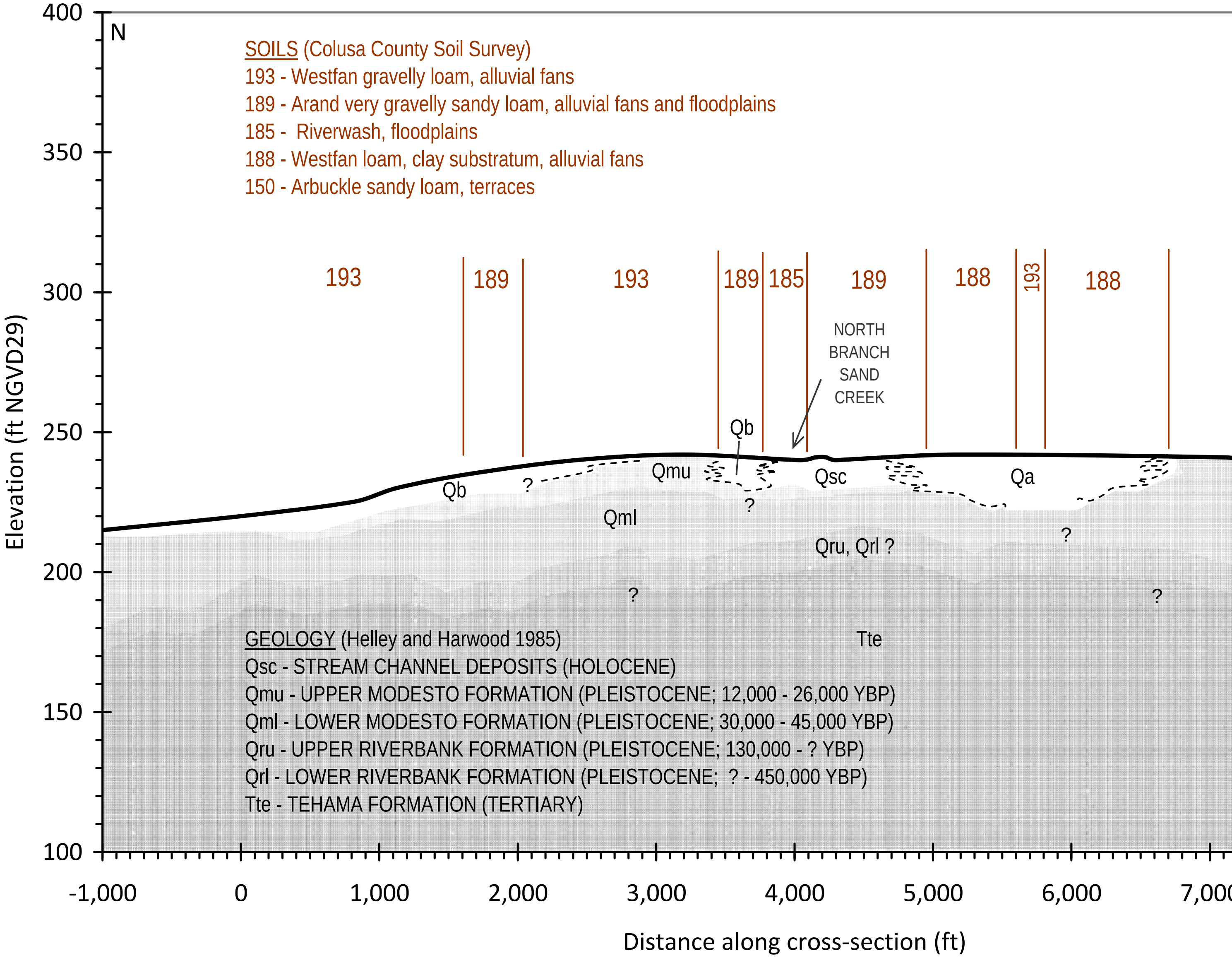


**Figure 17-Geology. North Branch Sand Creek**
**Distal Alluvial Fan Surface Cross-Section**
approximately 5,000 ft downstream from Interstate 5 Freeway and SP Railroad
(source: 5-ft contour interval USGS quadrangle, 1952 topography with 1949 photo revision)

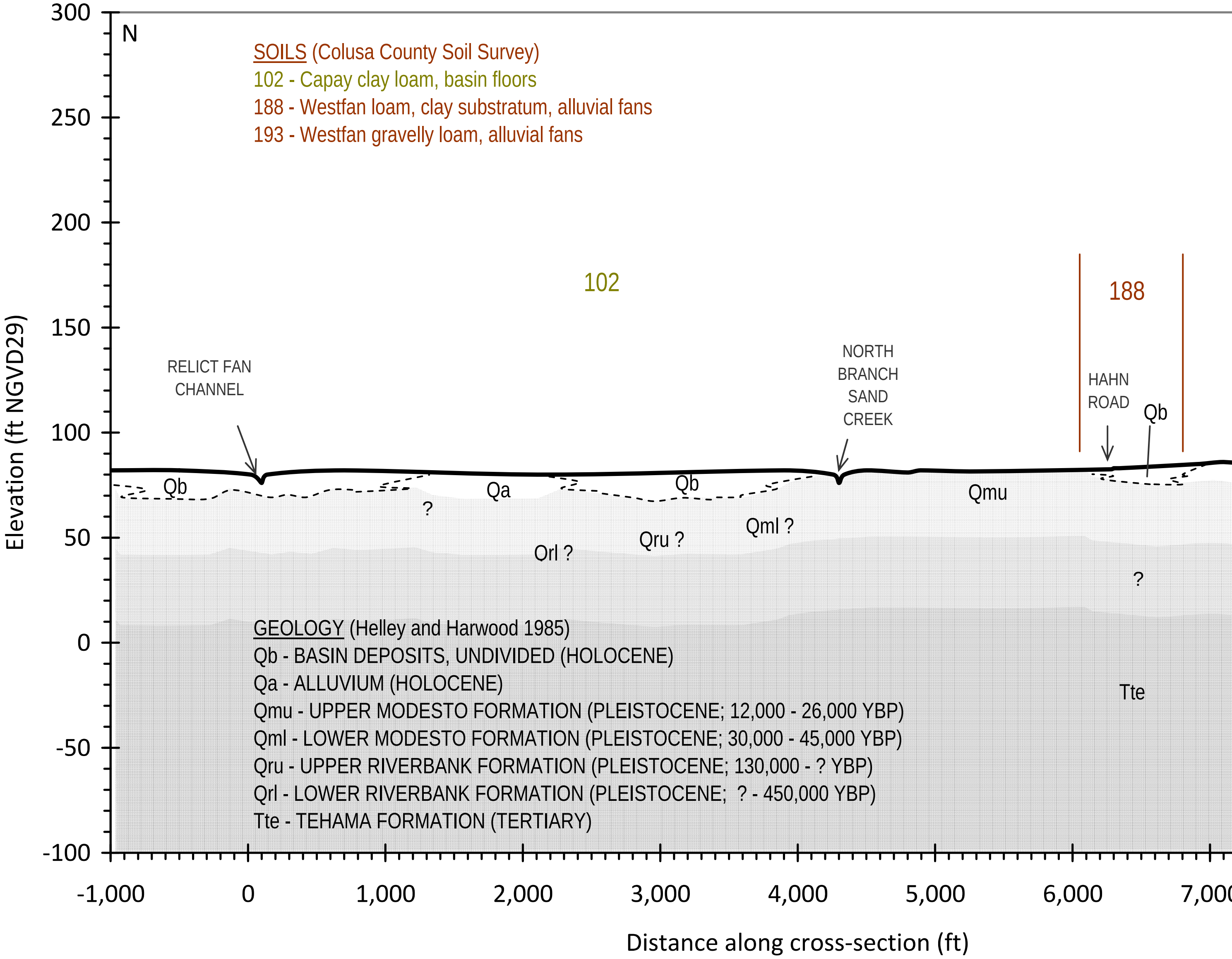
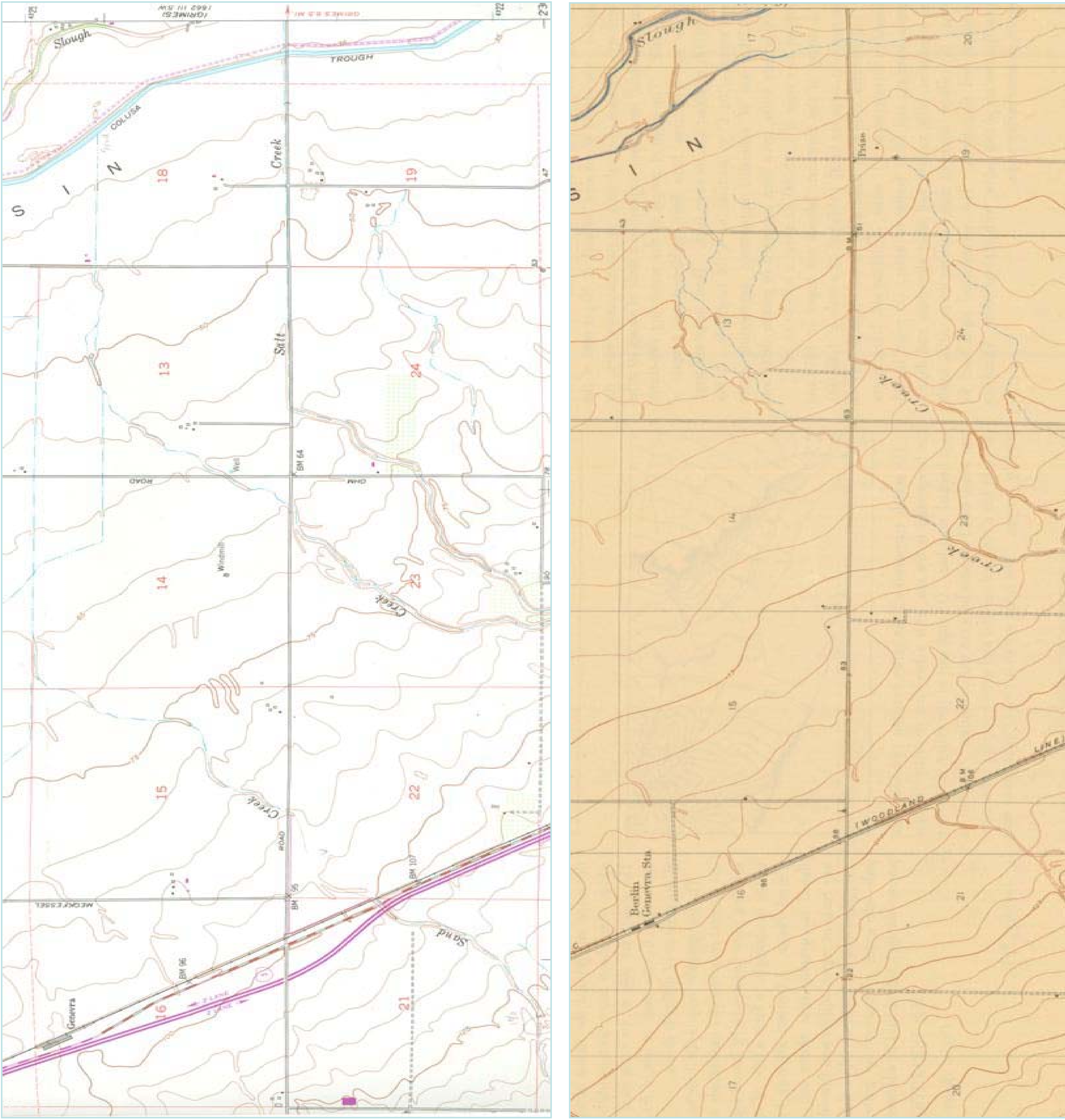



**Figure 18-Geology. North Branch Sand Creek topography, soils, and g**
**topographic maps, 1:62,500 geologic maps, and 1:24,000 soils maps).**




geomorph

**Figure 19-Geology.** North Branch Sand Creek topogr
freeway (sources: 1:24,000 topographic maps, 1:62,50


**Figure 20-Geology.** Colusa Basin topography, soils, and
(sources: 1:24,000 topographic maps, 1:62,500 geologic

# GEOMORPHOLOGY

## GEOMORPHIC SETTING OF THE COLUSA BASIN WATERSHED

Geomorphology is the study of the processes that generate and modify landforms on the earth's surface. Applied geomorphology seeks to predict and explain effects of human activities on geomorphic features such as hillslopes and streams, often to inform and guide the design of restoration actions.

The geomorphic setting of the Colusa Basin Watershed is virtually the same as its geologic setting because so much of the watershed lands are geologically recent alluvial deposits. When Helley and Harwood (1985) mapped the late Cenozoic surficial deposits covering the valley part of the watershed, in essence they prepared a map of the geology *and* geomorphology of its inhabited areas. The geology section of this assessment therefore describes the general geomorphology of the watershed.

This geomorphology section focuses on fluvial geomorphology of the watershed's streams: the current size, shape, and slope of its channels; the size of sediment stored on their beds; the presence/absence of floodplains; and the physical influences of semiconsolidated older alluvium where it forms the streams banks. Emphasis is given to describing the historical and current patterns of bank erosion, channel bed incision, sediment deposition and bed aggradation, and overbank flooding, bringing focus on the multi-objective management implications for the watersheds stream corridors. This assessment is necessarily general and somewhat speculative as there are few available data.

### Available Geomorphology Data

Bryan (1923) conducted much original field work and made many of the original and still correct observations of the geologic origin and structure of the watershed's landforms. His work suggested a seemingly obvious but useful landform classification dividing the foothills and its fringe of terraces from the smoothly sloping low plains and the channel ridged floodplain on the valley flat. However, Bryan (1923) gave scant attention to the form of its "minor" streams, reflecting only that their downstream ends were prone to overbank flows depositing much silt on the low plains and contributing greatly to the general seasonal flooding of the Colusa Basin on the valley flat.

Helley and Harwood (1985) mapped the late Cenozoic deposits forming the Pleistocene terraces and the recent (Holocene) stream channel, floodplain, and basin deposits in the foothill valleys, alluvial fans, and valley flat. Unfortunately, these map data are available in an out-of-print black-and-white paper format which does not easily reveal to the reader the watershed-wide patterns as much as a color version would, and does not readily lend itself to digital GIS database analysis. Observations made in this section of the assessment relied on detailed cross-examination of their 1:62,500 geology maps with the most recent available topographic map data (generally based on 1949 air photos) and 1:24,000 air photos underlying the soil survey maps.

Historical and recent soil surveys prepared by the Soil Conservation Service and the Natural Resources Conservation Service [NRCS] for each of the 3 counties in the watershed provide much of the scientific basis of available geomorphology information. Indeed, geomorphic analysis of alluvial fan settings typically relies on soils analysis to determine the extent of recent alluvial deposition and "age" the activity on the fan surface. Helley and Harwood (1985) relied heavily on soil survey data and maps, including sediment size composition of the soil and the degree of soil-development on various surfaces, as a key tool for distinguishing between the various age geologic units.

The recent Colusa County Soil Survey soil unit maps are delineated on 1:24,000 scale 1993-1999 air photos (orthophoto quads). The Holocene stream channel deposits (Qsc) Helley and Harwood mapped generally overlap the exposed sand and gravel beds of the streams where they are wide enough to be seen in the soil maps air photo underlay. The soil survey identifies these channel bed deposits and adjacent areas as the mapping unit "Riverwash," which can generally be taken as a proxy for modern floodplain deposits. Where there is an absence of Qsc and Riverwash, it is near the lower-gradient downstream channel sections where the streams have generally been modified and channelized for agricultural development and flood prevention.

More recently, in preparing the Environmental Impact Report for the South Fork Willow Creek Detention Basin, CH2MHill (2003) made field observations of the affected streams and generally discussed possible timing of channel incision, changes in channel form, and the causes and effects of land uses on upper watershed sediment runoff. It was not a detailed geomorphic assessment, but a brief geomorphology case study of one of the watershed's foothill streams.

There are USGS topographic maps made first during the 1900s and then updated as recently as the 1970s using topography drawn from circa 1949 air photos, generally with a 20-ft contour interval in and near the foothill valleys and a 5-ft contour interval on the alluvial fans and valley flat. Such moderate-detail topographic maps are adequate for this general watershed-scale geomorphic analysis as they record valley slopes and reveal patterns in the form of larger alluvial units, such as the channel ridge deposits of Cache Creek Slough, Funks Creek, and Sycamore Slough discussed in the geology section above. However, topographic maps with more than 2-ft contour interval are rarely used to evaluate fluvial geomorphology of small streams because they are generally insufficiently detailed for measuring at-a-station channel bed incision and longitudinal profile adjustments, or for determining channel shape and size and estimating channel capacity.

There are also numerous "old maps" and a sequence of historical air photos held in various depositories around the state. We reviewed the historical map holdings at UC Berkeley libraries, finding some general information not recorded on early USGS topographic maps, but nothing of the level of detail needed, for example, to completely reconstruct the pre-development condition of one of the watershed's foothill streams.

We did not undertake a thorough review of historical air photos, including 3-dimensional observations which may have been afforded by orthophoto pairs presumably made for some of the historical series. If early enough orthophotos exist, such an analysis would be beneficial for observing channel form in more detail and reconstructing the pre-development condition of one of the watershed's representative foothill streams. However, we found by cross-examination of the 1900s and recent 1:24,000 scale USGS topographic maps that the large majority of 20th century channel changes were made to the most bank erosion and flood prone lower-gradient downstream sections of the foothill streams, beginning with the first irrigated areas downstream from the Glenn-Colusa Canal, then within the later irrigated areas downstream from the Tehama-Colusa Canal. Many of these changes occurred before the earliest air photos were made. Examination of early orthophotos is discussed in the data gaps section of this assessment.

We synthesized the available information for one representative foothill stream in preparing geologic-geomorphic-soils profile and sections for North Branch Sand Creek presented in the geology section. This way, the North Branch Sand Creek case study illustrates in one part of the watershed the interrelationships between geology, geomorphology, and soils, which are general relationships that translate elsewhere. Additional and more detailed geomorphic mapping is discussed in the data gaps section of this assessment.

In November 2007, we made a half-day field tour with Jack Alderson, Colusa County NRCS Agricultural Engineer, which allowed us to make visual field observations and some spot width and depth measurements in Yolo and Colusa County foothill streams, mostly at and near road crossings. The most complete field observations were on Sand Creek and Stone Corral Creek, where public roads pass through the upper watershed areas all the way to the watershed divide.

### Fluvial Geomorphology of Colusa Basin Watershed Streams

This geomorphic assessment considers there are 6 general types of channels occurring along streams in the Colusa Basin Watershed:

| | |
|---|---|
| steep upland channels | typically narrow v-shaped channels dissected in the Cretaceous bedrock and Tertiary alluvial rocks underlying the foothills, with absent or isolated thin colluvial and alluvial deposits |
| foothill valley channels | typically narrowly meandering sand, gravel, and cobble bedded channels cut in Pleistocene alluvial deposits and outcrops of underlying Cretaceous and Tertiary rocks along the valley wall and on the valley floor, generally giving way downstream to more continuous and younger alluvial terrace deposits |
| proximal fan channels | where channel is at grade with the broader fan surface: typically wide shallow silt, sand, and gravel bedded meandering, locally braided, and anastomosing channels with unconsolidated silty sand and gravel banks occurring on the upper higher-gradient surfaces of alluvial fans, with natural gravelly sand levees and broadly spreading silty floodplain deposits where channel is incised into and confined between Holocene and in places semiconsolidated Pleistocene alluvial deposits, especially nearer to the foothill front: single-thread, narrowly meandering and often with less distinct natural gravelly sand levees and narrower silty floodplain deposits |

| | |
|---|---|
| distal fan channels | typically wide shallow silt and sand bedded meandering and anastomosing single-thread channels with unconsolidated locally semicohesive clayey silt banks occurring on the lower-gradient surfaces of alluvial fans and interfan basin areas, with natural sandy silt levees and wide clayey and silty floodplain deposits interfingering with and grading into the very flat aggrading surface of the Colusa Basin |
| valley flat channels | typically very low gradient moderately deep trapezoidal clay and silt bedded meandering and anastomosing single-thread channels on historical and active floodplains of the Sacramento River with natural sandy silt levees forming distinctive channel ridges winding in irregularly meandering pattern and often coalescing with other so-formed channel ridges to enclose flood basins on the floodplain |
| constructed channels | these are not channels constructed for irrigation and drainage but rather sections of once natural but still active streams where the original channel has been moved or otherwise entirely reconstructed, usually with a different cross-section shape and area and different longitudinal slope. This is a very widespread channel type, particularly among distal fan channel and valley flat channel sections impacted by agricultural development. |

The first 4 channel types occur along parts of all of the foothill streams in the watershed and are further described below. The North Branch Sand Creek geologic sections presented earlier are also referenced in the channel type descriptions by way of example.

**Steep Upland Channels.** The highest elevation sections of all of the foothill streams begin just downslope of the drainage divides of the foothill subwatersheds. These steep upland channel sections are variably bedrock, boulder, and cobble bedded with minor sand and gravel deposits and absent or narrow local floodplains and sediment transport dominated by hillslope processes including landsliding and other mass wasting. In general, upland channel slope is controlled by the bedrock canyon slope: by tectonics, deformation, and general bedrock weathering rate. There may be locally lower-gradient reaches and some accumulation of coarse alluvium and colluvium upstream from where there are landslide debris deposits in the canyon.

From a foothill watershed sediment budget perspective, steep upland channels receive and convey downstream the sediment generated in the steep upland watershed lands; long-term and temporary sediment deposition and storage are negligible in the steep uplands.

**Foothill Valley Channels.** Foothill valley channels are sections of foothill streams occurring in the upper foothill subwatersheds and just upstream from the foothill front where isolated or continuous alluvium-filled valley flats are dissected into the Cretaceous bedrock and Tertiary Tehama Formation. Foothill valley channels are distinctly alluvial compared to the steep upland channels upstream. Foothill valley channels are typically sand, gravel, and cobble bedded channels variably incised in the Pleistocene alluvial deposits which form the principal valley fill and terraces flanking one or both edges of the valley wall. Bedrock typically outcrops periodically in the bed, particularly in the narrower valleys where the Pleistocene alluvial fill is discontinuous and where outside channel bends impinge on the exposed valley walls.

The narrower, steeper upper valley sections generally give way downstream to somewhat lower-gradient wider valleys, where there are consequently more continuous remnants of Pleistocene alluvial deposits flanking the valley walls. These are typically dissected and backfilled with younger Pleistocene and Holocene deposits, forming multiple elevation terraces (see, e.g., **Figure 14-Geology**). Narrow modern floodplains may be present near the stream where valley width allows.

In some foothill subwatersheds the stream passes through a series of individual *isolated valleys* separated by geologically controlled steeper channel sections. For example, there are a number of large to small, generally north-south trending valleys in the foothills that are not all so closely related to the foothill front. Antelope Valley, which is actually a series of valleys drained by different channels, and Little Valley are examples. These valleys have relatively large areas of deep loam and clay loam soils, and many areas were farmed in the past. The channels are typically incised several feet through fine-grained material. Where occurring in isolated valley flats, channel slopes are typically controlled by bedrock elevations at the downstream end of the valley. Where occurring in continuous linear valleys with relatively deep alluvial fills and outlets along the foothill front, foothill valley channel slopes are typically controlled by natural geomorphic factors and processes including long-term climate effects on sediment supply.

Slopes measured down valley along the tops of the terrace surfaces of various geologic ages can be taken as indicating the slopes and elevations of the foothill valley streams at corresponding times in geologic history. In places, there are relict channels preserved in the surfaces of Pleistocene terraces, now resting several tens of ft above the modern channel bed; these exhibit the range of channel bed elevations and channel slopes which have occurred over time in the foothill valleys of the watershed.

From a watershed sediment budget perspective, these foothill valley channel sections transport sediment received from the steep upland channels, with lesser or negligible contributions from local bed and bank erosion, and negligible storage in floodplains.

**Proximal Fan Channels.** As detailed in the Geology section of this assessment, Pleistocene and Holocene alluvial fan deposits flank the front of the foothills along most of the length of the watershed, creating up to about 400 ft of relief along the western edge of the Sacramento Valley and the characteristic smoothly-sloping low plains of the watershed. Most of the foothill streams flow onto alluvial fans of their own construction when they leave the confinement of foothill valleys. Classically, streams leaving valley confinement in an upland area will change from a single-thread meandering form to a somewhat lower gradient and shallower actively migrating channel beginning at the fan apex, from which point multiple abandoned distributary channel emanate. Episodes of massive coarse sediment deposition in this vicinity continue to cause periodic abandonment of one channel for another. By this process the broadly sweeping convex-shaped alluvial fan surface forms over hundreds of thousands or millions of years. The steeper upper portion of the fan is termed *proximal* while the lower gradient surfaces downslope are termed *distal*.

In the Colusa Basin Watershed, the highest elevations on the fans (fanheads) are typically underlain by Pleistocene alluvium deposited there when the foothill streams debouched onto the fan from that higher elevation. Most of the watershed's foothill streams are deeply dissected in these Pleistocene fanheads such that the upper fan surfaces are not flooded by overflow from the foothill streams and the resulting fanhead terraces and corresponding down fan areas are said to be inactive (see, e.g., **Figure 15-Geology**). Within these dissected fanheads, the proximal fan channel sections of the foothill streams should and apparently do exhibit the same slope and form as their foothill valley stream sections immediately upstream, being really downstream extensions of the latter. These alluvial fans are said to have undergone "fanhead entrenchment".

The proximal fan channel sections emerge from the resulting confinement between the Pleistocene alluvial deposits forming the fanhead terraces at a location some distance downstream, the position of the currently active fan apex. Here the proximal fan channels may exhibit a form similar to that described above, being only shallowly incised in the broader fan surface with relatively wide and locally braided coarse-bedded channel, with natural gravelly sand levees flanked by narrow silty floodplain deposits (see, e.g., **Figure 16-Geology**).

Some of the foothill streams appear relatively deeply incised or entrenched in the entire proximal fan surface, such that most of the fan area is protected from stream overflow, and the proximal fan section of the stream is therefore typically single-thread and narrowly meandering without natural levees and floodplains. Proximal fan channel sections are naturally prone to severe bank erosion except where incised in semiconsolidated older alluvial deposits, including those of the lower Riverbank Formation.

From a watershed sediment budget perspective, the proximal fan channel sections deposit coarse sediment on the bed and fine sediment overbank where they are at grade with the broader alluvial fan surface, as evidenced by the long-term construction of the alluvial fan bodies. During periods of geologic time when they are incised in the fan surface they are more or less transport reaches, conveying the sediment supply from the upper watersheds and trading the coarse portion of that load with minor contributions from bank erosion.

The discussion of alluvial fans in the Geology section suggests that most of the foothill streams are severely to moderately incised in their proximal fan surfaces, with the shallower flood prone portions of the stream limited to the down fan area. That discussion also suggests that the foothill streams in the north-central part of the watershed, between Williams and Willows, have so deeply dissected the Cretaceous bedrock foothills (Tehama Formation being absent) that they emerge onto the low plains of the valley at elevations near 200 ft, such that alluvial fans are either poorly developed or otherwise completely buried by finer-grained deposits as would have been influenced by long-term rising base-level dictated by the Sacramento River floodplain. In the absence of alluvial fans the streams emerge from their foothill valley stream sections at the foothill front to flow onto these interfan basin areas exhibiting a channel form more similar to the low-gradient distal fan channel sections described below.

**Distal Fan Channels.** The classical alluvial fan exhibits a clear distinction between the higher gradient proximal channels near the fan apex and the lower gradient often multiple channels of the lower gradient distal fan surface. There is no such clear and consistent distinction in the Colusa Basin Watershed because the foothill streams are more or less incised in the upper fan surfaces and the lower-gradient downstream fan surfaces are thoroughly developed for agriculture. The most important physical distinction between the upper and lower channel sections is the frequent overbank flow broadly distributing sheets of silt-laden runoff over the low plains, a location probably best distinguished by examination of soil survey maps and anecdotal accounts.

Under pre-development conditions the distal fan channel sections were typically wide shallow silt and sand bedded meandering and anastomosing single-thread channels with unconsolidated locally semicohesive clayey silt banks with natural sandy silt levees and wide clayey and silty floodplain deposits interfingering with and grading into the very flat aggrading surface of the Colusa Basin (see, e.g., **Figure 17-Geology)**. Particularly in the watersheds with coarser sediment supply, well developed alluvial fans and greater relief distal fan channel sections may have had coarse-grained bars and loose, coarse-grained banks giving way downstream to finer bar deposits and primarily loose, fine-grained, very erodible bank material; the distal fan channel sections may have been actively meandering and locally widely braided wash-type channels. In places, the natural sandy silt levees created channel ridge deposits rising as little as 3-4 ft or as much as 10-15 ft above the adjacent landscape, a geomorphic form influenced by base-level rise and deposition during submerged conditions, similar to streams passing onto reservoir deltas, and generally resulting in an irregularly meandering planform.

From a watershed sediment budget perspective, the distal fan channel sections deposit what coarse sediment they carry on the bed and in its natural levees and deposit fine sediment on the floodplains forming the broader distal fan surface to either side. The finer fraction of the suspended sediment load is transported into the flood basins on the valley flat.

### Influences of Geologic Structure on Colusa Basin Watershed Streams

The geology section of this assessment highlighted the effects of differential uplift and warping of the Tehama Formation on the degree of upper watershed dissection and alluvial fan development. The Tehama Formation was uplifted to a higher elevation in the southern part of the watershed, creating a higher, wider band of Tehama Formation rocks along the foothill front, such that many of the foothill streams to the south have their entire upper watersheds cut in Tehama Formation rocks. The upper elevation of the Tehama Formation decreases gradually to the north to near the latitude of Williams where the unit is relatively densely faulted and its elevation decreases rapidly.

The Tehama Formation is absent between Williams and Willows. The foothill streams in this north-central part of the watershed have their upper watershed areas cut entirely in the Cretaceous marine sedimentary bedrock. These foothill streams have deeply dissected the marine bedrock down to elevations near 200 ft, such that alluvial fans are poorly developed or buried with fine-grained Holocene basin deposits (Qb). Holocene basin deposits cover the foothill valley flats extending up into the canyons of some of these foothill streams (e.g., Funks Creek, **Figure 4-Geology**). The foothill streams with large upper watershed areas in the deeply dissected Cretaceous rocks, with their layers of soft shale rocks, generate more clay- and silt-sized sediment which appears to explain the channel ridge deposits along Freshwater Creek, Stone Corral Creek, and Funks Creek.

We divide the watershed's foothill streams into 5 geomorphic provinces based primarily on the parent material of their upper watershed areas and related differences in drainage area, alluvial fan morphology and dissection, and degree to which the proximal fan channel sections of the streams are confined by semiconsolidated older alluvium:

1. Dunnigan Hills
Smith Creek
Willow Spring Creek
Bretona Creek
Oat Creek
Bird Creek
Dunnigan Creek

2. Southern Dissected Fans
Petroleum Creek
Wildcat Creek
Buckeye Creek
Little Buckeye Creek
Brush Creek
Elk Creek
Whiskey Creek

3. South-central Fans
Salt Creek
South Branch Sand Creek
North Branch Sand Creek
Chamisal Creek
Cortina Creek
Walters Creek
Spring Creek

4. North-central Dissected Foothills
Salt Creek
Freshwater Creek
Manor Slough
Glenn Valley Slough
Lurline Creek
Stone Corral Creek
Funks Creek
Hunters Creek
Logan Creek
South Fork Willow Creek

5. Northwest Dissected Terrace
Nye Creek
Hayes Hollow Creek
Salt Gulch Creek
French Creek
Wilson Creek
White Cabin Creek
Sheep Corral Creek
Walker Creek

The remainder of the Colusa Basin Watershed can be divided into 2 distinct geomorphic provinces: (6) Relict Stony Creek fan province, the relict southern portion of the Stony Creek fan lying to the north of Willows between Walker Creek and the Sacramento River; and (7) the valley flat province comprising the historical floodplain of the Sacramento River and associated flood basin deposits and basin rim deposits.

**Sediment Runoff and Transport**

There are too few available data for estimating the sediment yields, budgets, and reach-scale sediment transport and deposition processes in the foothill streams of the Colusa Basin Watershed. The best data probably exist in the field but haven't been compiled to date: grain size distribution of recent bar forms representative of bedload sediment in transport during recent winter storms, size distribution of the finer-grained overbank deposits where present, and size distribution and other characteristics of the recent alluvium forming the channel banks.

The discussion in the above geology section hypothesized that there is probably a greater supply of coarse sediment (sand- and gravel-sized sediment) from the foothill streams with well developed alluvial fans lying to the south of Williams. This is contrasted with an apparently dominantly silt- and clay-sized sediment supply from the north-central portion of the watershed where the Tehama Formation is largely absent and the foothill streams have deeply dissected the shales present in the Cretaceous bedrock.

UC Davis (1980) estimated that the foothill streams producing the greatest average sediment yields in the watershed were the streams draining the southern part of the watershed, such as Buckeye Creek and Oat Creek (Navigant Consulting Inc. 2000).

USGS (1972) measured suspended sediment concentration for many western tributaries of the Sacramento River including Stone Corral Creek, one of the approximately 32 foothill streams in the watershed. From these data, the sediment yield for Stone Corral Creek upstream from the USGS gage near Sites was estimated to be 99 tons per square mile per year (assuming a density of 37 $lb/ft^3$), or 0.12 acre-ft per square mile (CH2MHill 2003). USGS (1972) also estimated that bedload sediment yield was 2-7% of suspended sediment yield (CH2MHill 2003). CH2MHill (2003) estimated the sediment yield of the northern part of the watershed to be less than 300 tons per square mile per year, or 0.36 acre-ft per square mile.

More sediment yield data have been collected in the neighboring Stony Creek Watershed. These are relevant because the upper Stony Creek tributaries drain a terrain of similar relief and parent geologic material. Reclamation made several single-year sediment yield estimates of sediment discharged to the East Park and Stony Gorge Reservoirs in the Upper Stony Creek Watershed area north and west of the Colusa Basin Watershed. CH2MHill (2003) reported that these Upper Stony Creek sediment yield estimates were generally consistent with "the average estimates reported by the USGS investigation (USGS 1972)."

### Effects of Human Activities on Valley Flat Streams

Under existing conditions, there are only a few remnants of the anastomosed network of very low gradient clay- and silt-bedded "slough" channels which formerly conveyed Sacramento River flood overflow and foothill stream floodwaters into the Colusa Basin and drained those floodwaters down valley (**Figure 9-Geology**). Levee building and drainage works for flood protection and reclamation eliminated routine Sacramento River overflow onto the valley flat, and most of the slough channels have been farmed over.

Traces of the former slough channel network are visible in air photos, such as the remnants of Sycamore Slough south of Colusa (**Figure 20-Geology**). Under pre-development conditions, Sycamore Slough was a distributary floodplain channel of the Sacramento River which separated the upper and lower Colusa Basin. In its upper section it delivered flood waters and sediment forming the Vina loam into the upper end of the lower Colusa Basin. In its lower section it provided the primary north to south drainage through Colusa Basin. The Sacramento River Flood Control Project levee 'decapitated' Sycamore Slough and the numerous similar channels (Dry Creek Slough, Corbiere Slough, Byers Slough, Tule Slough, Hopkins Slough, etc.). The drainage function of Sycamore Slough has been replaced by the larger dredging maintained Colusa Basin Drain (**Figure 1-Geomorphology**).

### Effects of Human Activities on Foothill Streams

The effects of human activities on the watershed's foothill streams have been much less drastic than the effects on the valley flat streams. Foothill stream impacts are of 2 general types: direct effects caused by physical modifications (channelization, bank armoring, culverts for road and canal crossings, etc.) and indirect effects caused by general agricultural activities on the watershed lands (e.g., changes in stormwater runoff and sediment loading and possible associated channel bed incision and aggradation).

#### *Direct Effects*

**Channelization.** The majority of all of the distal fan channel sections have been straightened and realigned to conform to property boundaries and the grid-pattern of roads. Channelization often results in an artificially narrow cross-section with elevated levees on both sides. The modified channels convey deeper and faster floodwaters than the natural channel did, leading to elevated bed and bank erosion. Channel straightening typically makes the channels shorter and steeper than natural, whereas channel realignments that conform to roads and property boundaries tend to make the channels longer and more gradually-sloped, with 90° bends in places (**Figure 2-Geomorphology).**

Reconstruction of banks from the native stream bed material likely leaves them in an oversteepened, overburdened, loose, uncompacted state that is much more prone to bank erosion and slump failures than natural undisturbed alluvial bank materials. All these physical modifications run counter to the engineering design principles developed for natural stable channel design and stream restoration. It is therefore predictable that there would be regular channel bed and stream bank instability, need for expensive bank armoring, and repeat maintenance, as is apparently often the case.

Over time, some landowners either invest enough money into installing the necessary bank armoring and revetments or adapt the channel cross-section to reduce the need for repeat maintenance. Where enough adaptive design has occurred, some channelized stream sections are probably stable and therefore successful. Where this is not the case, frequent bank erosion occurring over long lengths of channelized streams may increase the coarse sediment loading on downstream reaches, possibly leading to local bed aggradation in downstream reaches and need for dredging maintenance for flood conveyance and bank stabilization (discussed below).

Before channelization, narrow bands of natural riparian vegetation once existed on the streambanks or the adjacent floodplains. Now, it is almost entirely eliminated, and opportunities for self-sustaining reestablishment, either naturally or through deliberate restoration efforts, are limited because channelization virtually always narrows the stream corridor and usually maintains steep natural banks or armored banks generally unsuitable for vegetation establishment.

Channelization is typically inspired by or otherwise accompanied by levee construction for flood protection and thereby eliminates all or part of what floodplain functions might have previously existed along the reach.

**Dredging and Levee Construction.** Repeat channel maintenance appears more frequent in the naturally floodprone lower-gradient downstream reaches of the distal fan channel sections, even where the stream has not been particularly straightened or realigned. Flood conveyance is maintained by dredging the channel beds and pushing the dredged material up onto the top of the banks to form elevated levees. Dredging maintenance is probably most frequent in the vicinity of road crossings where the bridge decks typically extend below the distal fan surface elevation, creating both an artificially narrow and low-ceiling bridge opening that may constrict flood conveyance, especially if the channel bed aggrades (**Figure 3-Geomorphology**).

This type of channelization has confined the distal fan channel sections between artificial banks and levees composed of loose, erodible sand and gravel material dredged from the channel bed (**Figure 4-Geomorphology**). From a geotechnical engineering perspective, these rather fine-grained artificial banks are also naturally prone to bank erosion owing to the low cohesion and strength of the bank material, relatively steep bank slopes, and the weight of overburden imposed by the overlying levees. Just as important, the natural tendency for shallow, low-gradient distal fan channel sections to be depositional and meandering by virtue of sediment supply and slope is still intact. Narrow confinement between elevated levees increases bank erosion potential by causing higher flood-flow velocities in the streams which exert higher shear stress on the bed and banks. The high flow velocities and shear stresses also act to sweep coarse sediment farther downstream, translating the zone of coarse sediment deposition downstream; and with it, the increased channel meandering pressure and bank erosion potential associated with coarse-grained bar deposition.

Repeat dredging maintenance along floodprone reaches and in the vicinity of bridge openings implies that the channel bed elevation restores itself periodically to the "problem" level, which may give rise to a perception that the channel bed is excessively aggrading even when it is simply refilling to "equilibrium" level. The equilibrium bed elevation may indeed be artificially high in places where poorly configured channelization work has been completed or where a narrow downstream road crossing or 90° bend creates a local backwater effect. Or the channel bed may in fact be actively aggrading in specific foothill subwatersheds where coarse sediment load has been elevated by human activities.

To an unknown degree, soil disturbance in the steeper terrace lands covering the upper fan surfaces has probably increased sand-sized sediment runoff to the proximal fan channel sections which generally passes downstream to the lower-gradient streams where it may create excess bedload sediment supply. Also, channelized stream sections with poorly vegetated frequently unstable channel banks probably cause periodic spikes in the sand- and gravel-sized sediment load during winter storms resulting in a downstream translating "wave" of channel bed aggradation which may take several winter storms to pass through the downstream lower-gradient reaches.

**Summary of Direct Effects of Foothill Streams.** Direct physical manipulations of the foothill streams have largely focused on conforming the alignment of the streams to rectilinear road network and property boundaries and elimination of frequent floodplain overflow onto agricultural lands. Virtually the entire length of the lower-gradient downstream reaches of the foothill streams (i.e., downstream from the Glenn-Colusa Canal) have been straightened, realigned, narrowed, dredged, and bounded with artificial levees. Stream-floodplain connectivity has been largely eliminated. This conversion occurred over the course of the 20$^{th}$ century, probably most rapidly during the latter half.

There have been significantly fewer and later direct physical effects on the foothill streams upstream from the zone of naturally frequent floodplain overflow, on the upper fan and dissected terrace surfaces near the foothill front. Here the streams are more or less incised in the broader alluvial fan surface and less prone to frequent overbank flows. Also the streams are more continuously incised in older, coarser, more consolidated alluvium making them naturally less prone to bank erosion. There are more numerous intact sections of foothill streams on the upper fan surfaces (**Figure 5-Geomorphology)**. With the importation of irrigation water to these upper fan surfaces via the Tehama-Colusa Canal beginning in the 1970s, there has been rapid development of row and particularly orchard crops which have had direct effects on the foothill streams there, including channel straightening and realignment work for eliminating local nuisance flooding and other agricultural efficiencies. This eliminated most of what riparian vegetation and floodplains existed. Increased channel instability along the manipulated reaches has probably increased the sand- and gravel-sized sediment supply to the lower reaches.

Orcharding on the upper fan surfaces has also increased the sand-sized sediment supply, which may cause channel bed aggradation in the lower-gradient reaches downstream

To date, there have not been studies completed to document the extent of still intact sections of foothill streams in the Colusa Basin Watershed. Nor have there been studies to map and document the effects of channelization and resulting unstable stream banks on downstream sediment transport and deposition in the foothill streams. These are discussed in the data gaps section of this assessment.

### *Indirect Effects*

**Sediment Supplied to the Foothill Streams.** As discussed above, there are too few data for estimating the background sediment supply to the foothill streams in the absence of land use impacts. The USGS (1972) sediment transport study was a short-term study generating sediment yield estimates which should be correctly viewed as a 'snapshot in time'. The USGS study does not provide enough data to substantiate whether or not the foothill streams currently produce more sediment than, for example, would be expected under pre-development conditions. They are also not enough baseline data for a future study to determine if there have been any definite trends in sediment runoff rate since 1972.

Some investigators of other Coast Range watersheds have hypothesized that certain rangeland practices in the upper watershed areas have increased sediment runoff and peak stormwater runoff. Reducing canopy cover and converting the grassland community from deep-rooted native grasses to shallow-rooted non-native grasses may have increased the rate of downslope soil creep and landsliding, which would increase both the coarse-grained and fine-grained sediment supply. There are generally insufficient data to evaluate these hypotheses in the Colusa Basin Watershed.

It seems more clear that first dryland cropping and later irrigated row cropping and orcharding on the upper alluvial fans surfaces have increased soil and sediment runoff from these moderately steep parts of the landscape compared to pre-development conditions. And the channelization of streams on the upper and lower fan surfaces for flood reduction and agricultural efficiency have probably served to increase the supply of coarse sediment because of the channel instability and frequent channel maintenance and dredging they have induced. The USDA/NRCS (1979) estimated that upland sediment sources (sheet and rill erosion by rainfall-runoff) and downstream sediment sources (bank erosion) were approximately equal for the Buckeye Creek and Dunnigan Creek subwatersheds in the southern part of the Basin (Navigant Consulting, Inc. 2000).

**Channel Incision and Bank Erosion.** Bank erosion and channel bed incision are natural geomorphic processes commonly operating in alluvial fan settings especially in semi-arid regions. Investigators have measured recent channel bed incision (i.e., 10 vertical ft or more) having begun in the late 19$^{th}$ century or early 20$^{th}$ century in many Coast Range watersheds and often hypothesized that the incision is related to the contemporary and similarly widespread occurrence of logging and grazing.

As discussed in the above sections of this assessment, the foothill streams of the Colusa Basin Watershed are relatively incised in the foothill valley alluvium and the upper alluvial fan surfaces, but studies have not been completed to document as far as feasible the timing and rate of this incision as would be needed to suggest hypotheses regarding the possible influences of human activities.

The 1904 5-ft contour interval topographic map shows that Stone Corral Creek was approximately 12 ft incised about ½ mile upstream from Swifts Stone Corral, and based on our field reconnaissance appears to be about 20 ft incised there today (**Figure 6-Geomorphology**). **Figure 7-Geomorphology** shows that the 25 January 2008 flood came within 4-5 ft from overtopping the bank there, suggesting that the same flood would probably have overtopped the bank in 1904, when the channel was only 12 ft deep and presumably narrower as well.

One-half mi downstream, near Swifts Stone Corral, the channel was approximately 10 ft incised in 1904 and about the same in 1957, according to 1958 10-ft contour interval topographic maps. Similarly, another 1.5 mi downstream, near Mills Orchard, the channel was about 8 ft incised in 1904 and 1957. It may be somewhat more deeply incised at those locations today, but these map data suggest that most of the incision seen in the foothill valley section of Stone Corral Creek may have occurred after the 1950s. In 1904, Funks Creek was about 3-4 ft incised at the foothill front about 2 mi west of Glenn-Colusa Canal and about 8 ft incised there in 1957.

Recent channel bed incision appears to have advanced into the foothill valley section of North Branch Sand Creek. As discussed in the geology case study section of this assessment, we observed that the grouted rip-rap apron on the downstream side of Sand Creek Road forms an approximately 15 vertical ft headcut of the creek (**Figure 11-Geology** and **Figure 12-Geology). Figure 8-Geomorphology** shows Sand Creek at a location about ¾ mi upstream from Cortina School Road and the Tehama-Colusa Canal where the channel is also incised about 15 ft. Local residents recall being able to drive a car across the channel of Sand Creek in this vicinity about 50-60 yrs ago, indicating that much of the North Branch Sand Creek channel incision probably occurred after 1950; similar to that indicated above for Stone Corral Creek.

Bank erosion is an intrinsic tendency of incised channels, and an incised channel is prone to accelerated bank erosion because flood flows are deeper and faster than they would be if a lower-elevation floodplain were present to accommodate a large percentage of flood flows. Bank erosion rates may be limited in incised channels where they are confined by resistant or semi-resistant bank materials or revetments. Rapid bank erosion is common where incised channels are confined by loose, erodible alluvium. Only after significant bank erosion occurs, can the average flood flow velocity decrease substantially enough to allow coarse-grained bars and fine-grained floodplains, energy dissipating features characteristic of stable, less erosive alluvial streams, to form by deposition during floods.

CH2MHill (2003) observed channel incision in the upper watersheds of Willow Creek and Wilson Creek and implied that much of it was due to soil compaction, grassland conversion, and canopy cover reduction caused by post-Euro-American grazing practices. However, evidence substantiating the timing of channel incision is generally scant or lacking in the foothill subwatersheds. Some field workers have suggested instead that much of the current channel incision occurred before EuroAmerican settlement, citing as evidence presence of Native American grinding bowls within massive bedrock exposed on the stream bed within steep upland channel and isolated valley sections of some foothill subwatersheds. Indeed, some pre-Euro-American incision is especially plausible considering the naturally high runoff potential of the shallow clayey upland soils and the possibility that Native Americans used fire as a method of vegetation management and hunting. Pleistocene alluvial deposits rise some 60 ft or more above the modern floodplain surfaces, exhibiting the long-term operation of cut-and-fill cycles, probably driven by climate change.

**Channel Bed Aggradation.** In alluvial fan environments, it is common for the dominant bed material to change from sand and gravel to almost exclusively sand and finer sediment. Typically, this so-called "gravel-sand transition" occurs on the upper part of the distal fan where the gradually reducing slope passes below a low threshold value. We could not find reliable indicators of the gravel-sand transition on several foothill streams during our November 2007 field observations. Overall, it appears that substantial amounts of gravel pass farther downstream than we would have expected based on our field experience with other alluvial fan environments. Finding more gravel farther downstream than expected may be partly explained by the otherwise wide and shallow distal fan channels having been almost completely narrowly confined between artificial banks and levees. That is, narrow confinement between levees increases the depth and velocity of winter flood flows, allowing gravel-sized sediment to be transported farther downstream than it would have under pre-development conditions. Moreover, these artificial banks and levees are composed of mixed sand and gravel materials dredged from the channel bed. Bank erosion probably supplies more gravel to downstream channel sections because the constructed banks contain more gravel than the pre-development channel banks, and they are more unstable because of their construction. Overall, stream channelization has probably lengthened and obscured the gravel-sand transition zone.

Increased coarse sediment supply might lead to channel bed aggradation in the downstream low-gradient reaches, especially locally where there are discontinuities in presence of levees, width of channel confinement, or local hydraulic backwater effects of narrow bridge openings and 90° bends.

Channel aggradation may be occurring on lower reaches of Cortina Creek (Jack Alderson, Colusa County NRCS Agricultural Engineer, pers. comm., July 2008). In the vicinity of Ohm Road, Cortina Creek is forming a multiple acre area with shallow sand deposits over clay soils where it has escaped from constructed confinement. This lower end of Cortina Creek was moved a couple of times since 1948 and channel confinement was extended farther east. In the 1948 soil survey, Cortina Creek ends at Ohm Road. A 1,000 to 2,000 ft-wide band of soil along Cortina Creek upstream of Ohm Road is mapped as Yolo sandy loam, very shallow, over Genevra clay. Several miles farther upstream there is an abandoned channel called Old Cortina Creek that flows north 2 to 3 miles and then northeast to end about 4 miles north of the Cortina Creek shown ending at Ohm Road. Both channels have a narrow band of Cortina sandy loam mapped along parts of the channel courses downstream of the branch point.

Overall, however, channel bed aggradation is not seen as a widespread management problem in Glenn County (Johnson, pers. comm.). Indeed, we observed several road crossings in the lower-gradient reaches where the headroom (elevation difference between the top of the channel bed and the lower chord of the bridge deck) appeared insufficient to pass likely flood discharges (**Figure 3-Geomorphology).** However, at these places the 1905 5-ft contour interval topographic maps seem to confirm that the bed elevations have not measurably aggraded. Five-ft contour interval maps are not necessarily accurate enough to substantiate the presence/absence of long-term channel bed aggradation. Still, field observations at these sites did not indicate obvious aggradation effects.

Real or not, channel bed aggradation is an easily perceived trend at a site where the bed is frequently dredged to maintain an unnaturally low channel bed elevation, only to refill during subsequent floods. This is especially true at road crossings, where the bridge decks are more or less consistently at grade with the adjacent floodplain, such that the depth or thickness of the bridge deck actually blocks part of the natural channel flow area, and blockage by vegetative debris is undoubtedly a common problem.

Figure 1-Geomorphology. Photo looking approximately northerly upstream fro
Colusa Basin Drain and Back Levee at right. Remnants of Sycamore Slough lie
the Back Levee. November 6, 2007.

Figure 2-Geomorphology. Photo of Whiskey Creek looking approximately ea
downstream from Whiskey Creek Road. Note the narrow confinement and u
banks. Hillgate Road at left. November 6, 2007.

**Figure 3-Geomorphology. Photo of Clarks Ditch (Petroleum Creek) looking southeasterly and downstream from left bank to College City Road bridge c the headroom beneath the bridge low chord is only 3-4 ft. The bridge deck grade. White Road intersection in background. November 6, 2007.**

Figure 4-Geomorphology. Photo of Petroleum Creek looking approximatel
from Wildwood Road crossing. Note the gravel-bedded channel devoid of
erodible artificial banks and levees. November 6, 2007.

geomorph

**Figure 5-Geomorphology. Photo of remnant natural pre-development cha community intact along North Fork Elk Creek looking approximately easte from Whiskey Creek Road crossing. November 6, 2007.**

geomorph

Figure 6-Geomorphology. Photo of Stone Corral Creek looking approxima
and downstream from edge of Maxwell Sites Road about 3 mi downstream
that the channel is deeply incised in the valley fill and rip-rap protecting t
edge of the road in the background. Soil is Corval clay loam of alluvial far
November 6, 2007.

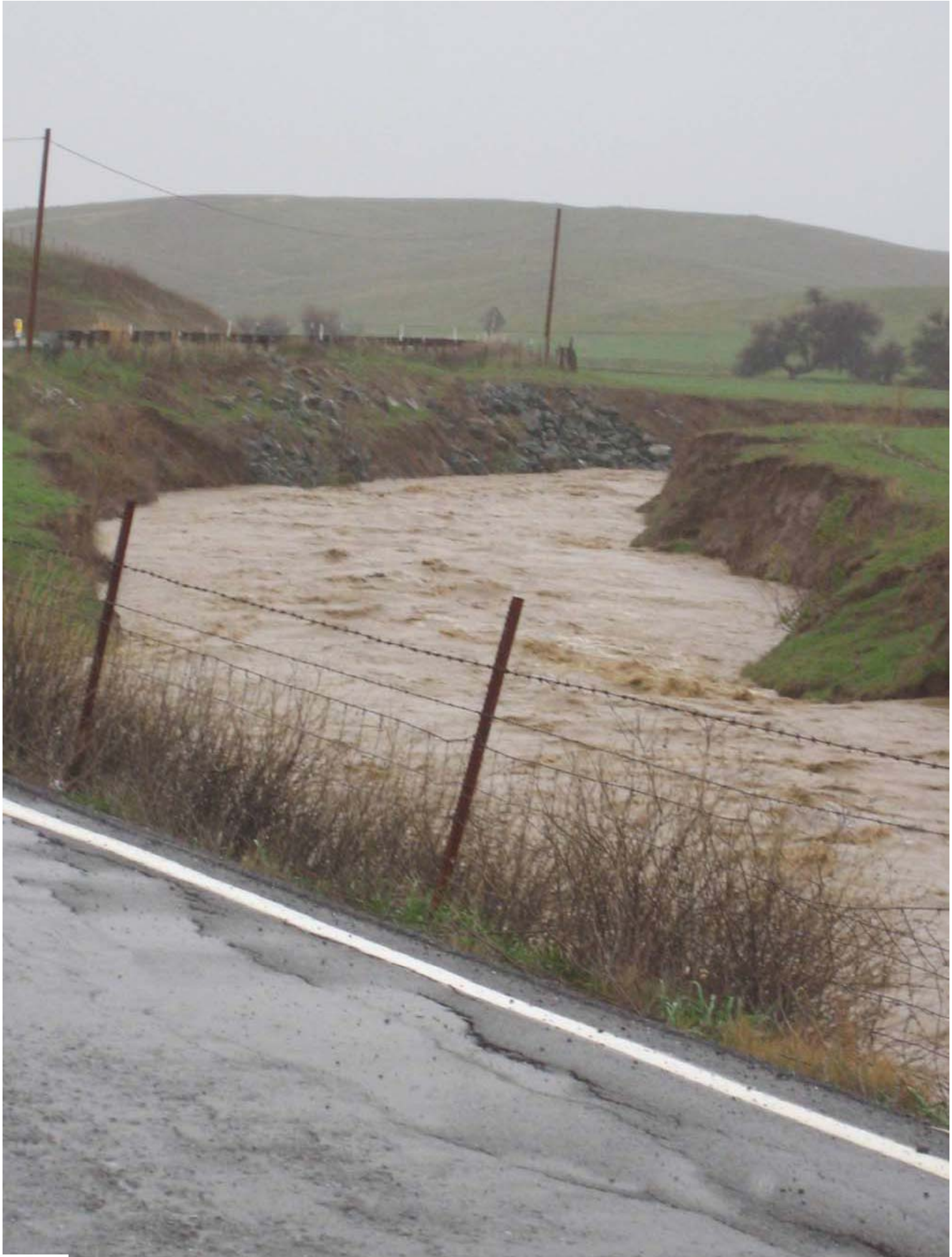


Figure 7-Geomorphology. Photo of Stone Corral Creek looking approximately southeasterly and downstream from edge of Maxwell Sites Road about 3 mi downstream from Sites during high runoff conditions. Soil is Corval clay loam of alluvial fans and floodplains. (Photo by Jennifer Masters, January 25, 2008).

geomorph

**Figure 8-Geomorphology. Sand Creek looking approximately westerly and top of right bank about ¾ mi upstream from Cortina School Road. Note cla channel in mid-ground. Elsewhere in vicinity bed is cut in grooved clay wit deposits. November 6, 2007.**

# SOILS

## OVERVIEW

The types and patterns of soils on the Colusa Basin Watershed lands follow somewhat directly from its geology and geomorphology. This section of the assessment summarizes the relationships between the basic soil characteristics and the geomorphic surfaces on which they developed, highlighting the influences of geologic parent material and age of the geomorphic surfaces on soil characteristics present.

General soil maps are reproduced and presented from the most recent soil surveys completed for each of the 3 counties with lands in the watershed, but no attempt is made to reproduce the soils data at the level of mapping or descriptive detail of the individual mapping units, except for the portions of the detailed soils maps presented in the geology section of this assessment for the case study of one of the foothill streams. In general, the reader will need to reference those soil surveys for detailed soils information about individual areas of the watershed.

The available data regarding the historical and existing distribution of alkali soils is also reviewed here as these soils are of particular interest because of the reclamation efforts which have been required to make productive agricultural use of those soils and because the areas not reclaimed provide unique and valuable wildlife habitat.

Available data regarding the permeability, runoff potential, and erodibility of the watershed soils are also reviewed. These data, among other factors, influence the patterns and rates of soil erosion and stormwater runoff from the watershed lands, including the potential for human land uses and activities to increase both of the same.

### Scope and Methods

There are more historical and recent soils and groundwater data for the Colusa Basin Watershed than any other type of data, both data being critical to the early development and future management of the current agricultural economy. Early soil surveys included the following:

Lapham, M. H., A. T. Sweet, A. T. Strahorn, and L. C. Holmes. 1907. Soil Survey of the Colusa area, California. pp. 927-972, 2 maps.

Mann, C. W., J. F. Warner, H. L. Westover, and J. E. Ferguson. 1909. Soil Survey of the Woodland area, California. pp. 1635-1689, 2 maps.

Mann, C. W. 1909. Alkali map: California, Woodland sheet.

These soil surveys were not obtained during the preparation of this draft of the assessment. They are probably held at the Shield Library on the UC Davis campus. Reproducing and evaluating historical alkali maps are discussed in the data gaps section of this assessment.

Later soil surveys were completed for each of the counties with lands in the watershed:

Harradine, F. F. 1948. Soils of Colusa County, California. University of California Berkeley Experimental Station. 140 pp.

Begg, E. L. 1968. Soil Survey of Glenn County, California. U.S. Department of Agriculture. 198 pp.

Anderson, W. F. 1972. Soil Survey of Yolo County, California. U.S. Department of Agriculture Soil Conservation Service. 170 pp.

[USDA/NRCS] U.S. Department of Agriculture, Natural Resources Conservation Service. 1998. Soil Survey of Colusa County, California.

We reviewed the most recent soil surveys for each of the 3 counties, and examined both the general soil maps they contain and the more detailed maps of the individual soil mapping units. The 2006 Colusa County Soil Survey contains the most useful narrative description of the soils including an explanation of the dominant soil-forming factors operating in the watershed: climate, topography, geologic parent material, vegetation, time, and geomorphic surfaces. An understanding of the watershed soils requires a synthesis of all of the available information for all the physical subject areas covered in this assessment.

## GENERAL DESCRIPTION OF THE SOILS OF COLUSA BASIN WATERSHED

### The General Soil-type Classification of Storie and Weir (1951)

Storie and Weir (1951) compiled soils data for the entire state of California and proposed a general classification of soils that is useful to review as an introduction to the soils of the Colusa Basin Watershed. For this purpose, Storie and Weir subdivided the landscape into landform-types based on topography one of the dominant soil-forming factors. Four of these topographic landform-types occur in the Colusa Basin Watershed. Note that these are not unlike the geologic-geomorphic landform-types proposed by Bryan (1923) and reviewed in the geology section of this assessment:

| | |
|---|---|
| Upland | – rolling hilly to steep topography |
| Terrace land | – gently sloping to undulating topography |
| Valley land | – gently sloping, smooth topography |
| Valley basin land | – nearly flat topography |

The published Storie and Weir (1951) is reproduced in this assessment as **Figure 1-Soils**.

The soil types occurring in the watershed are:

Upland – **En** – residual soils of moderate and fairly shallow depth to bedrock
Terrace land – **Cnm** – brownish soils with *moderately dense subsoils*, e.g., Ramona loam
Terrace land – **Cand** – soils having *dense clay subsoils*, e.g., Placentia loam
Valley land – **An** – deep alluvial fan and floodplain soils Valley basin land
Valley basin land – **Bnc** – imperfectly drained

Navigant Consulting, Inc. (2000) digitally reproduced Storie and Weir's general soil map to provide background soils information for the Integrated Resource Management Program ([IRMP] **Figure 2-Soils**). The following soil-type descriptions are adapted from the PEIS/R for that program.

*Upland soils.* Upland soils are generally shallow residual soils that occur in rolling, hilly to mountainous topography, mostly having been formed in place through decomposition and disintegration of the underlying parent bedrock. Low to moderate rainfall can support vegetation for grazing on upland soils. Typically light brown or light gray-brown in color and fairly low in organic matter, upland soils may be subject to erosion under undisturbed and particularly where vegetative cover is removed or following disturbance. Upland soils cover the western third of the Colusa Basin Watershed area within the Coast Range foothills.

*Terrace land soils with dense subsoils.* Terrace land soils are formed in the older and younger valley fill alluvium occurring in the foothill valleys and on the alluvial fans sloping up from the edges of the valley and basin lands, usually at elevations of 5-300 ft above the valley floor. Terrace land soils generally have dense subsoils as the result of clay translocated into the B horizon, such that generally medium-textured surface soil transitions abruptly to underlying very dense clay soil. Terrace land soils with dense subsoils exhibit poor drainage and are satisfactory for annual grasses and shallow-rooted crops. These generally occur on the older Pleistocene alluvial deposits where sufficient time has transpired for the dense clay subsoil to develop. The Pleistocene alluvial deposits form terraces along a narrow band on the upper fan surfaces lying along the edge of the foothills and in the upslope dissected foothill valleys from near Willows in the north to west of Zamora in the south.

*Terrace land soils with moderately dense subsoils.* These are usually brownish, neutral surface soils occupying the lower elevation alluvial fan surfaces where younger alluvium is present, and covered with grass or woodland grass. Terrace land soils with moderately dense clay subsoils generally occur south of Williams and east of the Colusa Basin Drain.

*Valley land soils.* In contrast to the relatively poorly drained terrace land soils, valley land soils are predominately well-drained alluvial soils formed in loamy alluvial fan and floodplain deposits. Valley land soils are generally brown in color and highly valued for irrigated crops. Some of these soils are slightly to moderately saline to alkali. They are located along the Sacramento River, in the area dissected in the Tehama Formation, and the oldest part of the relict Stony Creek alluvial fan lying northwest of Willows.

*Valley basin soils.* Valley basin soils occur in the lowest elevation parts of the watershed that are nearly flat and poorly drained. These soils are generally dark-colored and clayey, with a high water table. They are subject to frequent stormwater overflow and extended ponding and are primarily used for rice growing. Valley basin soils occur on the valley flat lying west of the Sacramento River floodplain deposits and east of the gently sloped alluvial fan deposits from the Coast Range foothills, comprising an area often referred to as a "low trough" extending from north of Willows to Knights Landing. The Colusa Basin comprises the southerly and lowest elevation part of the low trough on the valley flat. Valley basin soils also occur upslope from the rim of the Colusa Basin in the interfan basin area in the Maxwell vicinity.

### Influence of Geologic Parent Material on Soil Formation

Storie and Weir's soil-type classification is according to topographically distinct areas of the landscape, which could be distinguished by the distribution of geologic parent material summarized in the geology and geomorphology sections of this assessment. The steep upland soils are residual soils formed in the weathered Cretaceous bedrock and Tertiary Tehama Formation alluvium. The terrace land soils are formed in the Pleistocene alluvial deposits created as those uplands were uplifted and deeply dissected. Those with dense clay subsoils are generally those formed on the older alluvial surfaces: the foothill valley terraces, fanhead terraces, and broader areas on the more deeply dissected fans. Geologic parent material strongly influences the specific physical and chemical characteristics of soils (USDA/NRCS 1998):

> Parent material exerts a strong influence on soil formation. It is the unconsolidated, more-or-less chemically weathered mineral or organic matter in which the soils are developed by pedogenic processes. Along the Sacramento River and west-side streams, soils formed in alluvium deposited during periods of flooding. The properties of the alluvium affect texture, fertility, pH, salt content, color, and other soil properties. Tujunga and Vina soils formed in coarse textured alluvium and are high in sand content and low in clay content. Corbiere, Moonbend, and Sribner soils formed in silty alluvium.
>
> The soils of the Sacramento Valley are weathered to a considerable depth because the native conditions under which the soils formed were characterized by adequate moisture and heavy vegetation. Unaltered parent material of these soils was not observed during the soil survey, except in very deep ditches.
>
> Alcapay, Capay, Clear Lake, and Willows soils formed in very fine textured alluvium in the Colusa Basin and Butte Sink. A water table in these soils assisted soil formation through the deposition of salts. There is always the possibility that the current alluvial soils overlie a paleosol, or older buried soil, as deposition was continual under natural conditions.
>
> Soils on foothills formed in residuum derived from fine grained sandstone and shale, which are readily weathered if moisture is available. Most of these soils have a relatively low content of rock fragments for upland soils as a result of the readily weatherable nature of the parent rock. The fine grained nature of the parent material also results in soils that are generally high in content of clay. Several soils, notably Ayar and Balcom soils, formed in material high in content of carbonates and thus have a high content of these carbonates throughout.

### Relation between Older Geomorphic Units and Older Soils

Although there is a correlation between the terrace soils with dense clay subsoils mapped by Storie and Weir and the presence of older Pleistocene alluvial units in the watershed, Storie and Weir's **Cand** mapping unit is generalized and should not be used instead of the more detailed soil mapping in the USDA soil surveys.

In the south, the **Cand** unit is a wide band that appears to include a substantial upland area and upland soils underlain by the Tehama Formation; the mapping unit appears intended to circumscribe the relatively narrow Pleistocene alluvial deposits that occur in the foothill valleys upslope from the alluvial fan deposits. The unit also circumscribes many of the older alluvial deposits forming terraces along the foothill front and exposed on the surfaces of the more dissected alluvial fans, but not at all strictly according to the pattern of various aged surficial deposits of Pleistocene alluvium mapped at a much larger scale by Helley and Harwood (1985). For example, the **Cand** unit does not circumscribe the relatively young Modesto age alluvium on the alluvial fans developed along the Dunnigan Hills nor the Modesto exposures on the distal end of the Sand Creek fan, but does circumscribe the relatively minor Modesto exposures at the distal end of the Cortina Creek fan southeast of Williams. The **Cand** unit does not include an area of Corning soils developed on the lower Riverbank alluvial deposits forming Pleistocene alluvial fanhead of Cortina Creek. North of Willliams, the **Cand** unit similarly appears to circumscribe an area of dissected foothills, alluvial fans, and interfan basin area where there are prominent outcrops of older Pleistocene alluvium, primarily of lower Riverbank age, even though most of the older alluvium areas are covered with basin soils.

When compared to the general soil map of the Colusa County Soil Survey (USDA/NRCS 1998), the **Cand** mapping unit appears to circumscribe the more complicated watershed area covered with soils of the Hillgate-Arbuckle-Corval-Corning association (**Figure 3-Soils**), an association comprising soil series only some of which are notably prone to dense clay subsoils, and described by USDA/NRCS (1998) as comprising "Very deep, nearly level to moderately sloping, well drained soils on terraces, floodplains, and alluvial fans of the west side of the Sacramento Valley formed in alluvium from mixed rock sources."

The generalized soil map of Storie and Weir provides an overview that is useful at the scale of watershed assessment, but the actual pattern of soils with any special characteristics such as restricted drainage per dense clay subsoils is much more complicated. On the subject of characteristics of soils formed on the older alluvium, USDA/NRCS (1998) observed generally:

> A few of the soils in Colusa County formed under different, older climatic conditions known as paleoclimates. Corning soils are the best example. They were deposited during a period when the amount of annual rainfall was considerably higher. Bases in these soils are considerably leached, partly because of higher rainfall during the paleoclimate and partly because of the great age of the soils. The clay in these soils has been translocated into a thick, dense claypan, which, combined with a low base status, results in low fertility…
>
> …As more time passes, other soil processes take place, especially the translocation of clay from the A horizon to the B horizon. In the slightly older soils, such as Moonbend and Westfan soils, some clay has been translocated to the B horizon. Soils that are similar to Moonbend soils generally are less than a few thousand years old.
>
> As more time passes, to the point of tens of thousands of years, some soils develop a thick subsoil of heavy clay. Examples are Hillgate and Mallard soils, which have more than 40% clay in the B horizon.
>
> After long periods of time, soils develop to the point where further soil formation may not proceed with a change in the soil-forming factors. These soils may be characterized by a very dense claypan subsoil, a duripan, the leaching of bases, and iron oxidation. The very old Corning soils, for example, have a dense claypan, are of low fertility because of the leaching of bases, and

have characteristic red subsoil colors because of iron oxidation. Only resistant remnants of the old terraces where the Corning soils formed remain. These soils were deposited during the Pleistocene and are the oldest valley soils in the survey area.

### General Description of Soils Occurring on the Typical Geomorphic Surfaces in the Watershed

The geology and geomorphology sections of this assessment summarized the geologic-geomorphic landform-types Bryan (1923) proposed during his early field work in the Colusa Basin Watershed and the greater Sacramento Valley. Storie and Weir (1951) classified soil-types according to the same geologic-geomorphic landform-types, emphasizing the strong interrelationship between geologic parent material, geomorphic units, and soils occurring in the watershed. The best and most detailed geologic maps of the watershed lands, those of Helley and Harwood (1985), relied heavily on early soil survey data and maps, as key tools for distinguishing between the various age geologic units. The Colusa County Soil Survey organizes a discussion of the formation of soils according to the types and ages geomorphic surfaces present in the watershed. USDA/NRCS (1998) summarized these relationships as follows:

> A geomorphic surface is a mappable area of the earth's surface that has a common history; the area is of similar age and is formed by a set of processes during an episode of landscape evolution. A geomorphic surface can be erosional, constructional, or both. The surface shape can be plane, concave, convex, or any combination of these. Understanding geomorphic surfaces is very important to the understanding of soils in valley and on terraces and is used extensively in soil mapping.
>
> **Low Flood Plains**
>
> The area inside the levees on the Sacramento River has beaches of sand and gravel and numerous bars and channels. This area is heavily vegetated and frequently flooded. The soils under the dense vegetation of oaks, cottonwoods, willows, and grapevines are sandy and stratified.
>
> Inside the Sacramento River levees are areas 5 to 10 feet higher than the beaches and bars. This second surface has coarse-loamy Mollisols of the Vina series that have a very thick, dark surface horizon. The native vegetation was dense stands of oaks, cottonwoods, willows, grapevines, and poison oak. This surface is flooded occasionally and is used for orchards of walnuts and peaches. It continues on both sides of the river in some areas and also follows old slough remnant channels away from the river. The levees are often constructed at the edge of this surface on what was the edge of the natural river levee. The natural river levee is a slightly higher area of deposition from overbank flooding along the river.
>
> **High Flood Plains**
>
> This surface is now protected from flooding by the levees along the Sacramento River. Historically, the surface was flooded in most years during periods of high riverflow. It begins at the natural levee and slopes very gently toward the Colusa Basin. The soils are dominantly those of the Moonbend series, which have a high content of silt and a thick, dark surface horizon. These very productive soils are used mostly for orchards and some tomato production. The city of Colusa is constructed on this surface, because of less intense, less frequent flooding. The native vegetation was oak with scattered cottonwoods and dense, tall perennial grasses.

### Basins

This surface makes up most of the Colusa Basin and Butte Sink. The Colusa Basin received regular additions of fine textured sediments because of overflows from sloughs of the Sacramento River and streams flowing east from the Coast Range foothills. The fine textured sediments settled out of the slow-moving water once it entered the basin. Floodwater from the Sacramento River no longer reaches the basin because of levees, but the streams from the Coast Range foothills still reach the basin unimpeded. Flooding is still frequent and of long duration along the lowest areas of the basin. The soils in the basin occur as extensive areas of Willows and Clear Lake soils.

### Interfan Basins

This surface lies between the alluvial fans on the west side of the Sacramento Valley. The soils are those of the Capay, Alcapay, Willows, and Clear Lake series. They are fine textured, having horizons mostly of clay. This surface is depositional; fine textured sediments were deposited from the streams on the west side of the valley. These basins are used mostly for rice production.

### Alluvial Fans

The alluvial fans generally have two surfaces. The lower surface consists of immediate stream channels, which are flooded very regularly. This surface has been changed by stream diversion in many areas. The native vegetation was cottonwoods and willows that were mostly cleared but are returning in many areas. The soils are those of the Hustabel series, which have a texture of sandy loam in the upper part, and those of the Arand series, which are sandy. A slightly higher surface that is flooded less frequently makes up most of the area of the alluvial fans. The soils on this surface are those of the Westfan and Corval series, which are dominantly loamy. The cities of Williams and Maxwell are on these surfaces. Diversion of streams has reduced the risk of flooding. Flooding outside of stream channels occurs occasionally on the alluvial fan surface.

### Alluvial Terraces

This older surface is limited to terraces on the western margins of the Sacramento Valley and in a few areas in upland valleys. These terraces are no longer flooded, and erosion is replacing deposition as the means of constructing the surface. The soils are dominantly those of the Hillgate series, which have a subsoil of brownish clay or clay loam. The alluvial terrace surface grades very slowly into the alluvial fan surface and the interfan basin surface, which is difficult to locate in places. In the Arbuckle area, the alluvial terrace surface is overlain in places by a surface of alluvium that was deposited from streams that no longer deposit material on the surface. The soils in this area are those of the Arbuckle series, which generally are loamy and have gravel in the lower part of the subsoil.

The oldest alluvial terrace surface occurs as scattered erosional remnants on a small acreage along the lower margins of the foothills and in some foothill valleys. Erosion is the dominant process on this surface today. The soils are those of the Corning series, which are typically reddish brown or dark reddish brown, are dominantly neutral or slightly acid, and generally have dense clay in the upper part of the subsoil.

### Examples of Soil-type Patterns on the Landscape

USDA/NRCS (1998) prepared 2 schematic oblique 3-dimensional landscape sections, one showing the typical soils of the valley basin lands and the other showing the typical soils of the upland-alluvial fan interface along the foothill front (**Figure 3-Soils**). These characterize the general relief and relationship between older and younger geomorphic units with the soils present. Brief physical descriptions of each of the soils series shown in **Figure 3-Soils** are excerpted and paraphrased from the 2006 Colusa County Soil Survey and provided below in alphabetical order.

*Altamont Series.* The Altamont series consists of deep, well drained soils on foothills. These soils formed in residuum and colluvium weathered from calcareous sandstone, shale, and schist. Slope ranges from 5-50%. The A and B horizons texture is clay, silty clay, or clay loam. In some pedons, the lower part of the horizon is very gravelly. The depth to weathered shale ranges from 40-60 inches. (Hydrologic Soil Group D)

*Arbuckle Series.* The Arbuckle series consists of very deep, well drained soils on low terraces. These soils formed in alluvium derived from conglomerate and metasedimentary rocks. Slope ranges from 1-5%. The content of rock fragments ranges from 3-35%. The A and B horizon texture is clay, silty clay, or clay loam. In some pedons, the lower part of the horizon is very gravelly. The Bt1, Bt2, and Bt3 horizons texture is gravelly loam, gravelly sandy loam, gravelly sandy clay loam, gravelly clay loam, sandy clay loam, or loam. The content of gravel ranges from 3-35%. The content of clay ranges from 18-32%, and the content of coarse and very coarse sand is less than 20%. The BC horizon texture is stratified gravelly sandy clay loam to very gravelly clay loam. (Hydrologic Soil Group B)

*Ayar Series.* The Ayar series consists of very deep, well drained soils on hills. These soils formed in residuum weathered from calcareous sandstone, siltstone, and shale. Slope ranges from 5-50%. The weighted average clay content in the textural control section, from a depth of 10-40 inches, ranges from 40-55%. The depth to highly weathered bedrock ranges from 60-80 inches. The A, Bss, and Bw horizons texture is clay. The C horizon texture is clay loam or clay. (Hydrologic Soil Group D)

*Corbiere Series.* The Corbiere series consists of very deep, somewhat poorly drained soils on basin rims. These soils formed in alluvium derived from mixed sources. Slope ranges from 0-2%. The weighted average clay content in the 10- to 40-inch textural control section ranges from 35-50%. The sodium adsorption ratio ranges from 5-13 throughout the profile. The Ap horizon texture is silt loam. The content of clay ranges from 20-27%. The Bw horizon is silt loam or silty clay loam and averages 20-35% clay. The 2Bw horizon is silty clay and ranges from 40-55% clay. The 3Ab horizon is silty clay and has 40-50% clay. The 3Bssb horizon is silty clay and has 40-55% clay. (Hydrologic Soil Group C)

*Corning Series.* The Corning series consists of very deep, well drained soils on dissected terraces. These soils formed in alluvium derived from mixed rock sources. Slope ranges from 1-5%. The A horizon is clay loam. The content of gravel ranges from 0-15%. The Bt horizon is clay loam, clay, gravelly clay loam, gravelly clay, or gravelly sandy clay loam. The content of clay is 35-55% clay in the upper part of the horizon. The content of rock fragments is 5-35%, including 0-15% cobbles. The BC horizon is gravelly loamy sand, very gravelly loamy sand, gravelly sandy loam, very gravelly sandy loam, gravelly loam, or very gravelly loam. In some pedons, this horizon has discontinuous weak cementation. (Hydrologic Soil Group D)

*Corval Series.* The Corval series consists of very deep well drained soils on nearly level, high floodplains in narrow upland valleys and on alluvial fans. These soils formed in alluvium derived from mixed sources. Slope ranges from 0-3%. The weighted average clay content in the 10- to 40-inch textural control section ranges from 27-35%. The A horizon is loam or clay loam. The upper part of the Bw horizon is silty clay loam or clay loam. (Hydrologic Soil Group B)

*Moonbend Series.* The Moonbend series consists of very deep, somewhat poorly drained soils on floodplains. These soils formed in alluvium weathered from mixed rock sources. Slope ranges from 0-2%. The solum is 40-80 inches thick. The weighted average clay content in the 10- to 40-inch textural control section is 27-35%. The content of fine sand or coarser sand is 2-6%. The mollic epipedon is 25-42 inches thick. The Ap horizon is silt loam. The Bw horizon is loam, silt loam, silty clay loam, or clay loam and has 18-35% clay. The C horizon is loam or silt loam. (Hydrologic Soil Group C)

*Sehorn Series.* The Sehorn series consists of moderately deep, well drained soils on foothills. These soils formed in residuum weathered from calcareous sandstone and shale. Slope ranges from 9-50%. The weighted average clay content in the textural control section, from a depth of 10-35 inches, is 40-60%. The depth to highly fractured and weathered shale ranges from 20-40 inches. The A horizon is silty clay. The B horizon is silty clay or clay. Some pedons have very gravelly or extremely gravelly horizons in the lower part. (Hydrologic Soil Group D)

*Vina Series.* The Vina series consists of very deep well drained soils on floodplains. These soils formed in alluvium derived from mixed sources. Slope ranges from 0-2%. The weighted average clay content in the textural control section, from a depth of 10-40 inches, ranges from 12-18%. The Ap and A horizons are loam or fine sandy loam. The AC horizon is loam, fine sandy loam, or silt loam. The C horizon is sandy loam or silt loam. (Hydrologic Soil Group B)

*Willows Series.* The Willows series consists of very deep, poorly drained soils in basins. These soils formed in alluvium derived from mixed sources. Slope ranges from 0-2%. The weighted average clay content in the textural control section, from a depth of 10-40 inches, ranges from 40-60%. The A horizon is silty clay. The Bw, Bssy, and Bssky horizons are silty clay or clay. (Hydrologic Soil Group D)

### General Soil Maps from County Soil Surveys

**Yolo County.** At least 10 of the 12 soil associations mapped in larger Yolo County (Anderson 1972) occur within the Colusa Basin Watershed lands forming its northeast corner (**Figure 4-Soils**). These include well drained to poorly drained soils on alluvial fans, base rims and terraces and in basins lying east of the Hungry Hollow escarpment, and somewhat excessively drained to well drained soils on the deeply dissected uplands and high terraces comprising the Dunnigan Hills area, which are underlain by the Tertiary Tehama Formation alluvium.

**Colusa County.** Seven of the 12 soil associations mapped in Colusa County (USDA/NRCS 1998) occur in the Colusa Basin Watershed, the other 5 occurring in the foothills and mountains within the Coast Range geologic province lying to the west where a different geologic parent material is present **(Figure 5-Soils**). The soils in the foothills along the western third of the Colusa Basin watershed are mostly the Millsholm-Goldeagle-Contra Costa association, with lesser amounts of the Altamont-Ayar association (see, e.g., **Figure 3-Soils**). These associations comprise "gently sloping to very steep, well drained soils formed in residium from sandstone and shale" (USDA/NRCS 1998). The Millshol-Goldeagle-Contra Costa association occurs both on foothills dissected in the Great Valley Sequence rocks and the Tehama Formation — the General Soil Map of Colusa County maps the Tehama Formation in with the Great Valley Sequence.

The Altamont-Ayar soils are finer textured, occurring within the most deeply dissected Cretaceous bedrock areas including the Antelope Valley and the upper watershed areas of Stone Corral Creek and Funks Creek and the lesser upper watershed areas of Logan Creek, Hunters Creek, Lurline Creek, Manor Slough, and Glenn Valley Slough. Altamont-Ayar soils also occur on the northwestern portion of the Cortina Creek alluvial fan and immediately to the northwest where the Tehama Formation is deeply dissected including the northern part of the Walters Creek upper watershed and most of the Spring Creek upper watershed and on the lesser developed coalescing alluvial fans of Walters Creek and Spring Creek. Altamont-Ayar soils occur in patches within the lowest valley floor elevations along deeply dissected Cretaceous foothills from Williams to Willows, where it is commonly transected by the Tehama-Colusa Canal.

The Capay-Hillgate-Salt Canyon association comprise "very deep, nearly level to gently sloping, well to somewhat poorly drained soils on alluvial fans, terraces and basins in Coast Range valleys, formed in alluvium from mixed rock sources" (USDA/NRCS 1998) occurring within the eastern extent of the deeply dissected and alluvium filled Cretaceous bedrock foothills drained by Freshwater Creek, Glenn Valley Slough, Manor Slough, and Lurline Creek. Capay-Hillgate-Salt Canyon soils also occur widely on the mid-elevation foothill valley floor of Spring Creek and in lesser amounts on some of the older alluvium in the foothill valleys of Cortina Creek and Sand Creek.

The Hillgate-Arbuckle-Corval-Corning association is comprised of "very deep, nearly level to moderately sloping, well drained soils on terraces, floodplains, and alluvial fans of the west side of the Sacramento Valley, formed in alluvium from mixed rock sources" (USDA/NRCS 1998) occurring on the older alluvium forming the narrow foothill valleys and more broadly forming the upper alluvial fan and fan terraces from Petroleum Creek on the south to Cortina Creek on the north. Hillgate-Arbuckle-Corval-Corning soils also occur to a somewhat lesser degree on the foothill valleys and upper alluvial fan surfaces of Walters Creek, Spring Creek, and Salt Creek. Rather poorly developed in the Freshwater Creek subwatershed, the association occurs rather broadly in the mid-elevation upper watershed areas of Manor Slough, Glenn Valley Slough, and Lurline Creek. The association occurs much more broadly on the larger alluvial fans of Stone Corral Creek Funks Creek, and Hunters Creek, including to the east of Interstate 5 where the fans are primarily underlain by older alluvium of the lower Riverbank Formation. Its extent on these rather low elevation or otherwise poorly developed and more severely dissected and backfilled fans is comparable to its extent on the higher elevation fans between Cortina Creek and Petroleum Creek.

The Westfan-Mallard association are "very deep, nearly level to moderately sloping, well drained soils on terraces, floodplains and alluvial fans of the west side of the Sacramento Valley, formed in alluvium from mixed rock sources" (USDA/NRCS 1998). Westfan-Mallard soils occur on the lower elevation more gradually-sloped alluvial fans surfaces from Petroleum Creek on the south to Freshwater Creek on the north.

The Willows-Clear Lake-Capay association of basin soils also occurs on alluvial fans surfaces and interfan basin areas. These are "very deep, nearly level, moderately well to poorly drained, fine texture soils in basins of the west side of the Sacramento Valley, formed in alluvium from mixed rock sources" (USDA/NRCS 1998). These soils map rather consistently with the Holocene basin deposits (Qb) of Helley and Harwood (1985). Willows-Clear Lake-Capay soils occur in the upper parts of the lower Colusa Basin where they are probably several tens of ft deep. They also occur on the valley floor of Spring Valley and the mid-elevation foothill valley of Stone Corral Creek near the vicinity of Swifts Stone Corral.

The Vina-Moonbend-Scribner association of floodplain soils are "very deep, nearly-level, well to poorly drained soils on floodplains of the Sacramento River, formed in alluvium from mixed rock sources" (USDA/NRCS 1998) occurring along the length of the Sacramento River and deposited by Sacramento River sloughs within the Colusa Basin to form the valuable loamy Vina and Moonbend soils. Vina-Moonbend-Scribner soils are also mapped occurring on the channel beds of Sand Creek, Whiskey Creek, Elk Creek, Salt Creek, and Petroleum Creek, generally corresponding to the Holcene stream channel deposits (Qsc) of Helley and Harwood (1985). Where Helley and Harwood mapped the channel beds as undivided alluvium (Qa) or basin deposits (Qb), they are not mapped as Vina-Moonbend-Scribner soils.

An isolated area of Vina-Moonbend-Scribner soils lies along the distal end of the Salt Creek fan about 3 mi east-southeast of Arbuckle. These soils appear to be formed on loamy alluvium deposited by Sycamore Slough when it traced farther to the west than it did according to the earliest historical maps and accounts. College City lies on these soils, probably due to the reduced flooding intensity afforded by its somewhat higher elevation and well-drained soils. These soils probably also supported a riparian gallery forest affording microclimate benefits. It also appears that Sycamore Slough was enjoined by tributaries Dry Slough and Tule Slough near this location, possibly making it an early transportation hub given that the slough channels were probably used by the Native Americans for that purpose, and the sloughs later needed to be traversed by ferries during the early years of EuroAmerican settlement (Kelley 1989).

**Glenn County.** Fourteen of the 22 soil associations mapped in Glenn County (Begg 1968) occur in the Colusa Basin Watershed (**Figure 6-Soils**). Soils of the more recent alluvial fans and floodplains occur on the natural levees and alluvial fan type floodplain deposits along the western edge of the Sacramento River and the more recently active floodplain channels draining the relict Stony Creek fan to the southeast of Orland.

The basin soils occur on the lowest elevation, flatter gradient surfaces lying generally to the southeast of Willows where floodwaters from the Sacramento River, the relict Stony Creek alluvial fan surface, and the western foothill streams coalesce and form the upstream end of the low trough of valley basin lands characteristic of the watershed.

Soils of the older alluvial fans and low terraces occur on the inactive portions of the relict Stony Creek alluvial fan surface and the coalesced lower alluvial fan surfaces lying along the foothill front from near Orland to south of Willows. These soils also occur on the foothill valleys dissected in the Tehama Formation rocks in the northwest and the Cretaceous bedrock south of Nye Creek. Soils of the foothills occur on the dissected upland areas. Newville-Corning soils occur chiefly on the dissected Tehama Formation foothills underlying the Walker Creek and Wilson Creek upper watersheds, and develop a clay hardpan similar to the Corning soils occurring in Colusa County. Begg (1968) observed:

> In the foothills the soils formed mainly in material from hard, unaltered sedimentary rock of the Knoxville formation, and of other formations of the Cretaceous period, and from softly consolidated siltstone of the Tehama formation. Rock crops out in a few places, chiefly on steep hogback ridges. On the terrace the areas consist of poorly sorted gravelly deposits that overlie hard sedimentary rocks of the Knoxville formation and of the other formations of the lower Cretaceous period. The areas are partly dissected as the result of geologic erosion. Except for small, scattered remnants that dip gently to the east, little remains of the original surface of the terrace.

### Effects of Human Activities on Alkali Soils

In conducting his extensive field work between 1912 and 1914, Bryan observed the presence of salt grass indicative of alkali soils fringing the western edge of the Colusa Basin and referred to maps of alkali soils of Lapham et al. (1907) and Mann et al. (1909), but he seemed to minimize the agricultural problems alkali soils would pose to future agricultural development in the watershed (1923).

> Although there are in the valley large areas that have a shallow water table, which is favorable to evaporation and the accumulation of alkali, only comparatively small areas are unfitted for agriculture from this cause. This condition seems to be due to the following reasons:
>
> 1. The ground waters are of good quality. The east-side waters contain from 100 to 250 parts per million of dissolved substances, mostly calcium and the bicarbonate radicle, and the west-side waters contain from 200 to 600 parts per million of dissolved substances, largely calcium and the bicarbonate and sulphate radicles…
>
> 2. The water table is very flat over the basins, and movements of the ground water are sluggish. Water is supplied more freely at the bases of the slopes, and for this reason the principal concentration of alkali occurs at the edges of the basins. This is particularly the case on the west side, where alkaline patches and areas of salt grass border the basins along their western edges. The distribution of alkaline land on the west side of the valley is set forth in the soil reports on the Colusa and Woodland areas.

3. The heavy winter rains leach out much of the salts concentrated at the surface. Similarly flood waters wash out the salts in overflowed lands, and on the edges of the plains the same waters deposit mud or sediment, which often covers up the alkali.

By 1968, writing on the subject of alkali soils and reclamation potential in Glenn County Begg (1968:92) implied that not much reclamation had been accomplished by that time, and was seemingly rather dubious on the reclamation potential of alkali basin lands in southeastern Glenn County:

> In Glenn County the soils in 52,941 acres contain excess salts and alkali in amounts large enough to affect plant growth. These soils are mostly in basins south and east of Willows and southeast of Butte City (fig. 10)…
>
> Saline-alkali soils contain soluble salts and exchangeable sodium (alkali) in amounts that interfere with the growth of most crop plants. In saline-alkali soils the percentage of exchangeable sodium is greater than 15, and the electrical conductivity of the saturation extract is greater than 4 millimhos per centimeter at 25 degrees C. The pH reading of the saturated soil generally is less than 8.5…
>
> Three classes of saline-alkali soils were mapped: *Slightly saline-alkali, moderately saline-alkali,* and *strongly saline-alkali.* From 5 to 20 percent of the total area of a slightly saline-alkali soil is affected by salts and alkali. Only those crops that tolerate salt and alkali can be grown on such a soil, and these with moderate to good success. From 20 to 70 percent of the area of a moderately saline-alkali soil is affected by salts and alkali. Irrigated pasture, sugarbeets, and rice can be grown on such a soil with limited success, but the affected areas must be reclaimed before most other crops can be grown. More than 70 percent of the area of a strongly saline-alkali soil is affected by salts and alkali. No crops can be grown successfully on these soils without reclamation.
>
> Opportunity for reclaiming saline-alkali soils in Glenn County is now limited because large acreages of rice are grown in and around the affected areas. Ponding of water is necessary for growing rice, but it causes a high water table to develop. The resulting poor drainage prevents leaching of soluble salts and facilitates the buildup of excess salts and alkali in fields not used for rice.

Note that fig. 10 is reproduced in this assessment as **Figure 7-Soils**. It shows the close correspondence between the location of strongly saline-alkali soils and the present location of the Sacramento NWR.

Table 23 of the Colusa County Soil Survey (USDA/NRCS 1998) gives the salinity profile for individual soil types but not necessarily for every soil mapping unit. On the subject of alkali soils in Colusa County, USDA/NRCS (1998) states:

> Large areas of the basin surface were affected by the accumulation of sodium and have been partially reclaimed over the last 80 years. Additions of gypsum and other soil amendments and annual flooding for rice production leached the soil salts down to 3 or 4 feet in most areas. As rice roots extend to a depth of only about 12 inches, the soil reclamation efforts here are adequate for rice and excellent yields are obtained. It appears that the dense clays that extend to a depth of 8 feet or more and the ground water table, which is usually not lower than 6 feet, limit the further

> reclamation of these soils. Fields that are not planted for several years will have salts transported upwards to the surface through evaporation. As the basin rises to the west it meets distal ends of alluvial fans and joins some interfan basins east of Interstate 5…
>
> The accumulation of sodium was severe in these [interfan] basins, and reclamation was started in the 1970s, after the Tehama-Colusa canal was built. Many areas are now sufficiently reclaimed to produce good yields of rice, but salty areas remain. Alcapay soils have excess sodium as high as 2 feet in their profile and yet they produce good rice yields if managed carefully.

The 1948 Soils of Colusa County California includes a map of the distribution of alkali but it is not reproduced in this assessment. The locations of the Sacramento, Delevan, and Colusa NWRs generally correspond to areas with the strongest saline-alkali soils or the most severe alkali problems in the alkali maps from the old surveys (Jack Alderson, NRCS Agricultural Engineer, pers. comm., July 2008). Elsewhere, the acreage in rice production also generally indicates the extent of alkali soils. However, the correspondence between rice and alkali soils is not strong. Much of the rice ground is not on soils that were mapped as alkali. However, most of the soils that were mapped as alkali are either in the refuges or in rice.

### Effects of Human Activities on Soil Erosion

Soil erosion is a natural process that is difficult to measure accurately or model-estimate effectively. Long-term average soil erosion rates from a given surface depend on a multitude of factors including some measure of the soils intrinsic erodibility, its potential for inducing stormwater runoff sufficient to transport its eroded particles, and steepness of slope. The presence and type of vegetative cover, roots, and surface and subsurface organic matter also factor in the process, as do several climate factors, including freeze-thaw potential, mix of precipitation types, and measures of precipitation intensity, both average annual depths and individual storm depths and intensities.

Few estimates have been made of soil erosion rates in the Colusa Basin Watershed. USGS (1972) measured suspended sediment load for a few years at the now decommissioned Stone Corral Creek stream gage, estimating the annual sediment yield to average about 99 tons per square mile watershed area. This investigation provides a generally accurate snapshot of likely sediment yields from that one basin, estimates that are best viewed not as absolute values but in relative terms (i.e., how did the estimated sediment yield during those particular years compare with the estimates in other Coast Range watersheds?).

Planning work related to early and recent proposals to construct foothill detention reservoirs has generated model-estimates of sediment yield partly calibrated by those limited Stone Corral Creek data, which are presented in this section. These model estimates make use of the properties of the soils documented in the county soil survey reports: the NRCS delineates individual soils according to numerous measured and estimated physical characteristics, including engineering and drainage factors, color, texture, origin, agricultural potential, infiltration capacity, and susceptibility to wind and rill erosion. Some of these basic technical data are also summarized below.

Better sediment yield estimates are often obtained from reservoir sedimentation studies. Indeed, more and better sediment yield data have been collected in the neighboring Stony Creek Watershed where yields have been determined by measurement of cumulative reservoir sedimentation adjusted for estimated throughput of finer sediment. These are relevant because the upper Stony Creek tributaries drain a terrain of roughly similar relief and parent geologic material. For example, Black Butte Reservoir sedimentation resulting from sediment contributions from Upper Stony Creek watershed has been rather well documented (H. T. Harvey & Associates 2007). The watersheds contributing to Black Butte Reservoir, Stony Gorge Reservoir, and East Park Reservoir are only partly underlain by the Cretaceous bedrock forming the foothills of the Colusa Basin Watershed.

There is scarcely a technical basis from which to estimate the background (pre-development) sediment yields and soil runoff rates from the watershed lands, much less to estimate the amount that human activities have increased soil erosion. The geomorphology section of this assessment casually observed that there was likely increased sediment runoff generated on the steeper upper fan surfaces beginning with the rapid proliferation of dryland grain farming in the late 19$^{th}$ century. There may have also been a second wave of increased soil erosion in these areas after row crops and orchards were installed to make use of the irrigation water the Tehama-Colusa canal brought in the 1970s. The geomorphology section futher recognized that stream channelization of the foothill streams and lower alluvial fan surfaces, and later on some of the upper fan surfaces (generally corresponding with the irrigated agriculture installed there in the 1970s) may have significantly increased bank erosion. Undoubtedly invasion of Mediterranean annual grasses first and grazing impacts second have had some effect on soil erosion in the upper watershed areas. Loss of soil on the lowest alluvial fan surfaces and the basin lands has probably occurred not only resulting from agricultural practices, but certainly in some places more from flood control projects that have reduced, or in some cases displaced, contributions of soil-forming sediment from Sacramento River and foothill stream overflows.

**Soil Runoff Potential.** The NRCS defines 4 hydrologic soil groups based on estimates of runoff potential. Soils are assigned to one of 4 groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long duration storms. The 4 hydrologic soil groups are summarized below.

> Group A. Soils that exhibit a high infiltration rate (lowest runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission (approximately 8-12 mm/hr).
>
> Group B. Soils that exhibit a moderate infiltration rate (moderately low runoff potential) when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission (approximately 4-8 mm/hr).
>
> Group C. Soils that exhibit a slow infiltration rate (moderately high runoff potential) when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission (approximately 1-4 mm/hr).

Group D. Soils that exhibit a very slow infiltration rate (highest runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission (approximately 0-1 mm/hr).

Overall, a large percentage of the Colusa Basin Watershed is covered with soils with the highest and moderately high runoff potential, especially in the foothills area on the western half of the watershed. For example, CH2MHill (2003) determined that 55% of the Willows-Wilson Creek watershed area on the north side of the watershed is underlain by soils with high runoff potential (**Figure 8-Soils).** A comparable hydrologic soil type map was not located for other areas of the watershed during the preparation of this draft of the assessment.

**Soil Permeability.** Bertoldi (1973) prepared a general map of soil permeability of the Sacramento Valley floor which showed the most permeable soils in the Colusa Basin Watershed occurred along the distal alluvial fans surfaces south of Williams and within 4-5 mi west of Interstate 5 and also in parts of the Colusa Basin (**Figure 9-Soils**). Bertoldi also mapped presence of clay hardpan in Mormon Basin and underlying most of the Tehama Formation within his study area south of Williams, a mapping unit differing considerably from the area of terrace soils with dense clay subsoils (Cand) mapped by Storie and Weir (1951).

**Soil Erodibility.** The NRCS estimated soil erosion factors are the K factor (Kw and Kf) and the T factor. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. K factor estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and permeability. Values of K range from 0.02-0.69. The higher the value, the more susceptible the soil is to sheet and rill erosion by water. Factor K is only one of 6 factors used in the Universal Soil Loss Equation [USLE] and the Revised Universal Soil Loss Equation [RUSLE] to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. Erosion factor Kf indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size. Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind or water in tons per acre per year that can occur without affecting crop productivity over a sustained period.

**Sediment Yield Estimates.** UC Davis (1980) used a variation of the USLE or RUSLE to estimate the sediment runoff from 24 foothill and valley flat subwatersheds. In general, estimated sediment yields ranged from about 150-550 tons per square mile per year for the foothill subwatersheds and were generally as low as about 10 tons per square mile per year for the valley flat subwatersheds **Table Soils-1**. In general, foothill subwatersheds in the southern portion of the watershed, including Buckeye Creek and Oat Creek, were estimated to yield the greatest amount of sediment per square mile. Sediment yields from valley flat subwatersheds are generally about 2 orders of magnitude less than from the foothill stream subwatersheds.

In general, analytical sediment yield estimates based on the USLE and RUSLE equations are less accurate for watersheds with steep upland areas than they are for watersheds with low to moderate relief. The results are less reliable as absolute values of sediment yield, but useful as relative values for comparison between subwatersheds. Moreover, sediment yields should be expected to vary from year to year by at least 2-3 orders of magnitude. Estimated average annual yields may only be useful in planning for long-term reservoir sedimentation. Navigant Consulting Inc. (2000) used these estimates as a basis for evaluating potential reservoir sedimentation in each of the 14 foothill stormwater detention reservoirs proposed by Colusa Basin Drainage District [CBDD] and USBR. The foothill stormwater detention basins would trap coarse-grained but not fine-grained sediment and reduce coarse-grained sediment supplied to the downstream foothill streams.

According to Navigant Consulting, Inc. (2000) the U.S. Department of Agriculture Soil Conservation Service (1979) studied soil erosion using air photo and field investigation methods in the Buckeye Creek and Dunnigan Creek subwatersheds, finding that the primary sources of soil erosion were sheet and rill erosion by rainfall-runoff (52%), streambank erosion (44%); transportation facilities erosion (4%), and gully erosion (4%). Of the sheet and rill erosion amount, 78% was on rangeland, 18% on dryland and grainland, and 4% on irrigated cropland and other uses.

**Rangeland Practices.** Stakeholders have raised concerns that historical rangeland management and grazing in the foothill stream subwatersheds may have increased the frequency and severity of flooding on valley lands in the watershed. It is widely perceived that replacement of deep-rooted native grasses with shallow-rooted non-native grasses combined with the soil compaction and vegetation limiting effects of grazing have (1) substantially reduced the infiltration capacity of upland soils leading to increased peak flow discharges and (2) substantially reduced the stability of upland soils on steeper slopes leading to increased sediment discharges caused by increased mass wasting and soil surface rill erosion.

CH2MHill (2003) evaluated alternatives that the CBDD proposed for reducing flooding in the vicinity of Willows, specifically stormwater detention reservoirs at each of 3 foothill subwatersheds in Glenn County (North and South Fork Willow Creek and Wilson Creek). CH2MHill (2003) recommended changes in rangeland management practices and reforestation of upland areas to reduce peak flow and sediment discharged to the watershed and/or to the proposed detention reservoirs. These are summarized in the flood management section of this assessment. However, CH2MHill (2003) concluded that while rangeland management changes and reforestation would have a measurable impact on peak flow reduction, the potential benefits were limited by the widespread coverage of clayey-soils with naturally high runoff potential in the foothills area.

It should be noted that the introduction of Mediterranean annuals is a factor in the replacement of deep-rooted native perennials by shallow-rooted non-native annuals that is not entirely a result of grazing.

**Table 1. Soils. Estimated Sediment Yields from Foothill Subwatersheds.**

| Subwatershed | | | Soil Loss* | |
|---|---|---|---|---|
| **Number** | **Name** | **Area ($mi^2$)** | **(tons)** | **(tons/$mi^2$)** |
| I | Willow & Walker Creeks | 243 | 54,817 | 226 |
| II | Logan Creek | 149 | 26,902 | 181 |
| III | Stone Corral Creek | 128 | 42,645 | 333 |
| IV | Lurline Creek | 90 | 15,139 | 168 |
| V | Freshwater Creek | 122 | 27,299 | 224 |
| VI | Sand Creek | 146 | 22,500 | 154 |
| VII | Salt Creek | 31 | 11,197 | 367 |
| VIII | College City Area | 15 | 100 | 7 |
| IX | Petroleum Creek | 36 | 6,240 | 181 |
| X | Buckeye Creek | 52 | 28,634 | 548 |
| XI | Bird Creek | 14 | 3,329 | 233 |
| XII | Oat Creek | 31 | 13,280 | 435 |
| XIII | Brenton Creek | 21 | 6,341 | 298 |
| XIV | Smith Creek | 11 | 1,479 | 133 |
| XV | Dufour Creek | 36 | 3,444 | 95 |
| XVI | Meridian Edge | 8 | 1,783 | 217 |
| XVII | West Canal Landing | 20 | 134 | 7 |
| XVIII | Maxwell Northeast Drain | 10 | 68 | 7 |
| XIX | Provident Dram | 40 | 335 | 8 |
| XX | Larkins Children's Ranchero | 100 | 863 | 9 |
| XXI | Bounde Creek | 22 | 199 | 9 |
| XXII | Packer Road | 13 | 97 | 8 |
| XXIII | Harbison Grant | 37 | 276 | 8 |
| XXIV | Southeast Basin | 148 | 1,596 | 11 |
| **Totals** | | **1,523** | **268,924** | |
| **Average Soil Loss for Total Watershed** | | | | **117** |

* Rounded to nearest mi, ton, or ton/$mi^2$.

Source: Navigant Consulting Inc. 2000

## CASE STUDY: NORTH BRANCH SAND CREEK

Geologic cross-sections and profile sections of North Branch Sand Creek extended through the Colusa Basin were presented in the geology section of this assessment. We also mapped onto these section charts the individual soil mapping units where they occur along them and a legend of the individual soil mapping units. Floodplain soils occur where there are natural levees and gradually-sloped floodplain and basin deposits near the Sacramento River (**Figure 13-Geology).** Elevated channel ridge alluvial deposits and floodplain soils occur where Corbiere and Dry Creek Sloughs pass into the upper part of the lower Colusa Basin. Vina soils (171) occur on these elevated floodplain deposits. Frequently flooded willows silty clay basin soils (105) occur within the flat Mormon Basin. Vina soils occur again on the elevated Sycamore Slough channel ridge and floodplain deposits. The Sycamore Slough channel ridge encloses Mormon Basin and forms the northern boundary of the lower Colusa Basin. The upper Colusa Basin lies upstream from this ridge (**Figure 20-Geology**).

The upper basin appears to extend to within about 8000 ft from the Interstate 5 freeway, the western edge of Holocene basin deposits (Qb). The Willows Silt Clay (106) and other basin soils occur on the basin deposits. Basin soil Capay clay loam (102) occurs within 1000 ft of Interstate 5. The Capay clay loam occurs on a large part of the interfan basin area to the northwest extending to some distance away from the Colusa Basin.

A section is taken at the western edge of the Capay clay loam and considered a typical Holocene distal alluvial fan section (**Figure 17-Geology**). The Capay clay loam (102) occurs to the north of the North Branch Sand Creek channel where it is developed on eroded channel ridge (Qa) and basin deposits lying between the channel ridge (Qb) and the eroded upper Modesto (Qmu) lying to the south of the channel. Another abandoned channel ridge deposit (Qa) lies about 3000 ft to the south of North Branch Sand Creek which appears to be formed recently by a former distributary channel that was still somewhat well topographically preserved in 1949 (**Figure 19-Geology**). As is the pattern, basin deposits also occur on both sides of this abandoned channel ridge, but more narrowly either because the deposits are younger or limited by the somewhat steeper fan slope south of the channel than north of the channel (the currently active channel is situated to the north of its fan's central axis.) Floodplain soils are formed on the recent alluvial basin deposits, and basin soils are formed still farther to the south. These are associated with the area bounded by the more substantial and downslope reaching active channel ridge deposits of the South Branch Sand Creek and Salt Creek, which coalesce beginning just south of the section endpoint, about 5000 ft south of the North Branch channel.

Upstream from Interstate 5, the channel gets progressively steeper and the recent stream channel deposits of North Branch Sand Creek (Qa) are wider and better preserved (**Figure 13-Geology**). The soils continue to be sandy and loamy Westfan loam (112) until further upslope when they give way to Westfan gravelly loam (193) and Arand very gravelly sandy loam (189) beginning about 4000 ft upstream (**Figure 19-Geology**).

Beginning about 7500 ft upstream from the Tehama Colusa Canal, the active channel of North Branch Sand Creek widens considerably to about 300 ft width and both the 1993-1999 air photos and the 1949 topographic map indicate there are recently active natural distributary channels emanating from this area. This is also the vicinity below which fanhead terraces of the somewhat older Pleistocene lower Modesto alluvium Qml) are not exposed near the channel (**Figure 13-Geology**). A section is taken here to represent the Holocene alluvial fan apex (**Figure 16-Geology**). Riverwash floodplain soils (185) occur within the sand and gravel bedded active channel area. Arand very gravelly sandy loams (189) are formed on the recent alluvial deposits to either side, which to the south are recent basin deposits (Qb). These basin deposits appear confined within a narrow linear trough by a somewhat elevated former natural levee deposit of slightly older upper Modesto formation lying about 1000 ft south of the active channel. Gravelly loam (193) and locally very gravelly loams (189) are developed here and on the wide area of recent basin deposits (Qb) lying still to the north where the Sand Creek fan gives way to the lesser developed and more northerly trending alluvial fan deposits of Chamisal Creek and Cortina Creek.

A section is taken up fan near where the active fan apex was located approximately 300,000 to 450,000 years ago, where the section is taken up largely by a 60-ft-high terrace formed by alluvial deposits of the lower Riverbank Formation (**Figure 15-Geology**). Arbuckle sandy loam (150) is developed on the northerly Riverbank terrace surface, and Corning soils (230) are developed on the lesser remnant of the lower Riverbank alluvium flanking the Tehama Formation on the south end of the section. Corning soils are also developed on the adjacent dissected Tehama Formation surface. This contrasts with the more recently and steeper dissected Tehama Formation surfaces lying to the north of the section, where younger and shallower sandy clay loam and clay loam soils of the Goldeagle-Positas-Balcom Complex are developed. Riverwash soils (185) are developed on the active channel deposits, which are cut shallowly in the lower Modesto. The upper Riverbank terrace forming the southern part of the valley has been dissected where it is within about 1000 ft from the channel to form a lower terrace surface that appears flood prone under modern climate conditions. Sand Creek Road traverses this erosion lowered upper Riverbank terrace, where very gravelly sand loam (189) is developed. The Arbuckle sandy loam is developed on the higher remnant Riverbank terrace lying to the south.

A representative foothill valley section is taken about 13,500 ft upstream from the Pleistocene fanhead (**Figure 14-Geology**). Here the active channel is about 400 ft wide and scrolling slowly to the north despite the resistance of Tehama Formation rocks forming the valley wall. Lower Modesto alluvium forms the valley terrace. Where the terrace has been recently lowered within about 400-500 ft from the active channel there are recent channel bed formations typical of an active channel surface. Riverwash soils (185) extend to the south to include this lowered terrace area, although apparent recent channel bed incision in this section of the creek, discussed in the geology and geomorphology section of this assessment probably prevents flood overflow onto this surface. Arbuckle gravelly loam (152) is formed on the higher part of the lower Modesto terrace lying to the south, including where Sand Creek Road traverses its surface. Thin sandy clay loam and clay loam are developed on the steeply dissected Tehama Formation deposits forming the valley walls.

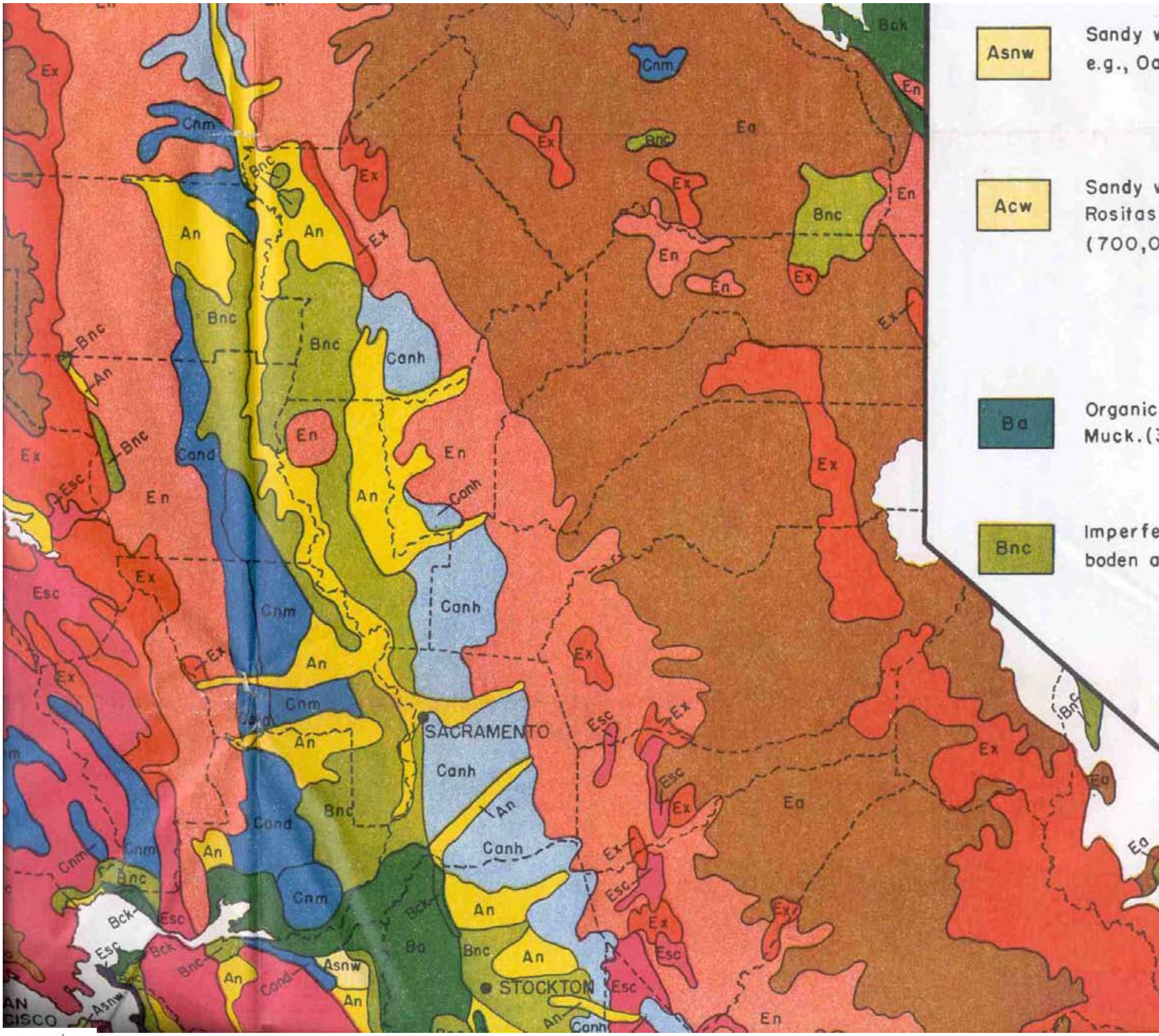
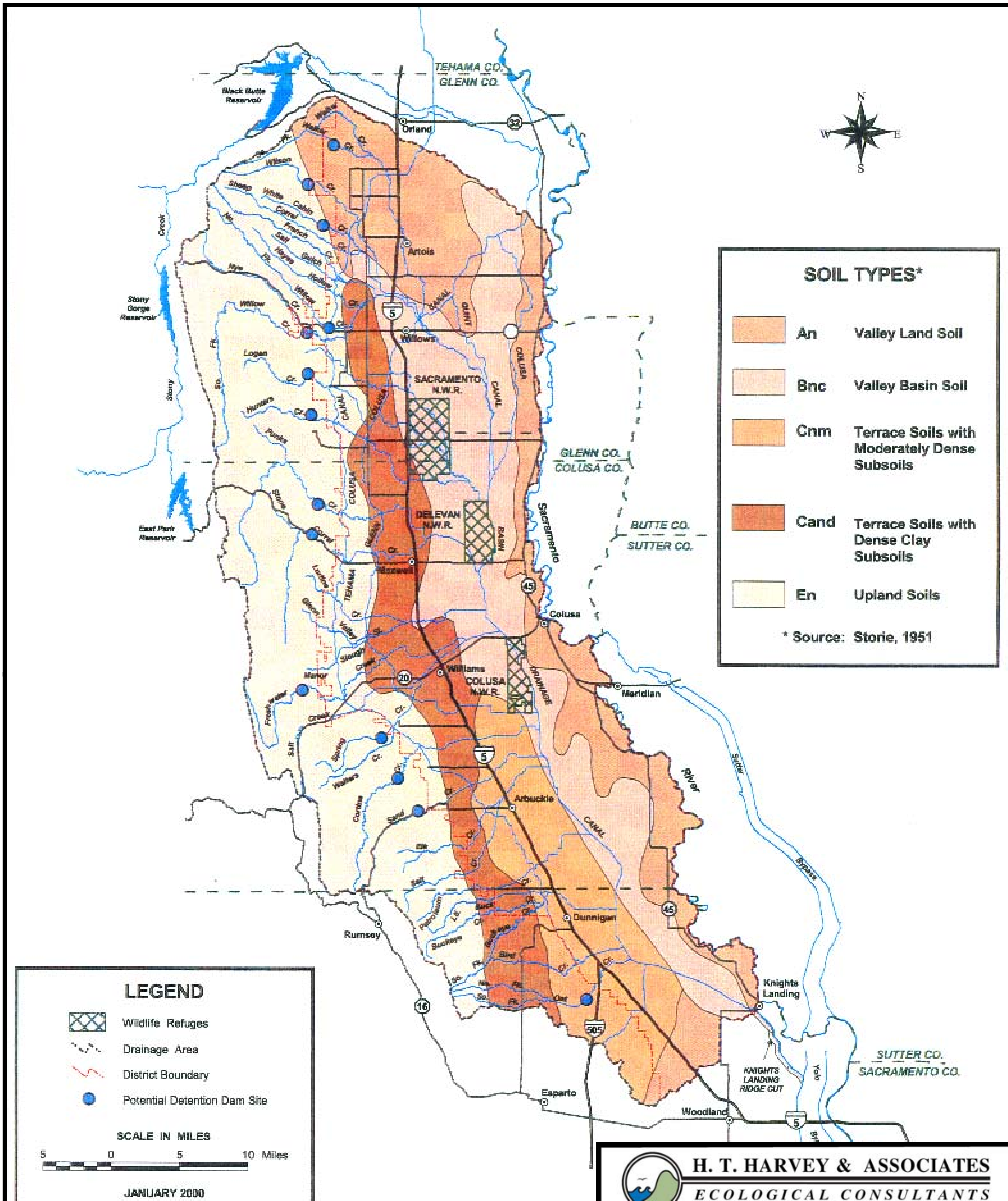



**Figure 1-Soils. Photocopy of generalized soil map of Storie and Weir (1951**
**Colusa Basin Watershed Area.**

geomorph

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*ECOLOGICAL CONSULTANTS*

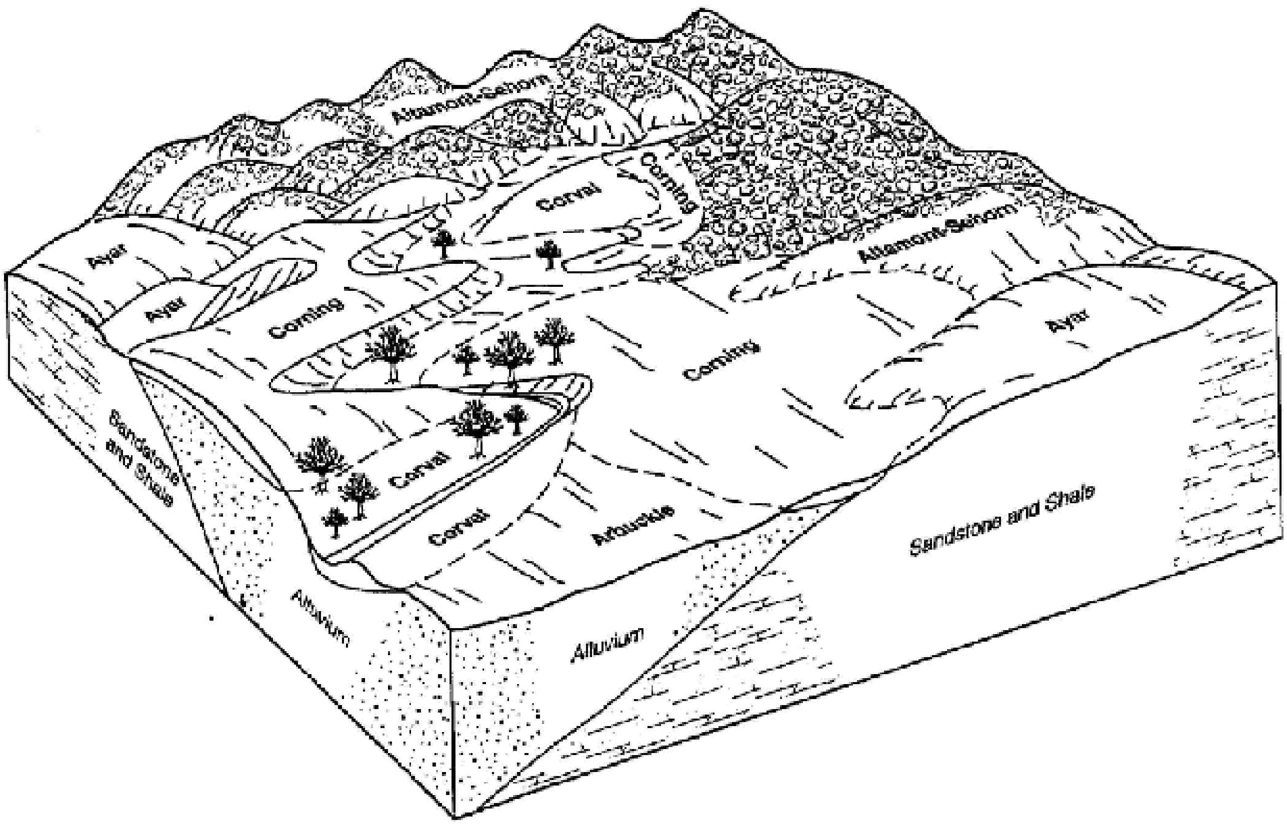
**Colusa Basin Watershed Assessment: General Soil Map**

| Proj No. **2850-01** | Date **Dec. 2008** | Figure **2 - Soils** |
|---|---|---|

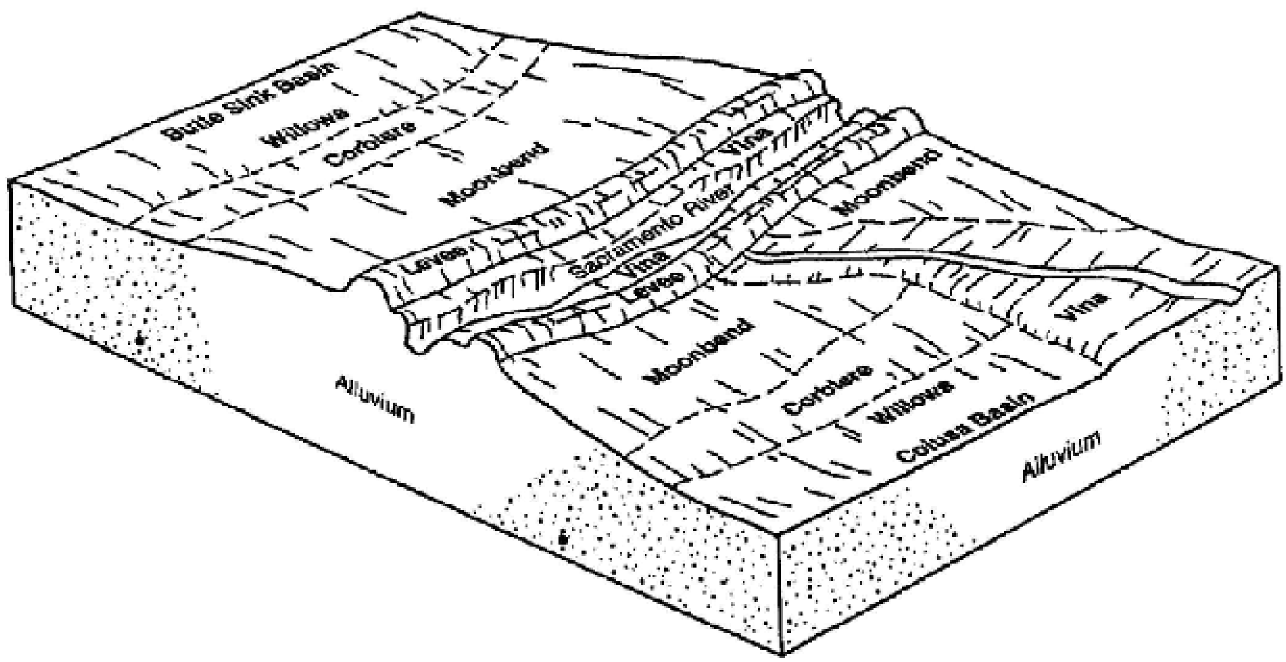
SM **N:\Projects\2850-01\Figures\April 2008**

**Source: Navigant Consulting 2000. Integrated Resources Management Program for Flood Control. Prepared for Colusa Basin Drainage District.**

**Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.**




Typical pattern of soils on the western edge of the Sacramento Valley and on the Coast Range foothills.




Typical pattern of soils along the Sacramento River, near the city of Colusa.

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ECOLOGICAL CONSULTANTS

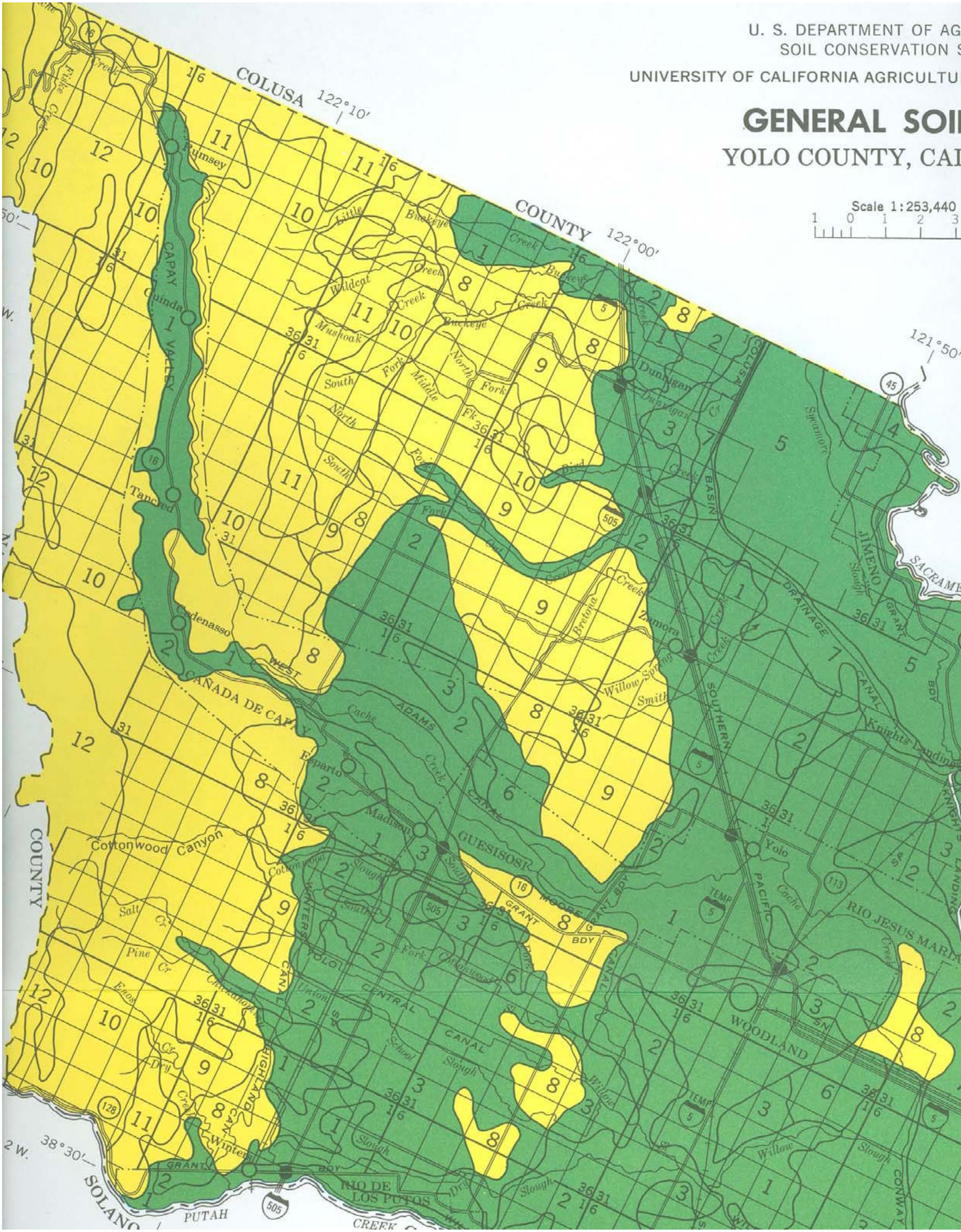
**Colusa Basin Watershed Assessment: Typical Soil Patterns**

| | | |
|---|---|---|
| Proj No. **2850-01** | Date **Dec. 2008** | Figure **3 - Soils** |

**SM** **N:\Projects\2850-01\Figures\April 2008**

**Source: United States Department of Agriculture and Natural Resources Conservation Service - 1998. Soil Survey of Colusa County, CA.**

**Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.**



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SOIL CONSERVATION S
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Tancred
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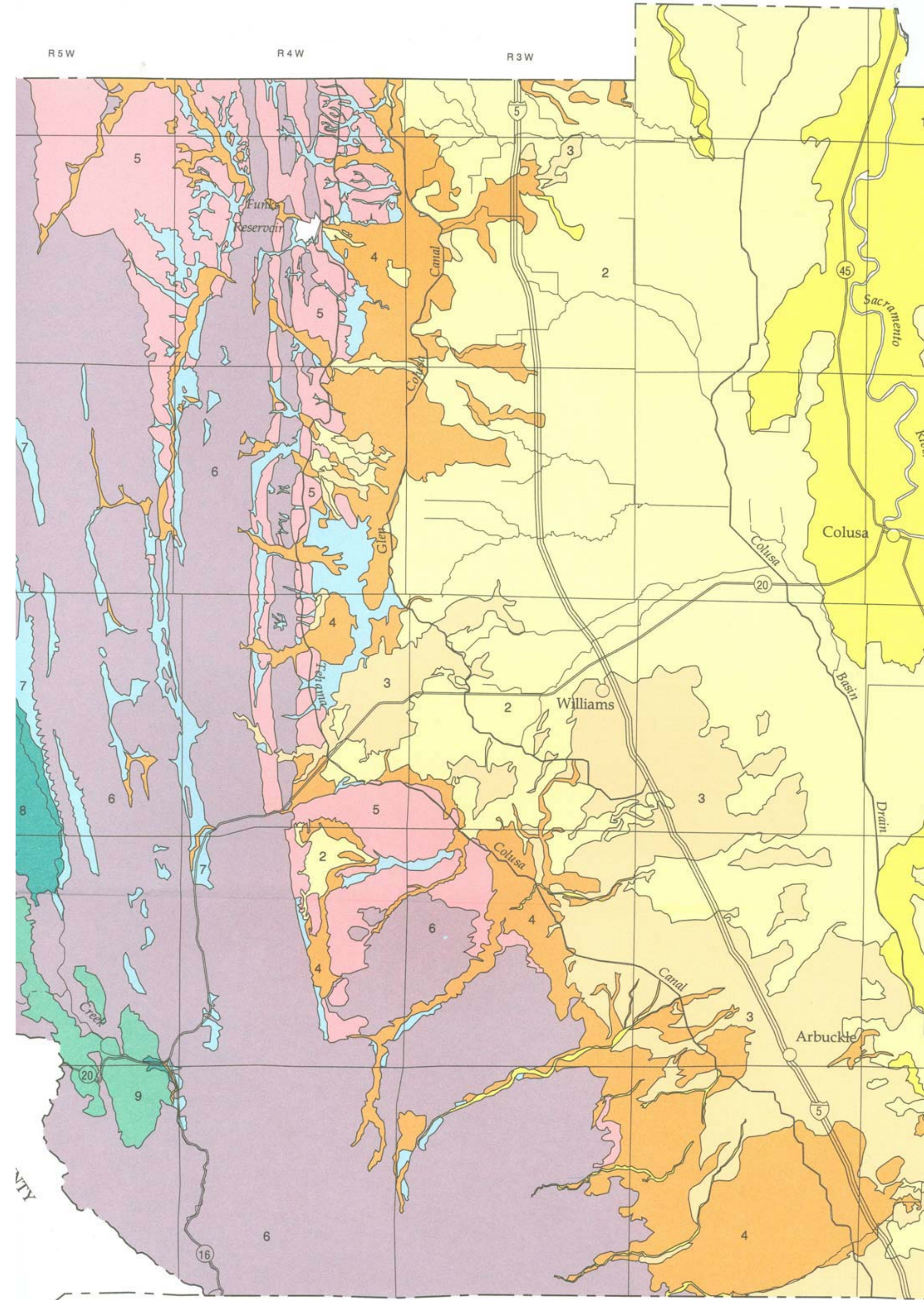
Madison
Dunnigan
Zamora
Yolo
Woodland
Winters
CAPAY VALLEY
CAÑADA DE CAPAY
WEST ADAMS CANAL
GUESISOSI
COLUSA BASIN DRAINAGE CANAL
JIMENO GRANT
SACRAME
KNIGHTS LANDING
RIO JESUS MARIA
RIO DE LOS PUTOS
PUTAH CREEK
SOUTHERN PACIFIC
WINTERS CANAL
YOLO CENTRAL CANAL
HIGHLAND CANAL
MOORE CANAL
GRANT BDY
CONWAY
Cache Creek
Buckeye Creek
Little Buckeye Creek
Wildcat Creek
Mushoak Creek
Bird Creek
Oat Creek
Bretona
Willow Spring Creek
Smith
Cottonwood Canyon
Salt Cr
Pine Cr
Dry Cr
Fiske Creek
Dunnigan Cr
Sycamore
Knights Landing
Cottonwood Slough
Union School Slough
Willow Slough
Enos
Chickahominy


R 5 W
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Funks Reservoir
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Tehama Colusa Canal
Colusa Basin Drain
Sacramento River
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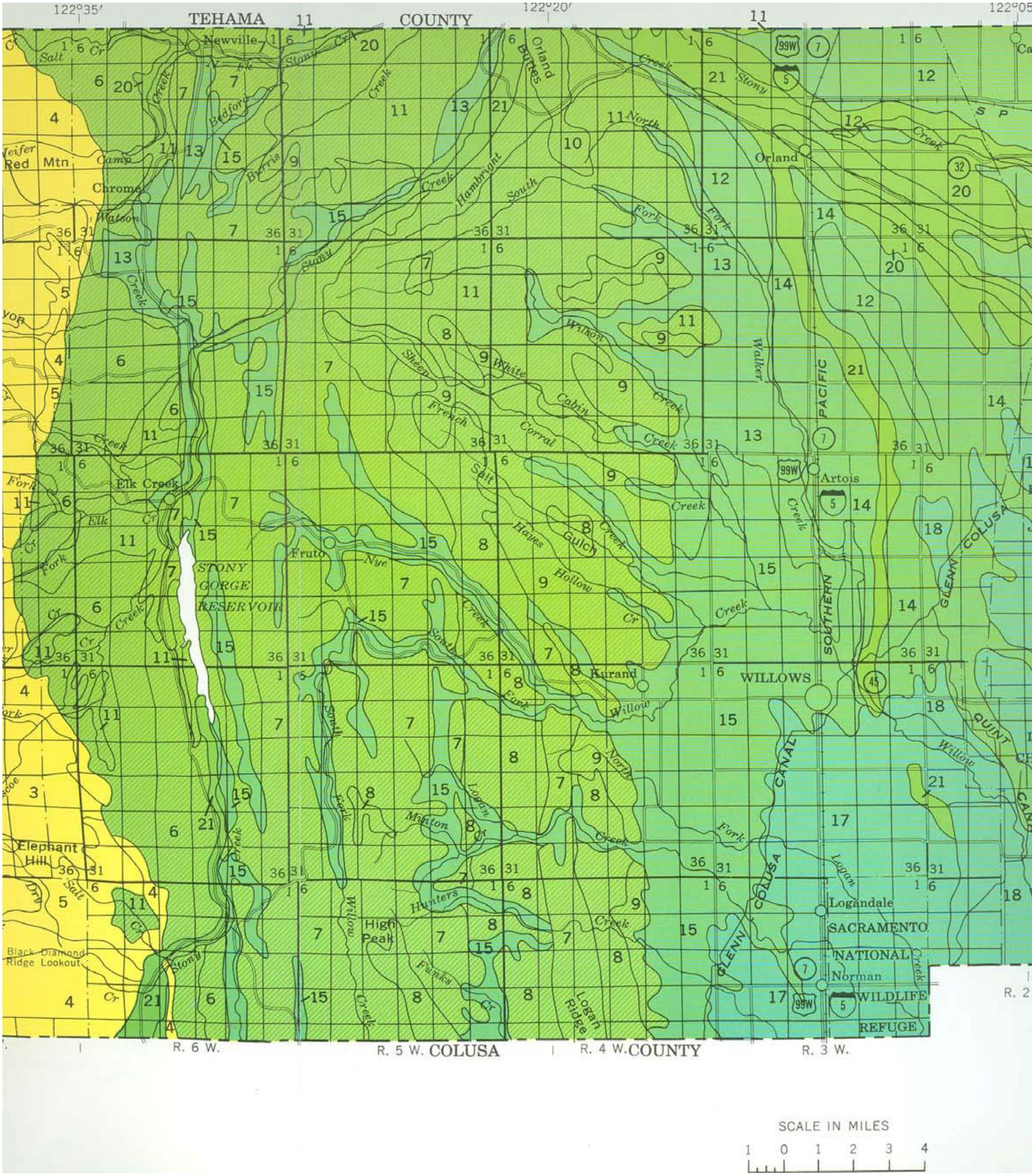



**Figure 6-Soils. Portion of General Soil Map of Glenn County (adapted from B**

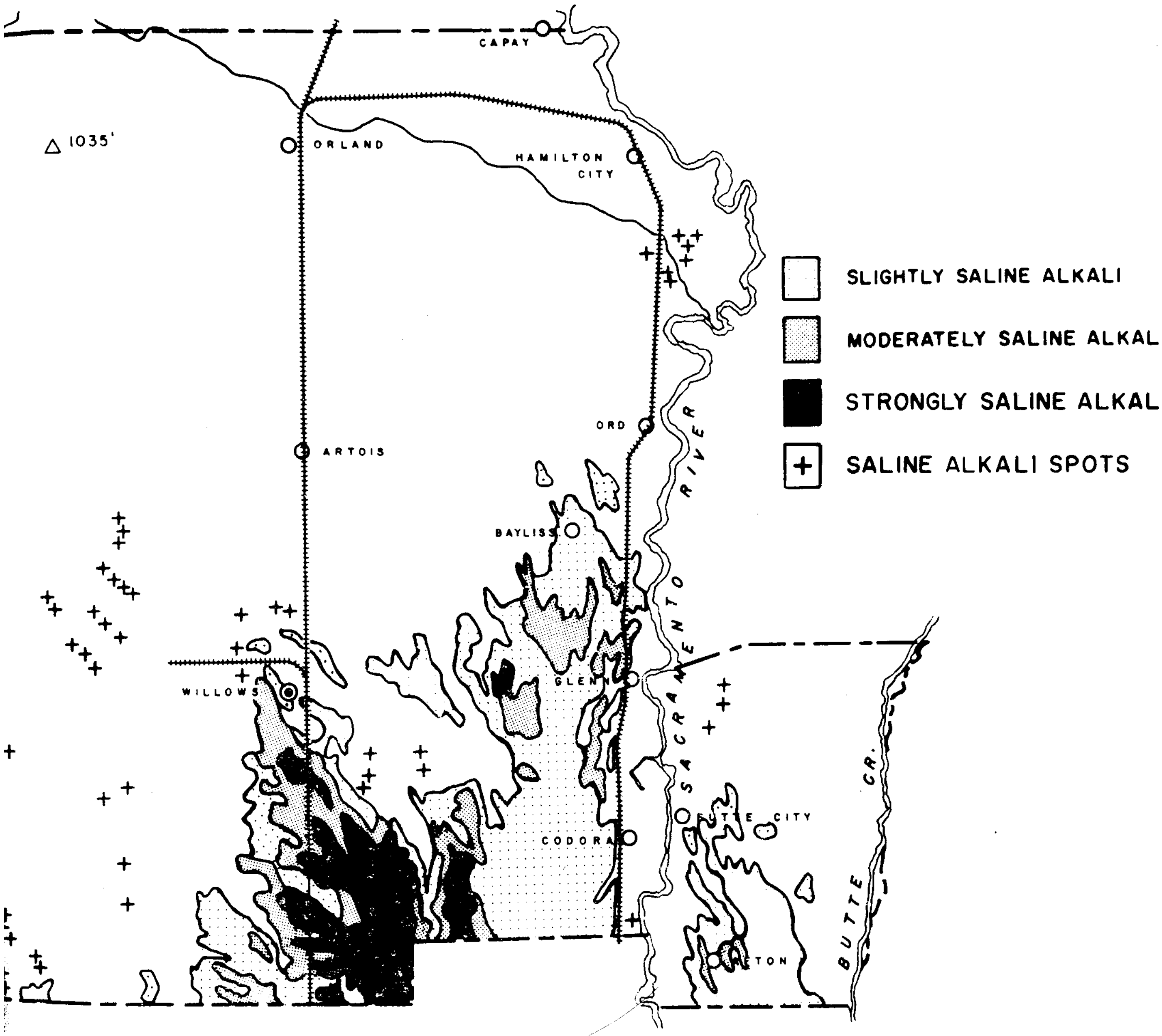
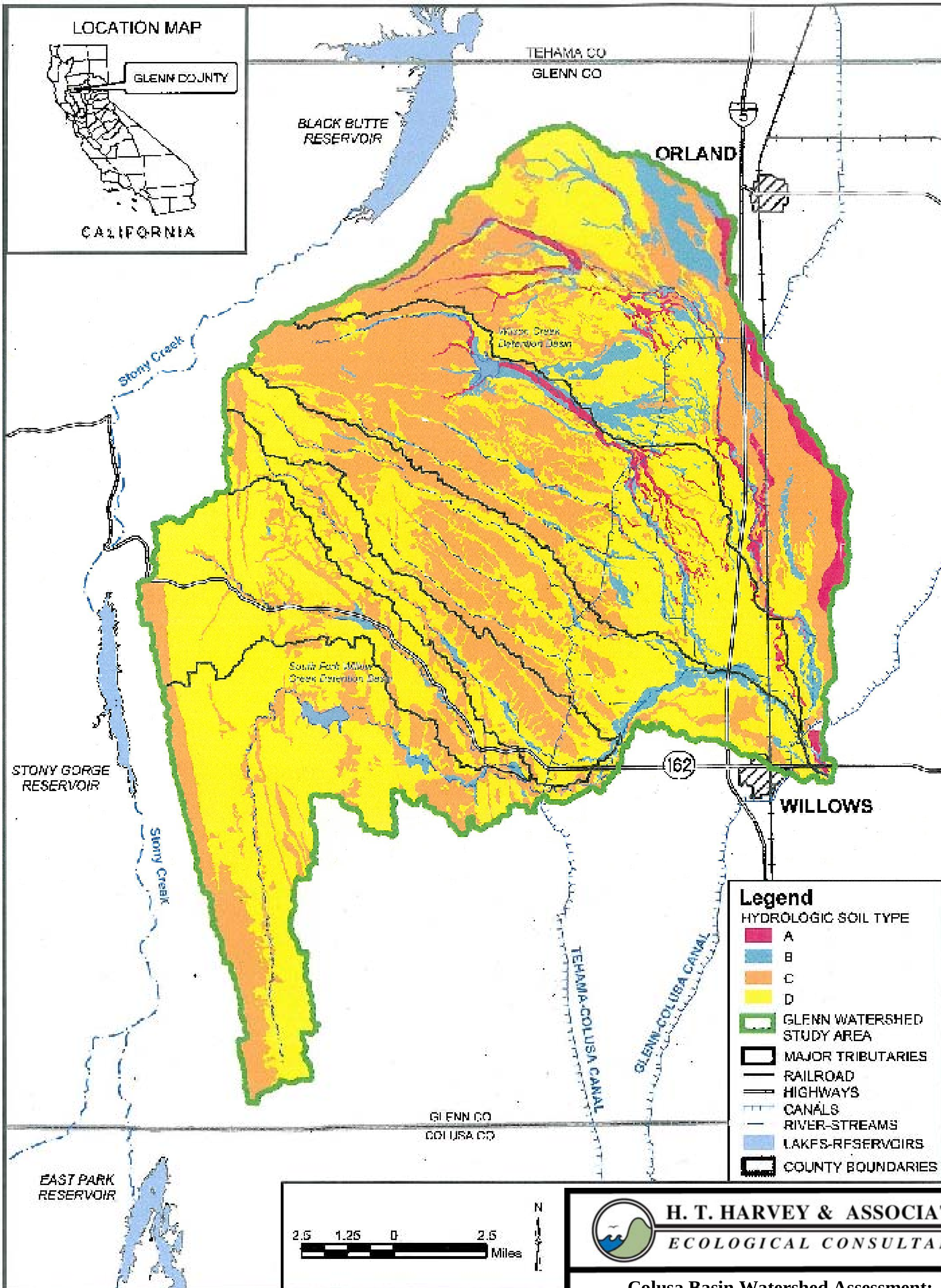



**Figure 7-Soils. Location saline-alkali soils in eastern Glenn County (adapted from Begg 1968).**




Source: CH2MHill 2003. Integrated Watershed Management Plan Draft Environmental Impact Report. Prepared for the Colusa Basin Drainage District

Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.

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**Colusa Basin Watershed Assessment: Hydrologic Soil Groups**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 8 - Soils |
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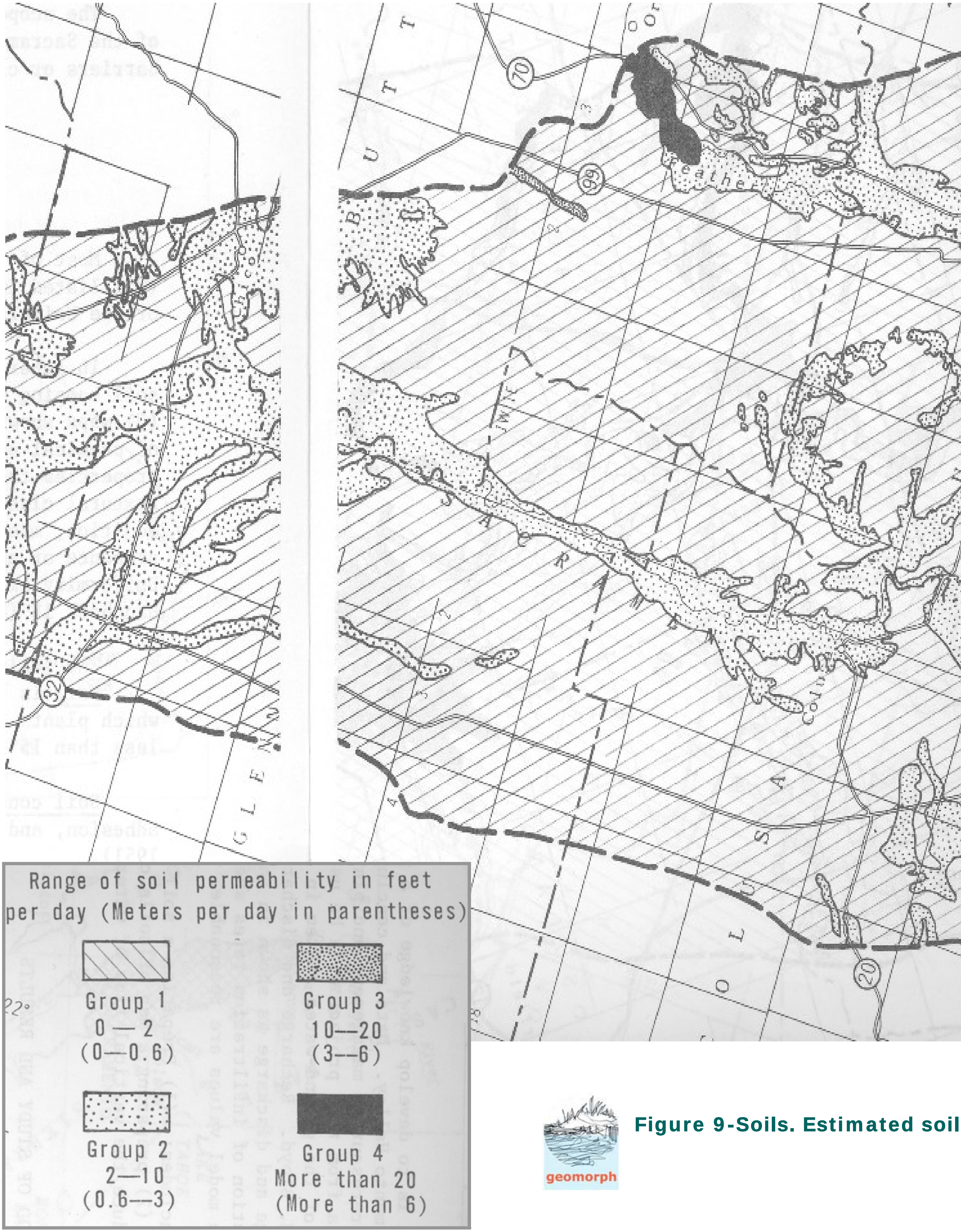



**Figure 9-Soils. Estimated soil**

# SURFACE WATER HYDROLOGY

## OVERVIEW

According to the best available subwatershed maps (Navigant Consulting, Inc. 2000) there are 32 foothill streams which are drained by 24 subwatershed areas comprising the Colusa Basin Watershed area (**Figure 2-Introduction).** Larger scale 7.5 minute USGS topographic quadrangle maps show that there are at least 36 named foothill streams. Indeed, the 24 subwatershed boundaries could be subdivided further, but it was generally beyond the scope of this assessment to evaluate stream hydrology and fluvial geomorphology on a finer scale. Accurately delineating subwatershed boundaries is also complicated on dissected alluvial fan surfaces where it is difficult to distinguish between the active and much larger number of relict distributary streams. Distributary channel network patterns occurring on dissected convex-shaped alluvial fan surfaces have more drainage boundaries than tributary channel network patterns on concave-shaped watershed surfaces. Moreover, foothill subwatershed boundaries have been changed in areas where stream channelization and land leveling for irrigation efficiency has moved drainage divides over time.

Historically, runoff from these foothill streams combined with stormwater runoff from the southern portion of the relict Stony Creek alluvial fan lying southeast of Orland and flood overflows from the Sacramento River to inundate a large area on the valley flat each winter. Many of the larger foothill streams deposited natural levees creating irregularly meandering channel ridges where their lower-gradient reaches graded into and were sometimes submerged by the slowly moving floodwaters on the valley flat. Sacramento River slough channels also created channel ridges in irregularly meandering traces leading away from the river and depositing sediment during flood times as they interlaced through the submerged basin floor. This way the runoff from the foothill streams never reached the Sacramento River, much of it being diverted to the south along the channel ridge deposits of Hopkins Slough and Sycamore Slough where they ultimately would have collected in the southern part of the Colusa Basin. The geomorphology of the Colusa Basin is reviewed at multiple locations in this assessment, and highlighted here only to make the point that the foothill streams discharged to a complex of basin areas that changed over geologic time.

As discussed in the flood management section of this assessment, flood control and irrigation development have evidently only somewhat changed where and how the foothill streams discharge to the frequently ponded area along the western edge of the Colusa Basin. There are no large reservoirs in the foothill subwatersheds so the foothill streamflow hydrology is similar to pre-development, except for effects of groundwater pumping, water imports, and irrigation drainage.

### Available Colusa Basin Watershed Hydrology Studies and Data

In preparing his summary of the geology and groundwater resources of the Sacramento River, Bryan (1923) gave scant attention to the foothill streams in the Colusa Basin Watershed. This is to be expected given that the watershed lands lie within a hydrologically "orphaned" area: the larger Stony Creek and Cache Creek watersheds draining much larger and higher elevation watershed areas wrapping around to capture the higher elevation Coast Range Mountain lands lying west of the watershed. Bryan (1923) simply noted that the runoff occurred in the smaller intermittent foothill streams during a season directly opposite from the irrigation season. In compiling an extensive history of the Colusa area Rogers (1891) waxed eloquently on the beneficence of Stony Creek, Grindstone Creek, Bear Creek, Elk Creek, and Cache Creek, while only noting about the watershed streams: “several others of minor note which include Walker, Willows, Cortina, Freshwater, and Sulphur Creeks, but which play no very important part in enriching the limited country through which they pass.”

Much for the same reason, early hydrographic surveys by Etcheverry (1915-1944) and later work by Blackie and Tibbets and McGlashan and Henshaw (1912) focused on the potential for water supply development and flood control benefits of flow management from the larger foothill watersheds.

Beginning as late as 1959, after the Sacramento River Flood Control Project had been substantially completed, the California DWR began studying the hydrology-related problems of flooding and drainage in the watershed (DWR 1962). DWR’s investigations gave rise to formal consideration of constructing flood detention reservoirs in the watershed’s foothills, among other methods of flood management. These proposals were more recently appraised by DWR (1990) and by the CBDD and USBR in preparing the Integrated Resource Management Program [IRMP] (Navigant Consulting, Inc. 2000) and the proposal to construct the South Fork Willow Creek detention reservoir (CH2MHill 2003). These are reviewed more thoroughly in the flood management section of this assessment.

DWR (1962) did not review the extent of stream flow data for the watershed, there being few at the time. However, DWR (1990) observed that “Nine surface water gaging stations have historically operated within the [Colusa Basin Watershed]. Currently there are only three active stations with which to describe the hydrologic character of the [watershed].”

Presently there are only 3 active gages in the watershed, those operated by DWR along the Colusa Basin Drain at Highway 20 and at the Knights Landing Outfall Gates, and the discontinued USGS station on South Fork Willow Creek near Fruto of which DWR resumed operation after the 1998 flood. The Colusa Basin Drain gages only measure mean daily flow contained in the drainage canal. Flood flows escaping the canal are not measured, and DWR does not publish estimated annual peak flows at those sites. The USGS currently publishes historical records for 3 discontinued gages: Walker Creek at Artois, South Fork Willow Creek near Fruto, and on Stone Corral Creek near Sites. The extent of available USGS and DWR stream flow gage data for the Colusa Basin Watershed is summarized in **Table 1-Hydrology.**

In 1998 DWR resumed gaging operations on the discontinued USGS gage South Fork Willow Creek near Fruto, but not until after the February 1998 flood event (CH2MHill 2003). DWR does not publish these data on their web-based Water Data Library [WDL] data server. The DWR gaging station on the Colusa Basin Drain at Highway 20 near Colusa has been operated since 1924, but only data after May 1941 are available via the WDL server.

**Table 1. Hydrology. Historical Stream Gage Data Summary.**

| Agency | Site ID | Site Name | Decimal Latitude | Decimal Longitude | Lat/Long Coordinates | Drainage Area (mi$^2$) | |
|---|---|---|---|---|---|---|---|
| USGS | 11390655 | SF Willow C Nr Fruto CA | 39.5409919 | -122.3897102 | NAD 83 | 38.9 | Dis |
| USGS | 11390660 | Walker C A Artois CA | 39.62543684 | -122.1969283 | NAD 83 | 60.4 | Dis |
| USGS | 11390672 | Stone Corral C Nr Sites CA | 39.2882206 | -122.3010909 | NAD 83 | 38.2 | Dis |
| DWR | A02976 | Colusa Drain Nr Hwy 20 | 4,338,917N | 581,103,0E | NAD 83 | 973 | |
| DWR | A02945 | Colusa Drain at Knights Landing | 4,295,406N | 610,743,0E | NAD 83 | 1619 | |
| **Agency** | **Site ID** | **Site Name** | **MDF Data Begin Date** | **MDF Data End Date** | **MDF Data Count** | **Peak Data Begin Date** | **Pe E** |
| USGS | 11390655 | SF Willow C Nr Fruto CA | 7/1/1963 | 9/30/1978 | 5,571 | 1963 | 1/ |
| USGS | 11390660 | Walker C A Artois CA | 8/1/1965 | 9/30/1981 | 5,905 | 2/4/1966 | 1/ |
| USGS | 11390672 | Stone Corral C Nr Sites CA | 4/1/1958 | 9/30/1985 | 9,680 | 4/2/1958 | 3/ |
| DWR | A02976 | Colusa Drain Nr Hwy 20 | 5/1/1941 | Present | ND | N/A | |
| DWR | A02945 | Colusa Drain at Knights Landing | 10/1/1975 | Present | ND | N/A | |

The drainage area tributary to the Colusa Basin Drain at the Highway 20 gage is 973 $mi^2$ (about 623,000 ac), approximately 60% of the 1,045,445-ac Colusa Basin Watershed. Annual average runoff at the Highway 20 gage for the period of record is 496 thousand acre-ft [taf] per year (CALFED 2001). Note that 496 taf of runoff from a 623,000 ac watershed area is equivalent to an average runoff depth of 9.6 inches. This is much more than the natural amount of runoff from a watershed area with mean annual precipitation ranging generally from 17-27 inches and reflects the influence of irrigation water imports on the hydrology of the Colusa Basin Drain and to some lesser extent on the hydrology of the foothill streams lying downstream from the Glenn-Colusa Canal.

It was beyond the scope of this assessment to prepare an updated water budget for the watershed, and the most recently available water budget analysis appears to be that of DWR (1990). DWR (1990) prepared irrigation season (1 April – 30 September) water budgets for the CBDD for 1977 (drought year), 1980, and 1988. These results are reproduced in **Table 2-Hydrology** and **Figures 1-Hydrology** through **3-Hydrology**. During those years, imported water ranged from 996-1470 taf and the "westside" foothill streams contributed from 10-31 taf. Groundwater extractions were from 360-461 taf, more in drought years when imports were least. These water budgets demonstrates how much imported water dominates the hydrology of the Colusa Basin Drain in the summer months, and possibly also to some lesser extent, the hydrology of the otherwise dry foothill streams lying downstream from the Glenn-Colusa Canal. These water budgets do not paint a picture of the non-irrigation season when imports and groundwater extractions are severely reduced and the foothill streams flow in response to periodic rainstorms. It may not be feasible to prepare a reliable winter season or total annual water budget there presently only one gage in the basin that measures annual maximum peak flows: South Fork Willow Creek near Fruto.

The more recent multi-objective flood management studies by CBDD and USBR used regression analyses of these scant streamflow data to estimate monthly and annual water yields from the major foothill subwatersheds, input data for evaluating the potential for flood detention reservoirs in combination with other measures to reduce flooding and improve water supply in the watershed. For example, Navigant Consulting Inc. (2000) synthesized 1922-1992 annual water yield data for each of the foothill stream subwatersheds. These synthesized data are of an accuracy and time step resolution suitable for general water supply planning and feasibility-level design, as well as generally hydraulic and economic modeling of flood control alternatives. Summary monthly and annual water yield data estimates were presumably made by drainage area ratio extrapolation from the USGS stream gage data records for the 3 foothill streams and other longer-term regional precipitation and stream gage data. The long-term synthesized water yield record reveals the natural climate-driven unreliability of within watershed surface water yield, and the importance of water supply planning for future critical drought periods, comparable to droughts that occurred in the watershed during 1929-1937 (i.e., the dust bowl era), 1976-1977, and 1988-1992.

**Table 2. Hydrology. Colusa Basin Drainage District Irrigation Season Water Budgets for 1977, 1980, and 1988**

| Colusa Basin Drainage District Water Budget<br>1000 acre-feet<br>April 1 — September 30 | | | |
|---|---|---|---|
| | **1977** | **1980** | **1988** |
| **Inflow** | | | |
| Imports | | | |
| Tehama Colusa Canal | 73 | 294 | 347 |
| Glenn Colusa Canal | 568 | 789 | 741 |
| Other Sacramento River Diversions | 355 | 387 | 340 |
| *Subtotal Imports* | *996* | *1470* | *1428* |
| Western Streams | 10 | 31 | 21 |
| Ground Water Extraction | 461 | 394 | 360 |
| **Total Inflow** | **1467** | **1895** | **1809** |
| **Outflow** | | | |
| Percolation to Ground Water | 190 | 224 | 142 |
| Surface Outflow | 77 | 292 | 273 |
| Evaporation and Transpiration | 1147 | 1315 | 1325 |
| **Total Outflow** | **1414** | **1831** | **1740** |
| **Change in Storage = Inflow – Outflow** (Permanent and Seasonal Marsh) | **53** | **64** | **69** |

**Summary Analysis of Foothill Stream Hydrology Data**

The USGS operated stream gages located near the foothill front on 3 foothill streams in the watershed: Stone Corral Creek, South Fork Willow Creek, and Walker Creek (**Table 1-Hydrology**). The gage on Stone Corral Creek near Sites was installed first and began recording data 1 April 1958. The approximately 28-year-long record is continuous through 30 September 1985 with the exception of the 1965 water year, for which no data were published. The Willow Creek and Walker Creek gages were operated continuously for approximately 16 years each.

All of these data are presented as individual annual hydrographs for each of the water years from 1958-1985 in **Appendix 1-Hydrology**. The Stone Corral Creek data are presented on all of the individual annual hydrographs except for the 1965 water year. The Willow Creek and Walker Creek data are presented overlapping the Stone Corral Creek data for the water years where there is an overlapping record. This facilitates cross-examination of each of the 3 gage records. The reader is encouraged to scan through **Appendix 1-Hydrology** as a means to quickly review the period of record. These are all of the hydrology data for the foothill streams in the Colusa Basin Watershed. Some observations are summarized below.

Stone Corral Creek had zero or near-zero flow most of the year during normal and dry years with positive flow typically occurring only as the result of individual rainstorms between November and April. Stone Corral Creek had zero flow for the entire water years of 1964, 1965, 1972, 1976, and 1977 and practically zero flow during 1960, 1961, 1966, and 1985. These were presumably dry years for all of the watershed's foothill streams. During normal years Stone

Corral Creek had several rainfall generated flows but few of these flows were large enough to sustain baseflow until the next successive storm unless they were closely spaced together. During wet years, Stone Corral Creek did sustain baseflow during periods lasting as long as several weeks as the result of numerous closely spaced rainstorms in the upper watershed. Wet years were 1958, 1967, 1969, 1970, 1973, 1978, 1980, 1982, 1983, and 1984.

South Fork Willow Creek near Fruto has a similar-sized drainage area as Stone Corral Creek and presumably a similar pattern of mean annual precipitation as its upper watershed is adjacent to and within the same range of elevations, and it is underlain by similarly dissected Cretaceous bedrock. The 16-year-long South Fork Willow Creek record overlaps the Stone Corral Creek record every year except for 1965. Cross-examination of the Stone Corral Creek and South Fork Willow Creek data records during those 15 years of overlap confirm that they are virtually identical: both streams had similarly timed and similarly sized peaks resulting from individual winter rainstorms, with very few exceptions. In November 1964, Stone Corral Creek rose briefly to 12 cubic ft per second [cfs] during which time South Fork Willow Creek did not flow at all. For some storms, Stone Corral Creek flowed 20-30% higher than Willow Creek, and for others vice-versa (**Appendix 1-Hydrology**).

Walker Creek at Artois captures a large drainage approximately twice as large as the Stone Corral and Willow Creek gages, and it lies farther to the north giving it opportunity to differentially sense individual rainstorms. **Appendix 1-Hydrology** shows that there were about 4 individual rainfall-runoff producing rainstorms during the 1966 water year. Walker Creek recorded a small flood spike in mid-November 1965 that was not sensed at the Stone Corral and Willow Creek gages. During a January 1966 storm, all 3 gages recorded almost the same sized discharge. In February 1966, Walker Creek recorded approximately twice the rainfall-runoff as did Stone Corral and Willow Creek. A smaller storm at the end of February that year was practically only sensed at the Walker Creek gage.

With its larger watershed area Walker Creek sustained winter baseflow (i.e., flow between storms) for a larger portion of the November to April rainy season (**Appendix Hydrology-1**), but at times had zero or near-zero streamflow between storms, especially during dry years and most normal years. The Walker Creek record also noticeably demonstrated the effects of irrigation runoff during the irrigation season. During the 1 April to 30 September irrigation season when there was reliably zero or near-zero flow at the Stone Corral Creek and Willow Creek gages, the Walker Creek gage measured a fluctuating flow that averaged between 5 and 12 cfs most years but less in extreme dry years, overall averaging about 5.6 cfs for the 16-year period of record. Walker Creek collected irrigation runoff or groundwater underflow without losing it to groundwater, indicating that the groundwater table was not far below the stream channel bed in this area.

Historical information suggests that this reach of Walker Creek supported a wide and well-established riparian corridor even before the effects of irrigation, lending support to the idea that the groundwater table is naturally near the stream bed elevation here (GIC 2003). It is possible that groundwater underflow from the Stony Creek fan supports high groundwater along this reach, as the bed of Walker Creek is approximately 50 ft below that of the Stony Creek at Orland several mi due north. Relatively high groundwater may be supported by thick clays underlying the Stony Creek gravels which rise to within 40 ft from the ground surface along the Willows anticline (DWR 2006).

### Effects of Human Activities on Foothill Stream Hydrology

There are too few data available to assess what the effects of human activities have been on the characteristic hydrology of the foothill streams. In general, because they are intermittent streams with unreliable year-to-year water yields and reliably dry channel beds during the entire irrigation season, few diversions have been constructed to make use of their winter flows for water supply purposes. Anecdotal reports indicate that some dryland grain farmers did occasionally turn silt-laden winter flows onto their lands both for the irrigation benefit and for the capturing of fertile silt deposits. The extent to which this happened is not well documented. It seems fair to conclude that the characteristic annual pattern of brief winter flows during November-March rainstorms and dry channel bed conditions during April-October has not been appreciably changed by human activities in the basin.

As discussed above in the groundwater section of this assessment, groundwater pumping severely lowered the groundwater table in places, especially on the higher elevation areas of the low plains near the foothill front. The groundwater table substantially recovered in most areas following the completion of the Tehama-Colusa Canal in the 1970s. Still, in some years the groundwater table in the vicinity of the foothill streams is probably several ft lower than it was prior to EuroAmerican settlement. More analysis would be required to estimate the pre-EuroAmerican groundwater table elevation relative to the foothill streambeds and floodplains. If the pre-EuroAmerican groundwater table were substantially closer in places along some foothill streams, then it is possible that these foothill stream sections may have supported more riparian vegetation than they presently are able to support.

Much more focus has been put on the potential effects of human activities on the magnitude of winter peak flows discharging from the foothill streams, because these floods contribute to the majority of the winter flooding problem still extant in the watershed. Anecdotally, it has been generally observed that completion of the Tehama-Colusa Canal reduced the Colusa Basin Drain flood peak lag time from about 72 hrs to about 24 hrs.

As discussed elsewhere in this assessment, rangeland management, channel bed incision, and floodplain disconnection may have increased foothill stream peak flow discharges. Neither DWR (1962) nor DWR (1990) explicitly considered these effects, but more recently Navigant Consulting, Inc. (2000) and CH2MHill (2003) considered the potential for improved rangeland management practices to reduce peak flow discharges and resulting valley flat flooding into their flood management alternatives analyses. Associated hydrologic modeling analyses suggested that improved rangeland management could reduce foothill watershed peak flows by as much as about 5%. This result suggests that the current rangeland management practices may have had a measureable effect on peak flows discharging from the upper watershed areas.

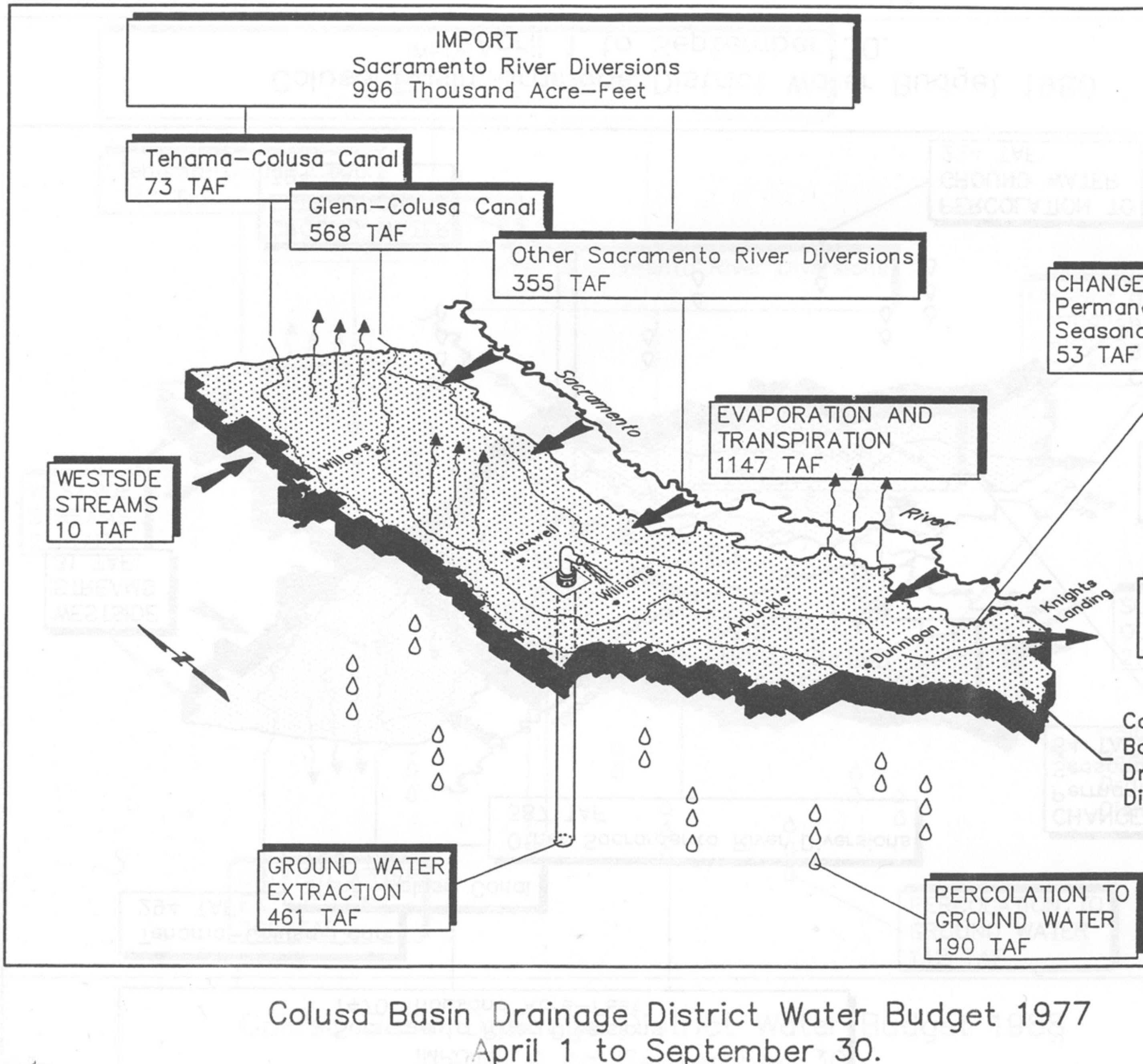



**Figure 1-Hydrology. Colusa Basin Drainage District irrigation season wate 1977 (adapted from DWR 1990).**

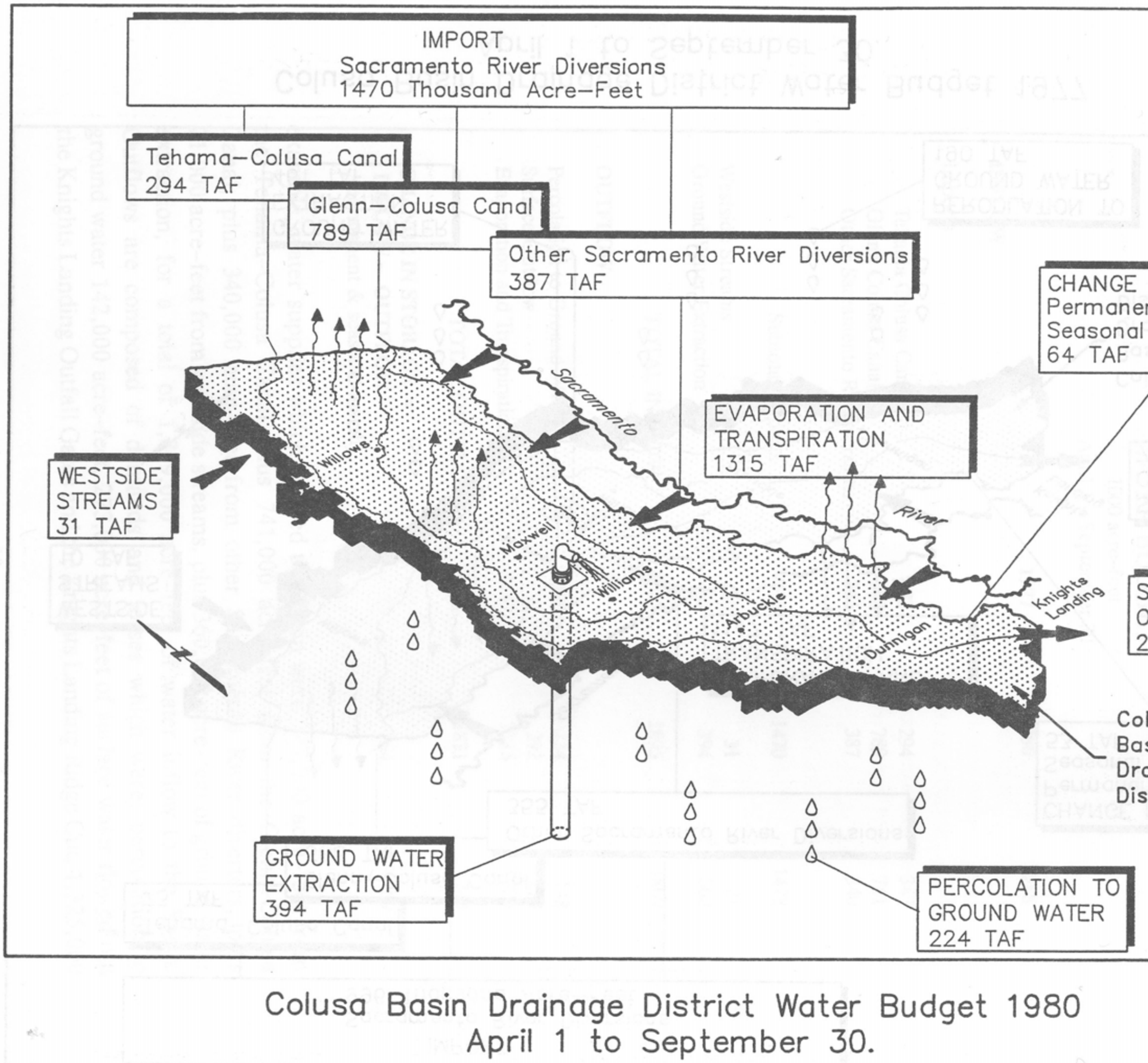



**Figure 2-Hydrology. Colusa Basin Drainage District irrigation season wate 1980 (adapted from DWR 1990).**

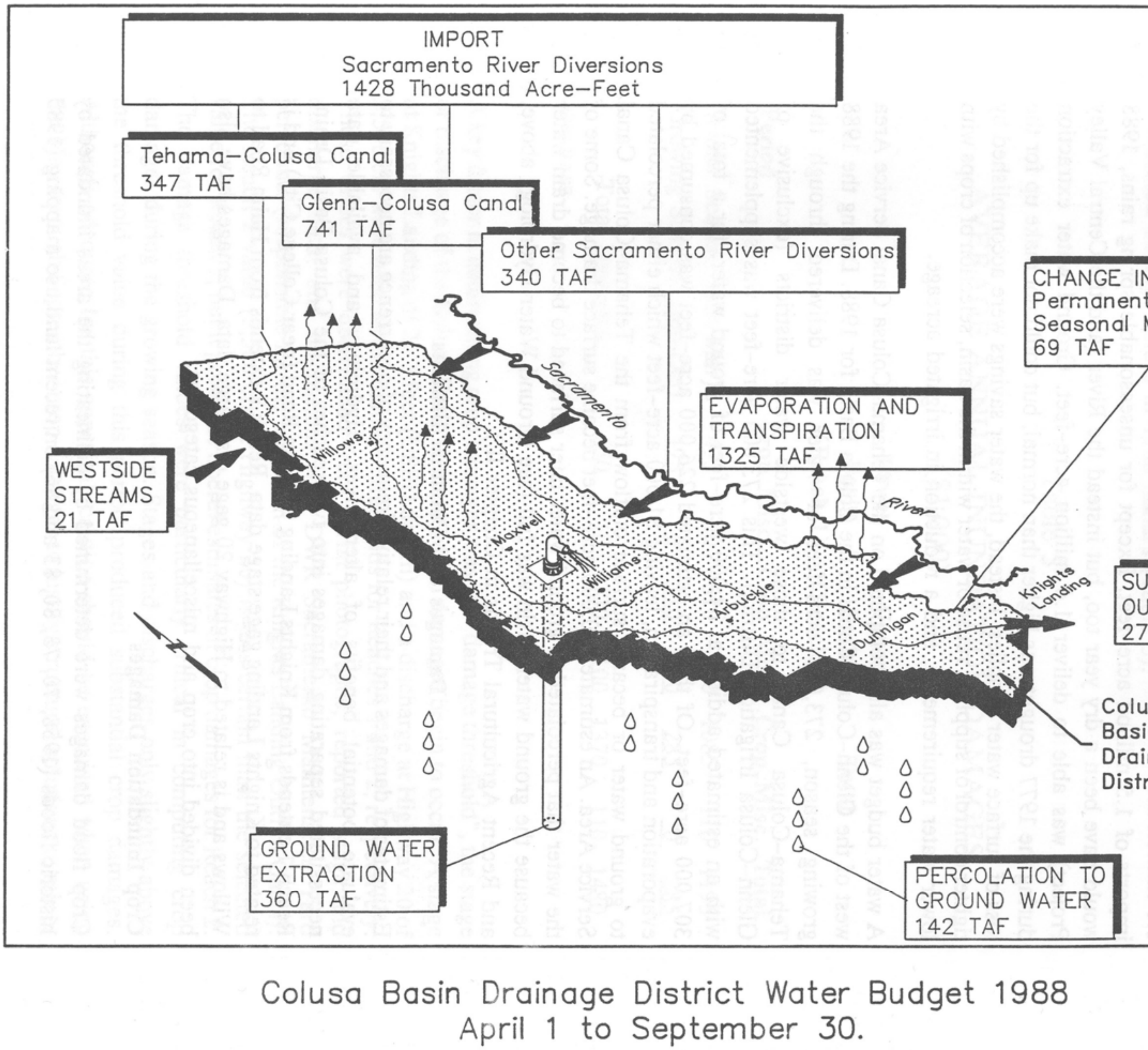



**Figure 3-Hydrology. Colusa Basin Drainage District irrigation season water 1988 (adapted from DWR 1990).**

# GROUNDWATER HYDROLOGY

## GROUNDWATER SUBAREAS

Groundwater occurs in the alluvial deposits underlying the alluvial fans, low plains, and basin flats of the Colusa Basin Watershed. In California's Groundwater Bulletin 118, DWR (2006) recognizes the Colusa Groundwater Subbasin as comprising the part of the larger Sacramento Valley Groundwater Basin lying approximately under the Colusa Basin Watershed footprint, being "…bounded on the east by the Sacramento River, on the west by the Coast Range and foothills, on the south by Cache Creek, and on the north by Stony Creek."

The base of the Tehama Formation is the base of groundwater-bearing alluvial deposits in the Colusa Groundwater Subbasin. Therefore the Tehama Formation forms both the bottom of the subbasin and its western edge where the Tehama Formation contacts the non-water-bearing Cretaceous marine sedimentary rocks in the western part of the watershed (**Figure 1-Geology**). There is no boundary to inflow and outflow from the subbasin on the north, east, and south. The groundwater-bearing geologic formations in the subbasin include all of the alluvial deposits overlying the Cretaceous bedrock: the Tehama Formation of Tertiary age and the overlying Quaternary alluvial fan, flood basin, and alluvial deposits.

The following descriptions of the composition, thickness, and general groundwater-bearing characteristics of these geologic formations are adapted or paraphrased from DWR (2006) and augmented with information from other sources. The distribution of these geologic units is also described in the geology section of this assessment.

**Pliocene Tuscan Formation.** The Tuscan Formation occurs in the northern portion of the subbasin where it lies about 400 ft below the ground surface. The Pliocene Tuscan comprises volcanic mudflows, tuff breccia, tuffaceous sandstone, and volcanic ash layers. Younger layers of the Tuscan consisting of massive mudflow or lahar deposits have a lower permeability than the older underlying layers, creating confined groundwater conditions.

**Pliocene Tehama Formation.** The Pliocene Tehama Formation is the principal water-bearing geologic unit within the Colusa Subbasin and the larger western Sacramento Valley, where its reaches a maximum thickness of about 2000 ft (Olmsted and Davis 1961). The Tehama Formation consists of moderately compacted sandy-silt and clay, with occasional gravel and sand deposits and cemented conglomerate. Occasional deep sands and thin gravels and thin gravels constitute a poorly to moderately productive deep water-bearing zone. This alluvium derived from erosion of the Coast Range and Klamath Mountains and deposited under floodplain conditions during the Pliocene. The depth to the top of the Tehama Formation is generally about 150-200 ft. Its depth is as much as several hundred ft near the Sacramento River and as little as 50 ft along the western edge of the valley. Deformation including folding and faulting as expressed in the Corning anticline, the Willows arch, and possibly also the Dunnigan anticline may affect the movement of groundwater through the Tehama Formation. Quaternary alluvium has generally not been deformed. Groundwater typically occurs under semiconfined to confined conditions in the Tehama Formation and unconfined conditions in the alluvial fans and alluvium (Navigant Consulting, Inc. 2000).

**Pleistocene Modesto and Riverbank Formations.** The Riverbank and Modesto Formations are composed of alluvium derived from dissection by Pleistocene foothill streams of the uplifted Tehama Formation siltstones and Cretaceous marine sedimentary bedrock. They have been subsequently dissected by the same streams so that they now form terraces in the foothill valleys and on the alluvial fans and interfan basin areas lying everywhere upslope from the valley flat. The Modesto was deposited between 14,000 and 42,000 years ago and the Riverbank was deposited between 130,000 and 450,000 years ago. The Modesto consists of moderately to highly permeable gravels, sands, and silts ranging in thickness from 10-200 ft. The older Riverbank terraces occur above the Modesto and consist of poorly to highly permeable gravel and small cobble interlensed with reddish clay, sand, and silt. The Riverbank thickness ranges from 1 ft to over 200 ft and yields moderate quantities of groundwater to domestic and shallow irrigation wells and also provides water to deep irrigation wells with multiple depth perforation zones.

**Holocene Flood Basin Deposits.** Flood basin deposits consist primarily of silt and clay occurring between the natural levees of the Sacramento River and the low alluvial plains to the west of the natural levees. Flood basin deposits also occur between abandoned channel ridge deposits on alluvial fans and covering broader areas of low-gradient plains lying between the alluvial fans and where the alluvial fans are not well developed, referred to elsewhere in this assessment as interfan basin areas. The basin deposits are thin on the low-gradient plains along the edge of the basin flat lands, but may reach hundreds of ft in thickness underlying the valley flat. These deposits are clay-rich and of low permeability, and generally yield low quantities of water to wells. Groundwater quality is also low from some depths in some basin deposits.

**Holocene Alluvium.** The recent alluvial deposits occur along the foothill streams and within the natural levee and gently-sloping floodplain deposits bordering the western edge the Sacramento River, and extend from the river into the Colusa Basin along the courses of the river's distributary sloughs. Recent alluvium consists of unconsolidated well sorted to poorly sorted gravel, sand, silt, and clay. The maximum thickness of the recent alluvium is generally up to 80 ft (Helley and Harwood 1985) but it is as much as about 130 ft in the Sacramento River north of Colusa (Navigant Consulting, Inc. 2000).

DWR (2006) describes the subareas of the Colusa Groundwater Subbasin as follows:

> **Stony Creek Fan.** The Stony Creek Fan occupies the northern extent of the subbasin and extends from the Black Butte Reservoir to the City of Willows, northeast from the City of Willows to the Sacramento River, and north beyond the Tehama County line. The geologic units within the fan area include Holocene alluvial deposits, Pleistocene deposits of the Riverbank and Modesto formations, and Pliocene deposits of the Tehama and Tuscan formations.
>
> Holocene alluvial deposits are observed along Stony Creek to the north and along the Sacramento River to the east. Modesto and Riverbank deposits extend to the east along Stony Creek and south and southeast within several ancestral stream channels (DWR 2000). Older alluviated floodplain and channel deposits reach a thickness of 150 feet at Stony Creek and 110 feet along the Sacramento River.
>
> Thick clays of the upper Tehama formation underlie the intermediate water-bearing zone of the Stony Creek plain at a depth of 300 feet, rising to a minimum depth of 40 feet on the axis of the

Willows anticline. Wells installed 4 miles east of Highway 99W intersect occasional Tehama formation gravels between 225- and 625-ft depths.

Tuscan Units A, B, and C are believed to extend into the Colusa Subbasin north of the City of Willows. The sediments of the Tuscan Formation interfinger with the sediments of the Tehama Formation in the subsurface (Lydon 1969). The degree of hydraulic conductivity between the Tuscan Formation, the Tehama Formation, and the overlying Stony Creek fan deposits has not been well established.

**Willows-to-Williams Plain.** Basin deposits overlie much of the flat alluvial plains in the area between Willows and Williams. Permeabilities of the near-surface soils are extremely low. Riverbank deposits are observed along the western subbasin boundary north of Maxwell. The interstream areas of the Westside creeks contain little gravel and are underlain by poorly pervious, occasionally alkaline, claypan soil. The Tehama Formation contains little gravel and is not an important water-bearing material in this region.

**Arbuckle and Dunnigan Plains.** Quaternary surface deposits of alluvium, Modesto, and Riverbank formations and basin deposits in the Arbuckle and Dunnigan plains occur east of Hungry Hollow and Dunnigan hills from Williams to Cache Creek. Basin deposits overlie older alluvial deposits. The region north of Arbuckle is alluviated to depths of 20- to 60-feet with moderately to highly permeable sands and gravels from Sand and Cortina creeks. This zone extends east of highway 99W and, in the College City area, appears to be Sacramento River deposits. The area between Salt and Petroleum creeks is composed of poorly to moderately permeable gravels, clayey sands, and silts. Petroleum and Little Buckeye creeks have deposited a thin, moderately to highly permeable sandy gravel and sandy silts over older stream and terrace alluvium.

The area in the vicinity of Zamora is underlain by a homogeneous section of gravels, sand, and interbedded clays to minimum depths of 450 feet. Water producing members range from 25- to 35-percent of total material penetrated. Well production is high within gravel channels. A poorly to highly productive water-bearing zone consisting of alder alluvial deposits and Tehama deposits on the western and southwestern edges of the Arbuckle Plain ranges in depth from 100- to 300-feet. The zone thickens easterly to depths of 400- to 450-feet.

Tehama deposits coarsen in this area and are an important water-bearing unit. The upper 800- to 900-feet contains 10- to 13-percent fine pebble gravel with a well-sorted, fine to medium sand matrix. This portion of the Tehama Formation is highly pervious, loose, and well bedded. The gravel beds range from 5- to 20-feet in thickness and are well confined within a silt and clayey silt section.

**Cache Creek Floodplain.** Holocene stream channel deposits are observed along the entire extent of Cache Creek (DWR 2000). The Cache Creek area is alluviated with floodplain deposits which are exposed north of the town of Yolo and extend to Knights Landing. The relative proportion of sand and gravel for the depth interval of 20- to 100-feet is approximately 27 percent.

Between depths of 100- to 200-feet the proportion is reduced to 24 percent. The percentage of sand and gravel for deposits extending northward from Cache Creek averages 22 percent for the 20- to 200-ft interval. Farther east the proportion increases to 36 percent for the same depth interval (Olmsted and Davis 1961). Tehama deposits are penetrated in the depth interval of 100- to 200-feet.

## Historical Groundwater Studies and Data

Bryan (1923) appears to have conducted the first comprehensive study of the specific groundwater resources in the Colusa Basin Watershed. During his extensive geologic studies and groundwater well monitoring between 1912 and 1914, he noted the presence of small artesian flows occurring in deep wells from College City northward to Willows, the most southerly being the Chandler well and the most northerly being the well on the Spaulding (formerly Rideout) ranch, near Norman station, south of Willows. Both of these wells had a natural artesian flow of about 3 gallons per minute. Further Bryan (1923) observed:

> The largest group of flowing wells in the valley is south of Colusa, along Dry and Sycamore sloughs. The material encountered consists of thick beds of clays with streaks of fine sand in which the artesian water is found. The wells range in depth from 100 feet to nearly 1,000 feet. The pressure is rarely great enough to raise the water more than 2 or 3 feet above the surface of the ground. In some wells, the water rises only a few inches above the normal water table, and some of the wells only in winter. These variations in depth and pressure indicate that the beds underlying the valley are not uniform in structure but that the flows are due to recurring favorable structural conditions which have their origin in the manner in which valley filling took place.
>
> Flood basins or similar depressions appear to have existed in approximately their present position during most of the period of valley filling. In these depressions clays and similar impervious deposits were for the most part laid down, but occasionally streams extended into the basins and deposited beds of sand. These sands are connected with the sands and gravels of the low plains and supplied by them with water. Where the level of the ground water in the plains is enough higher than the surface of the adjacent basin to overcome the friction of flow through the sands, wells in the basin will overflow. Fluctuations of ground-water level in the plains therefore cause fluctuations in the flow of certain of the wells. As the difference in altitude of the basins and the low plains is slight, only small pressures are obtained.

Bryan (1923) provides a detailed summary of the specific geologic conditions affecting depth to groundwater and well production in each of several areas within or adjacent to the watershed: Orland-Hamilton, Willows, Williams, Colusa-Meridian, Arbuckle, and Woodland. These observations are of general interest but too detailed to be reproduced in this assessment. Bryan (1923) measured depth to groundwater throughout the watershed and published a groundwater elevation contour map of the Sacramento Valley. The contours in the vicinity of the Colusa Basin Watershed were from measurements mostly made in the fall seasons of 1912-1913. A copy of that Fall 1912-1913 groundwater contour map is reproduced in this assessment as **Figure 2b-Groundwater**.

The Colusa Basin Appraisal prepared by DWR (1990) includes a useful summary analysis of groundwater elevation trends from Spring 1975 to Spring 1998 that reflected the substantial groundwater recovery that followed from the imported irrigation water by the Tehama-Colusa Canal in the 1970s. These results are summarized below and compared to updated groundwater elevation trends for 4 of the representative groundwater wells.

### Current Groundwater Management

Sufficient data exist for monitoring changes in groundwater storage and to provide baseline data for evaluating future groundwater management efforts. DWR monitors groundwater levels in 98 wells approximately semi-annually and maintains up-to-date published databases of period of record well data (DWR 2006).

Groundwater management in the Colusa Basin Watershed is complicated by multiple overlapping jurisdictions and water rights issues. Each of the 3 counties with lands in the watershed has completed, or is in the process of completing, an individual county-level groundwater management plan.

Glenn County adopted its Groundwater Management Plan 15 February 2000. For more information about the Glenn County Groundwater Management plan the reader is directed to: http://www.glenncountywater.org/management_plan.htm. Yolo County adopted its Groundwater Management Plan 6 June 2006. According to a March 26, 2008 press release from Glenn County titled "Glenn County Groundwater Update":

> The semi-annual spring groundwater level measurements for Glenn County made by the California Department of Water Resources, Northern District (DWR) were completed during the week of March 10-14, 2008. Spring measurements are the basis for groundwater level Basin Management Objectives (BMO) established to determine groundwater safe yield in many groundwater management sub-areas of the County.
>
> During the time of measurement, 8 wells within the County that utilize spring measurements for BMO compliance were below average for this time of year. As a comparison, 16 wells were below average at the same time last year. Overall, groundwater levels are much improved from last year with an average 4 to 5 feet above where they were last year at this time.
>
> Lower than average groundwater levels are the result of insufficient rainfall during the winter and spring months, accentuated by the need for early irrigation to permanent crop plantings throughout the County. Precipitation and surface application of irrigation water are the primary sources of recharge in our area to meet the needs of the majority of wells used for irrigation. As the irrigation season progresses, groundwater levels will experience seasonal fluctuation, which may cause sporadic difficulty during the peak irrigation season. Keeping this in mind, consider any and all methods of conservation available to you and remember your neighbor may be pumping the same time you are.
>
> BMO's for groundwater levels were established and adopted by the Board of Supervisors in June, 2001. Currently, all of the wells utilized for BMO compliance are for domestic or agricultural use. Over the years, there have been many dedicated monitoring wells installed by the County and Water Advisory Committee (WAC) member irrigation districts to monitor groundwater levels and quality. The intent of the monitoring wells is to develop a monitoring network independent from these production wells. During the summer of 2007, 21 distinct aquifer zones from dedicated monitoring wells throughout the County were utilized to establish Summertime BMO's for groundwater level. These established levels are considered interim until they are finally adopted. The WAC is in the process of incorporating these wells towards the development of Countywide BMO's for spring, summer, and fall.

> Current and historic groundwater levels in our region can be viewed on DWR's Water Data Library. Their web page is: http://wdl.water.ca.gov/gw/map Point to Glenn County and navigate regionally from there. Butte County has developed a regional groundwater information data base program that provides access to groundwater-related information for agencies as well as interested parties with information relating to established BMO's for groundwater elevation, water quality, and land subsidence monitoring. The website address for access to the program is: http://bc-gis-ims-02/bmoic3"

Colusa County initiated the process of preparing a Groundwater Management Plan in February 2007. This planning process is expected to continue through 2007 and conclude in the spring of 2008. A public draft Groundwater Management Plan is currently undergoing public review and comment and is expected to be adopted by the Colusa County Board of Supervisors in July 2008. The adopted plan will serve as a long-term guide to manage the groundwater resources in Colusa County.

Other groundwater management plans covering areas within the watershed include those adopted by Glenn-Colusa Irrigation District (adopted 26 May 1995), Dunnigan Water District (adopted 15 February 2001); and Reclamation District No. 787 (adopted 16 November 2005).

### Groundwater Level Trends

Bryan (1923) monitored the natural and pumping influenced fluctuations of the groundwater table of the Colusa Basin during 1912-1913, observing:

> The annual fluctuations of the water table are large. The rise begins in September and is gradual until the coming of the rains, when the rate of increase is more rapid until some time in March. Beginning about in March the water falls until, in the latter part of June, it reaches the summer level, which is nearly constant except when affected by pumping. The characteristic fluctuations in the basin lands are shown in figure 5, which gives the average depths to water observed weekly in 24 wells in Colusa Basin. The curve is very similar to the curves given by Lee for the moist lands in Owens Valley. The summer low stage is more protracted, however, and the rise and fall before and after the winter rains are much sharper. The rise of ground water in the fall before the winter rains begin is due chiefly to the decrease in loss by evaporation with cooler weather, while replenishment by percolation from higher levels continues. In the plains areas, where depth to water is 15 to 25 feet in summer, the winter rise brings the water within 5 to 15 of the surface.

Note that figure 5 referred to by Bryan shows an annual average groundwater elevation hydrograph showing that the groundwater dips to about 4 ft below the ground surface in June-October and maintains near about 1 ft below the ground surface during February-March.

As irrigated acreage increased through the 1960s, concurrently increasing groundwater withdrawals generally resulted in gradually lowering groundwater elevations and, in some areas, land subsidence. The Tehama-Colusa Canal began making deliveries to Glenn, Colusa, and Yolo counties in the 1970s. This imported water resulted in reduced groundwater withdrawals in some areas allowing groundwater elevations to rise up to 40 ft west of Willows and as much as 30 ft in the vicinity of Arbuckle between 1975 and 1988 (**Figure 1-Groundwater**). Navigant Consulting, Inc. (2000) suggested that relatively stable groundwater levels between the Colusa

Basin Drain and the Sacramento River during that same time interval may be maintained in part by seepage from the Sacramento River.

According to DWR (1990) groundwater elevations ranged from 20 ft above sea level near Knights Landing to about 220 ft above sea level near Orland in Spring 1988 (**Figure 2-Groundwater**) and declined during the 1988 irrigation season in amounts varying by watershed location (**Figure 3-Groundwater**). The groundwater table dropped about 10 ft in 2 Glenn County locations: one centered about 1.5 mi north of Artois and the other about 2 mi northwest of Willows. There was a 15-ft decline centered about 3 mi northeast of Williams and numerous 10-ft depressions along the fringe of the low plains from Williams to Dunnigan. A 25-ft depression occurred just west of the Colusa Basin Drain about 5 mi northeast of Dunnigan. DWR (1990) noted that these seasonal pumping depressions were not significant compared to others that have developed in the larger Sacramento Valley Groundwater Basin. DWR (1990) also noted that where there are rather minor seasonal groundwater fluctuations (about 5 ft is considered minor) it reflects a general lack of groundwater storage space or near full groundwater conditions which contributes to winter rainfall runoff and associated flood management problems along the western edge of the Colusa Basin.

It is notable that the 5-ft and 10-ft seasonal groundwater elevation depressions that occurred along the eastern edge of the low alluvial plains in 1988 along are similar to those Bryan (1923) observed in this vicinity during 1912-1913.

In the latest update of California's Groundwater Bulletin 118, DWR (2006) concluded generally that neither the seasonal fluctuation nor long-term trend appeared to indicate overdraught:

> Review of hydrographs for long-term comparison of spring-spring groundwater levels indicates a slight decline in groundwater levels associated with the 1976-1977 and 1987-1994 droughts, followed by recovery to pre-drought conditions of the early 1970's and 1980's. Some wells increased in levels beyond the pre-drought conditions of the 1970's during the wet season of the early 1980's. Generally, groundwater level data show an average seasonal fluctuation of approximately 5-feet for normal and dry years. Overall there does not appear to be increasing or decreasing trends in groundwater levels.

### Representative Period of Record Groundwater Hydrographs

DWR (1990) reported 1970-1988 groundwater hydrographs for 4 representative wells in the watershed (**Figure 4-Groundwater**). DWR (1990) observed that all of the wells except 17N/3W-10C1 showed seasonal groundwater elevation decreases, interannual and multiple-year down trends associated with the 1976-1977 and 1986-1988 drought periods, and up trends associated with Tehama-Colusa Canal water imports. Well 17N/3W-10C1 is east of Delevan and is representative of shallow domestic wells that produce water from the basin deposits underlying the Colusa Basin, an area that has been receiving water imports from the Glenn-Colusa Canal since the early 1900s. There is little use of groundwater in this area and deep percolation from surface water irrigation and possibly also seepage from the Sacramento River keeps the ground water basin full. Naturally high groundwater levels in this vicinity are managed down slightly to prevent evaporation leading to alkaline soils conditions and thereby improve rice yields.

The other 3 wells are representative of groundwater elevation conditions beneath the alluvial fan deposits to the west of the Glenn-Colusa Canal, all of which showed a general water level decline during the 1970s prior to the importation of water by the Tehama-Colusa Canal. **Figure 1-Groundwater** shows that the largest increases in spring groundwater levels form 1975 to 1988 were in the area that is upslope from the Glenn-Colusa Canal and downslope from the Tehama-Colusa Canal. The water level rise after the Tehama-Colusa Canal imports is due to both reduced pumping and increased recharge from the applied irrigation water.

To evaluate groundwater level trends since 1988, we downloaded semi-annual groundwater level data for each of the 4 representative wells evaluated by DWR (1990). We extended each of these groundwater hydrographs back to 1963 and forward to 2008 (**Figure 5-Groundwater).** The alluvial fan wells showed a multiple-year downtrend in elevations during the early 1990s drought period ranging from 10-20 ft. Levels then gradually recovered to their late 1980s wet years levels by the end of the wet years at the end of the 1990s. Well 19N/4W-12E1 has maintained that relatively high level since 1998, but the other wells have declined somewhat. Well 17N/3W-10C1 continues to fluctuate within a narrow band of elevations most recently reflecting a regular seasonal pattern from about 4 ft below the ground surface in spring to about 8 ft below the surface in fall. This pattern may reflect recent changes to the groundwater table management for alkali prevention and rice production.

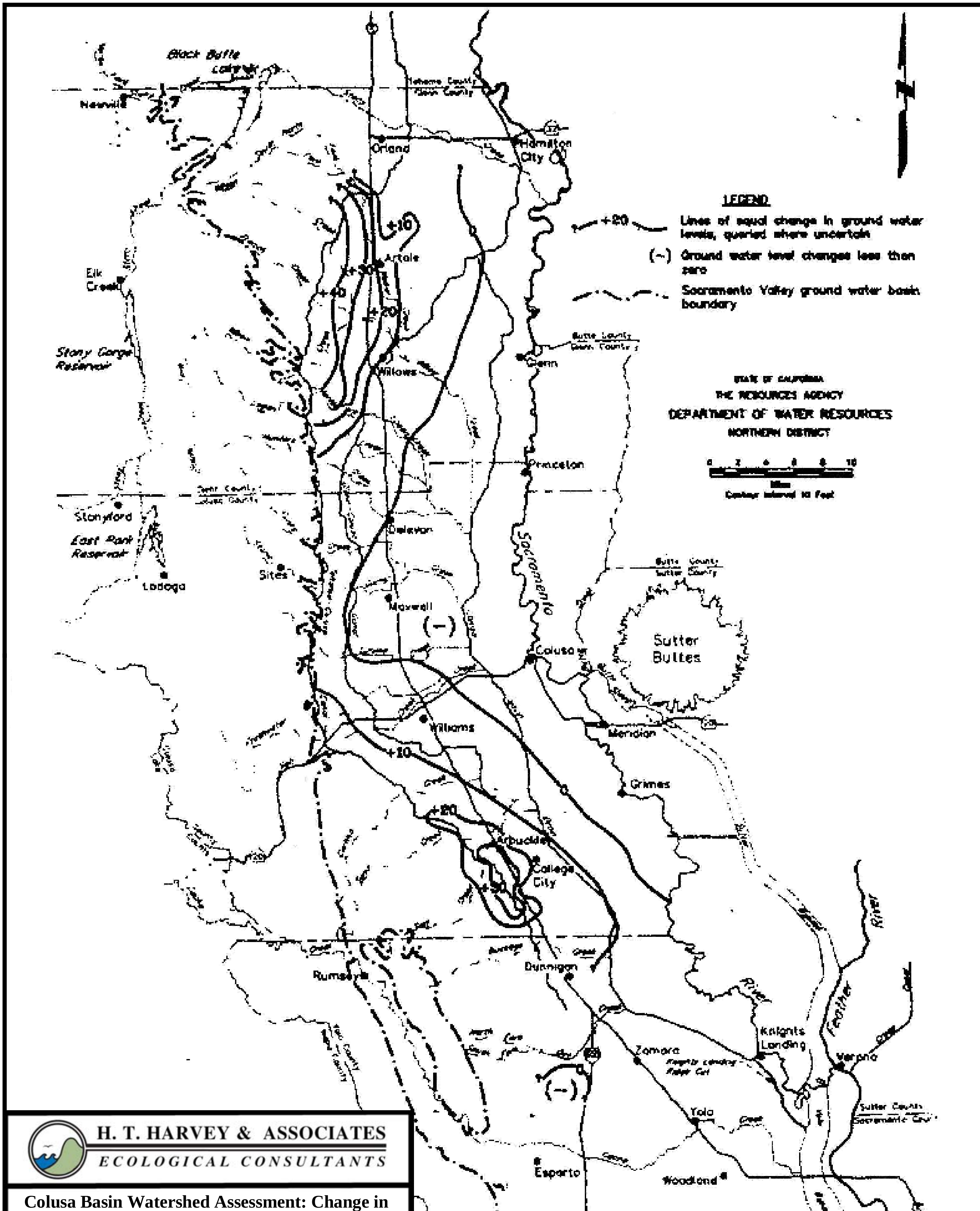
### Land Subsidence

Land subsidence is the lowering of the land surface over a broad area typically caused by groundwater withdrawal from deep alluvial aquifers. When groundwater is pumped from an alluvial aquifer, it reduces the pore water pressure in the spaces between grains of sand and gravel. And reduced water pressure in the sand and gravel causes slow drainage of water from any clay and silt beds adjacent to the sand and gravel aquifer. These clay and silt beds are compressible and will compact after water is drained from them, resulting in subsurface and surface settlement. The subsidence in the Davis-Zamora area appears to be attributable to this mechanism; deeper clay layers compacted after sand and gravel pore water pressure was reduced by groundwater pumping (Navigant Consulting, Inc. 2000).

Lofgren and Ireland (1973) identified 2 main areas on the southwestern part of the Sacramento Valley near Davis and Zamora where land subsidence had exceeded 1 ft by 1973. The USGS (1973) found that as much as 2 ft of subsidence had occurred in at least 2 areas of groundwater pumping, east of Zamora and west of Arbuckle (**Figure 6-Groundwater**). USGS (1973) noted that roughly 1 ft of subsidence results for each 10-100 ft of groundwater table elevation decline below historic low levels. The maximum long-term groundwater level decline occurred near Arbuckle, where a 100-ft pumping depression existed in 1969, before the Tehama-Colusa Canal began importing water to the watershed (DWR 1990).

Land subsidence monitoring since 1973 showed some local land subsidence in the Davis-Zamora area during the 1987-1992 drought period. Work to relevel the Zamora-Knights Landing line in 1988 revealed 3 ft of subsidence at Zamora, 3.9 ft about 2 mi east of Zamora, and 0.5 ft at Knights Landing. As of 2000, total subsidence at Zamora was reportedly as much as 6 ft (Navigant Consulting, Inc. 2000).

DWR with assistance from the associated counties is currently establishing a cooperative GPS subsidence network for the Sacramento Valley from Yolo County to Redding. The GPS network will allow DWR or the county agencies to periodically resurvey the network to determine if and how much land subsidence is occurring. Such networking will facilitate more cost-effective and thus more frequent monitoring.

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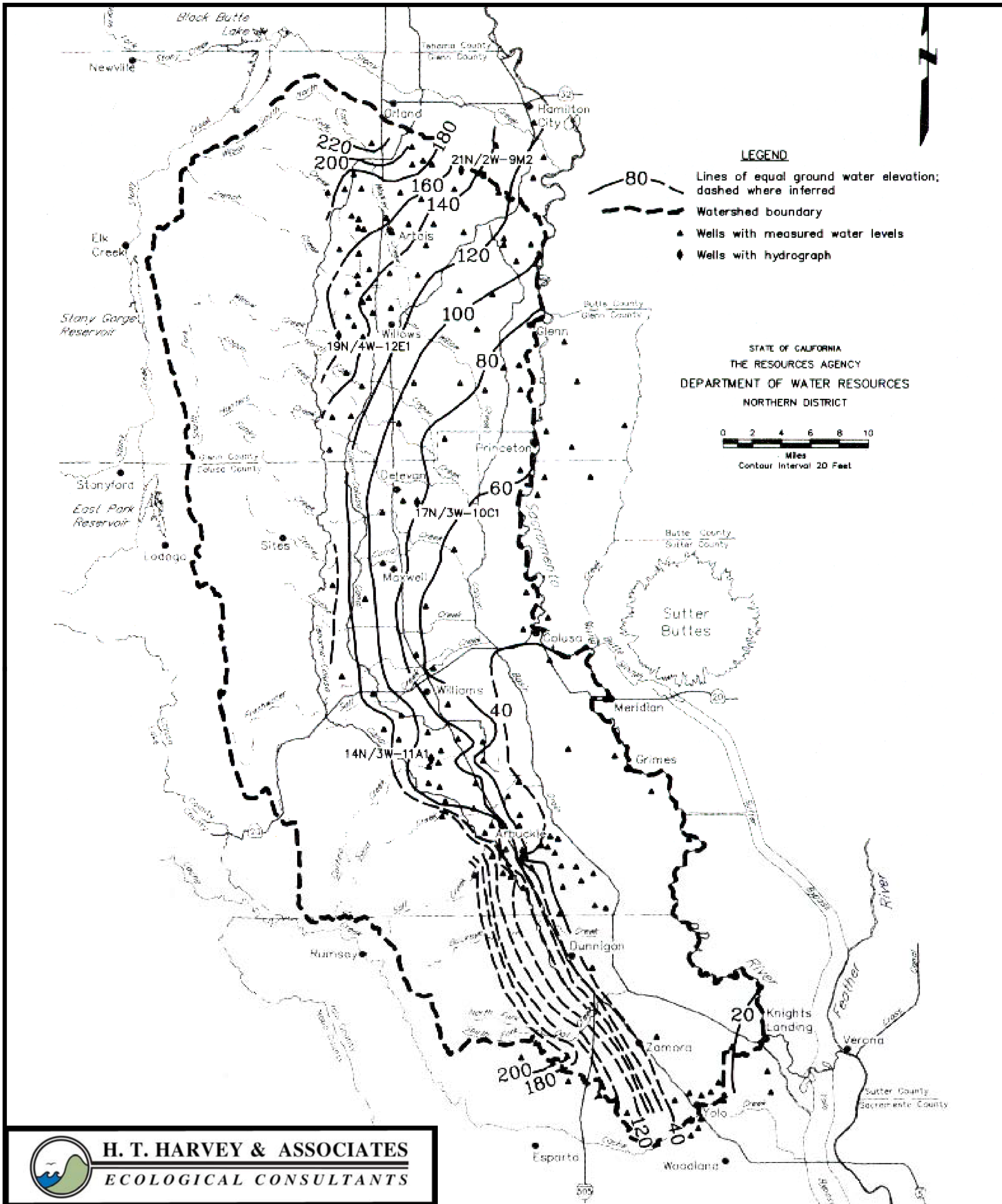
**Colusa Basin Watershed Assessment: Change in Groundwater Levels Spring 1975-Spring 1988**

| | | |
|---|---|---|
| Proj No. **2850-01** | Date **Dec. 2008** | Figure **1 - Groundwater** |
| SM | **N:/Projects/2850-01/Figures/April 2008** | |

**Source: California Department of Water Resources, Northern District, Date. Colusa basin appriasal.**

**Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.**

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**Colusa Basin Watershed Assessment: Ground Water Contour Map 1988**

| Proj No. **2850-01** | Date **Dec. 2008** | Figure **2a - Groundwater** |
|---|---|---|
| **SM** | **N:\Projects\2850-01\Figures\April 2008** | |

**Source: California Department of Water Resources, Northern District, Date. Colusa basin appriasal.**

**Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.**

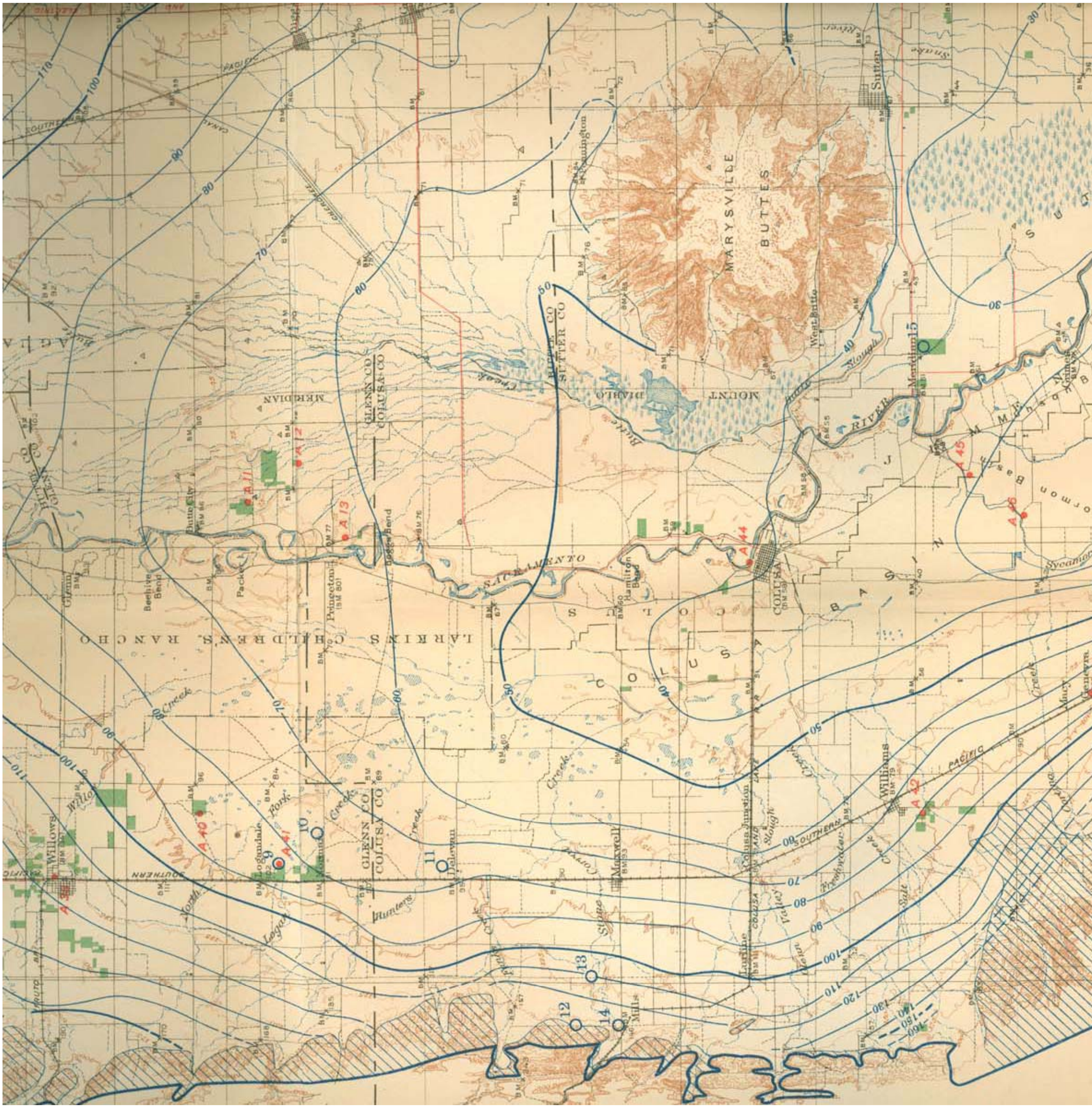
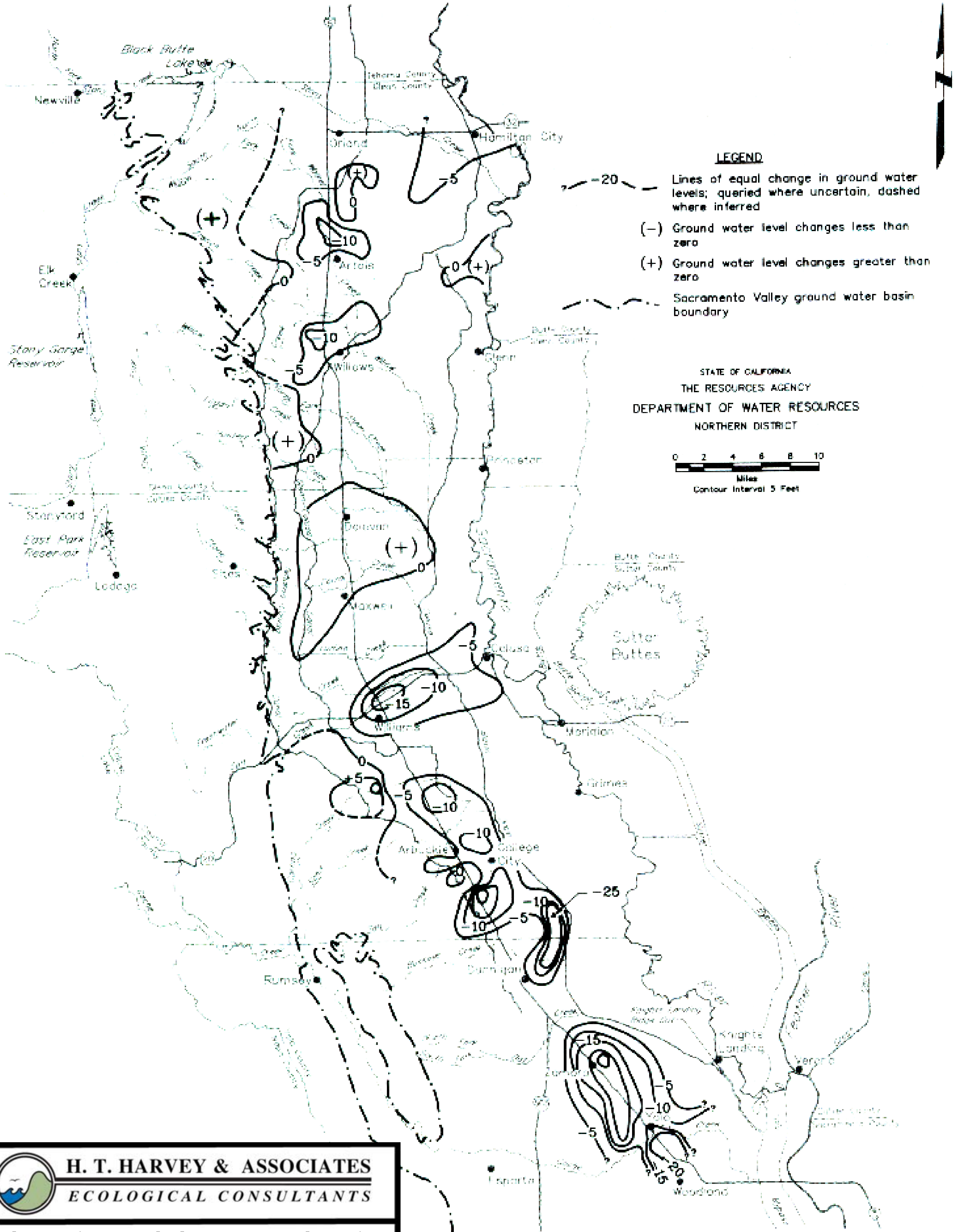



**Figure 2b-Groundwater.** Excerpt s from Plate IV of Brya
elevation contours of the Sacramento Valley including the
measured during 1912-1913.

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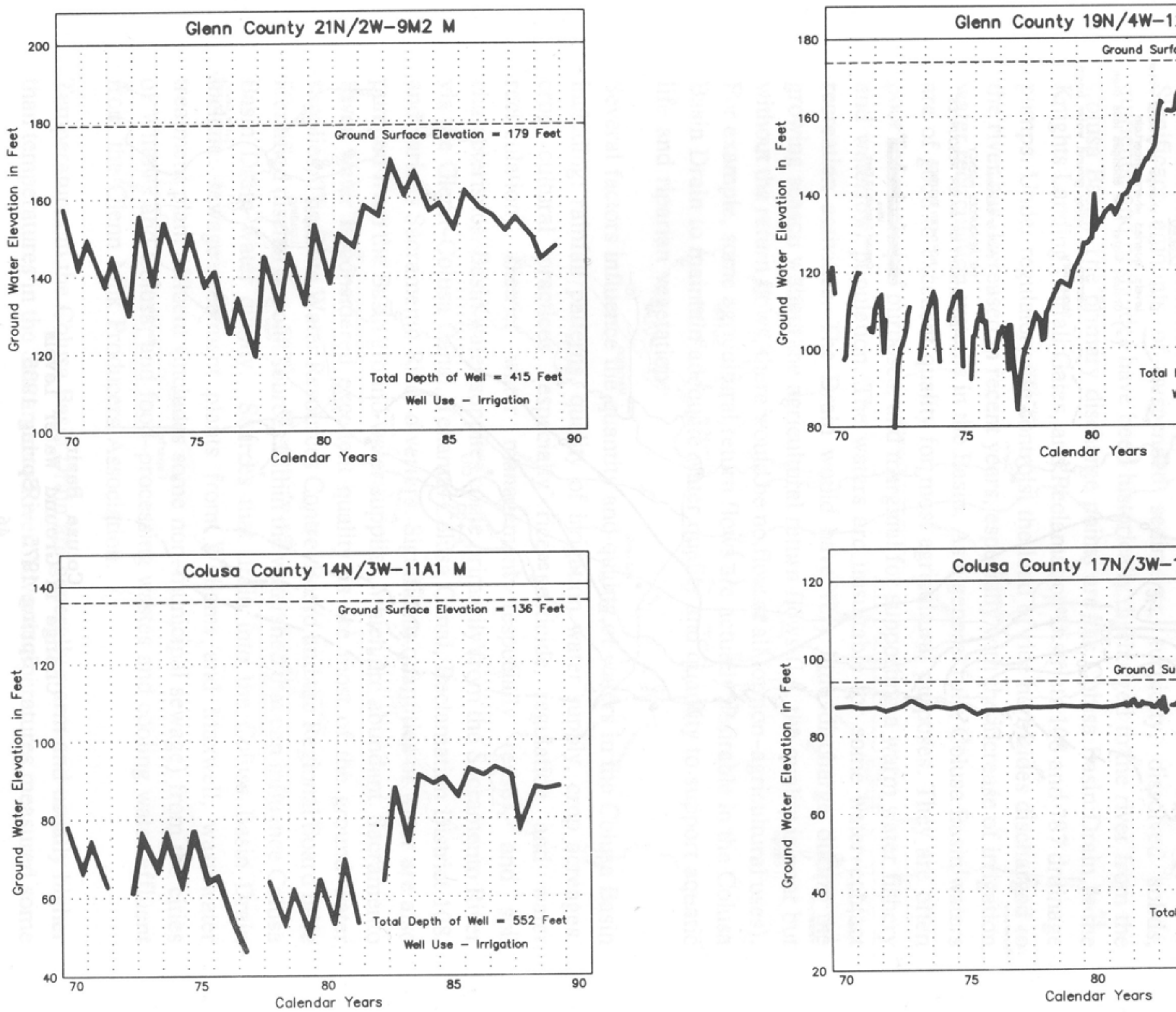
**Colusa Basin Watershed Assessment: Change in Groundwater Levels Spring 1988 - Fall 1988**

| Proj No. **2850-01** | Date **Dec. 2008** | Figure **3 - Groundwater** |
|---|---|---|
| SM | N:\Projects\2850-01\Figures\April 2008 | |

**Source: California Department of Water Resources, Northern District, Date. Colusa basin appriasal.**

**Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.**




Colusa Basin
Representative Ground Water Hydrographs

**Figure 4-Groundwater. Representative groundwater well hydrographs 1 (adapted from DWR 1990).**

**Figure 5a-Groundwater. Representative groundwater well hydrographs 1963-20**
**GLENN COUNTY 21N/2W-9M2**
**(Source: DWR Water Data Library)**

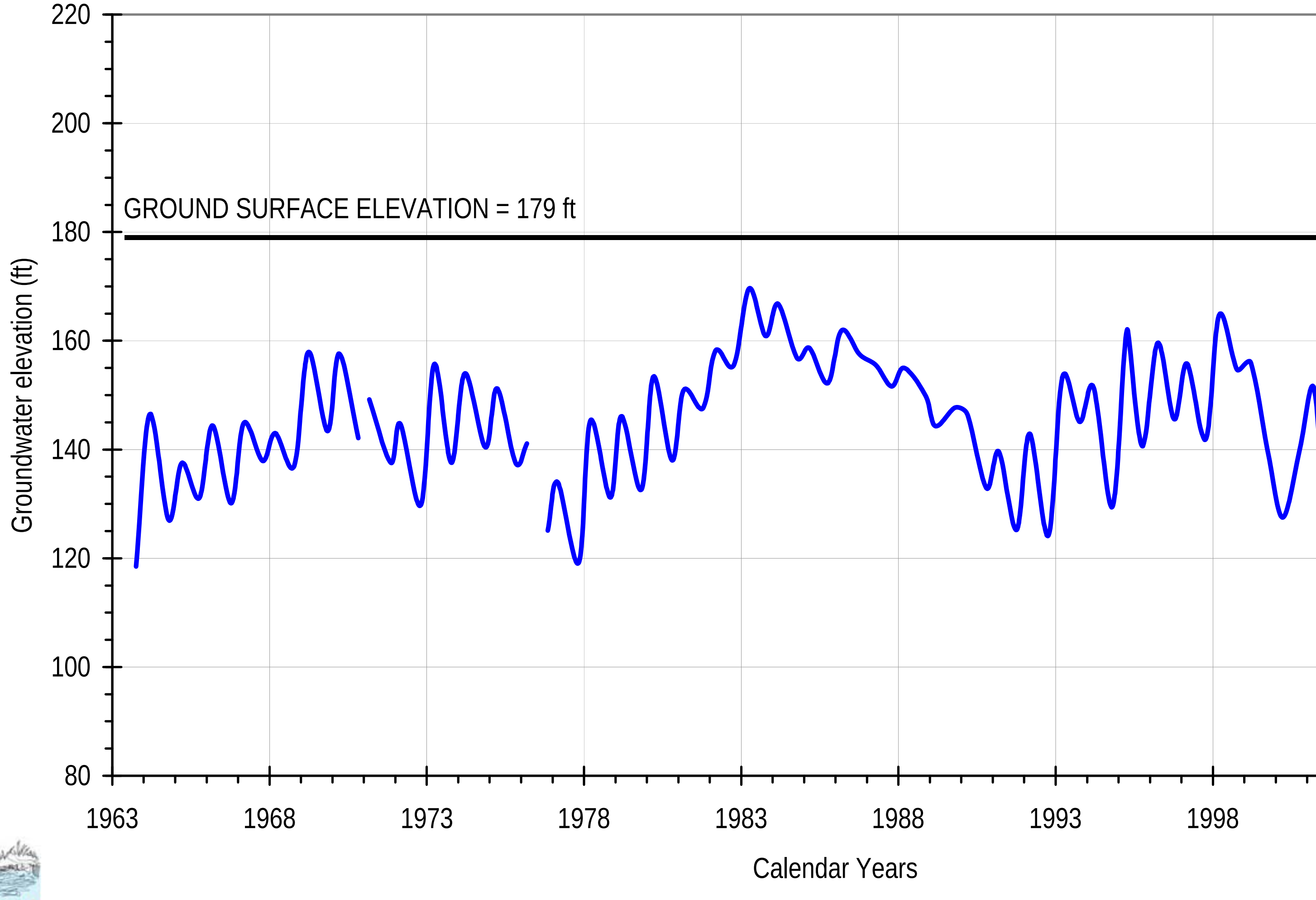


**Figure 5b-Groundwater. Representative groundwater well hydrographs 1963**

**GLENN COUNTY 19N / 4W-12E1**

**(Source: DWR Water Data Library)**

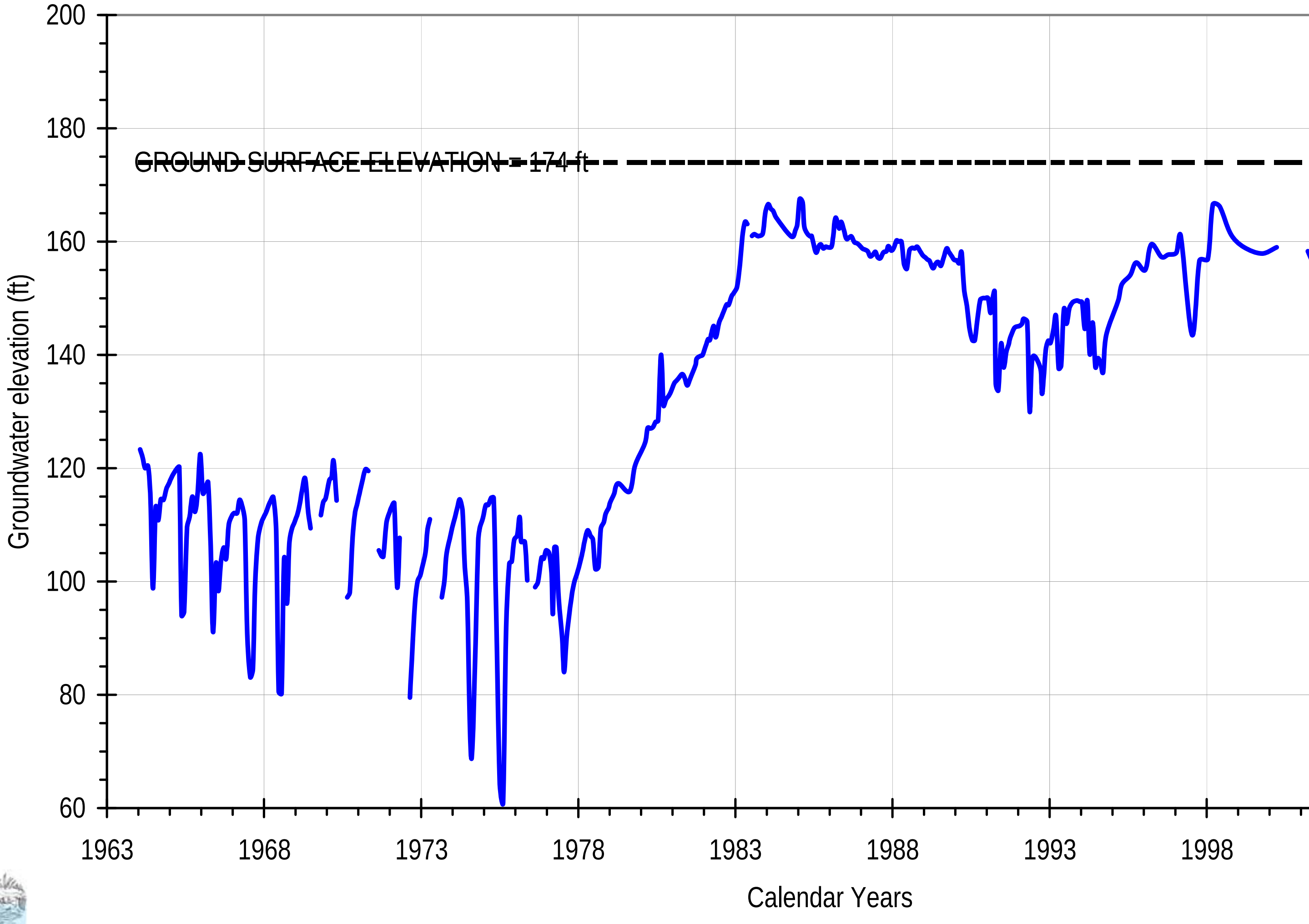


**Figure 5c-Groundwater. Representative groundwater well hydrographs 1963**
**COLUSA COUNTY 14N / 3W-11A1**
**(Source: DWR Water Data Library)**

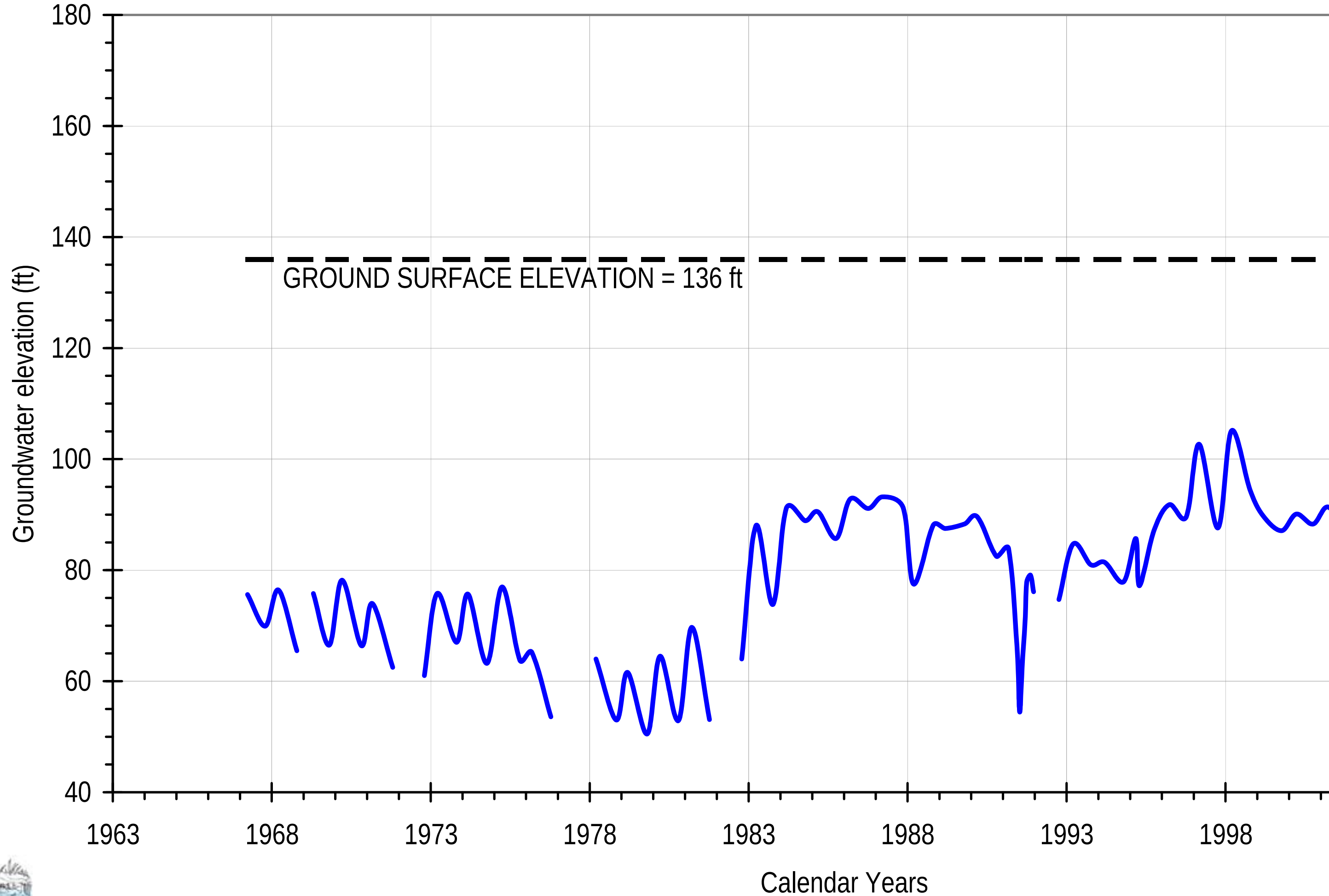
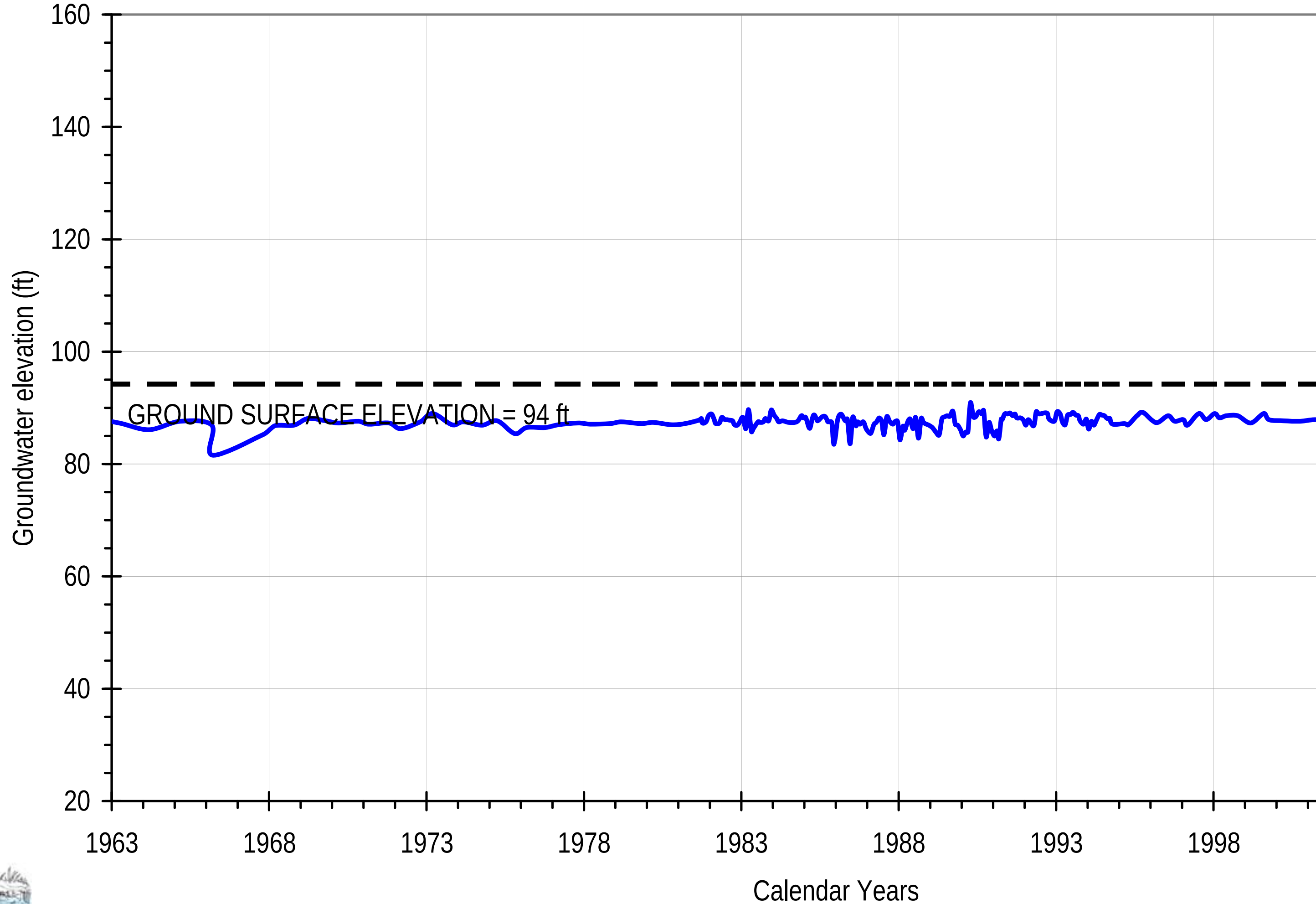


**Figure 5c-Groundwater. Representative groundwater well hydrographs 1963**

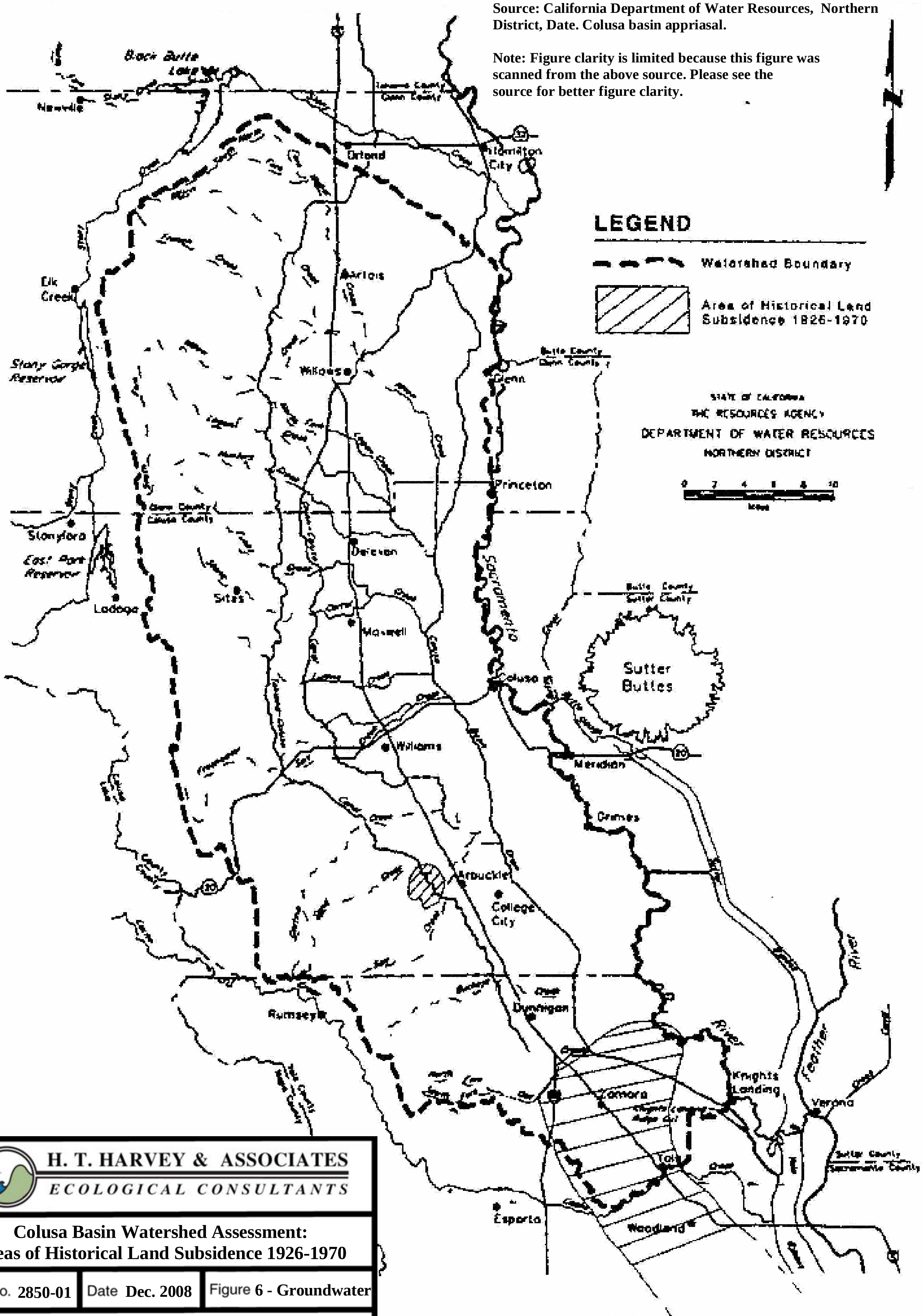
**COLUSA COUNTY 17N / 3W-10C1**

**(Source: DWR Water Data Library)**



Source: California Department of Water Resources, Northern District, Date. Colusa basin appriasal.

Note: Figure clarity is limited because this figure was scanned from the above source. Please see the source for better figure clarity.





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**Colusa Basin Watershed Assessment:**
**Areas of Historical Land Subsidence 1926-1970**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 6 - Groundwater |
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# FLOOD MANAGEMENT

The eastern third of the Colusa Basin Watershed lies within the natural floodplain of the Sacramento River. The geology and geomorphology of the valley flat is described above. Its surficial geology records its pre-EuroAmerican condition: a surface covered with Sacramento River floodplain deposits which were deposited by slough channels in ribbons over the surface enclosing flood basins where finer grained sediment fell out as flood basin deposits, features that progressively disappeared from the old maps of the area as these overflow and swamplands were progressively reclaimed for agriculture. Kelley (1989) reflected on early explorers' assessments of the scene:

> The flatlands of the Valley were studded with oaks – high, stately trees with broad spreading crowns. The deep flowing Sacramento dominated the scene, its banks lined by a tangled riverine growth of tall oaks, sycamore, cottonwood, willow, and ash, about a mile in width. Men travelling horseback across the Valley floor in the late 1840s rode through open seas of wild oats and other grasses standing six feet high, stretching as far as the eye could see, and so thickly grown that their horse could only make their way with difficulty.
>
> In normal flow the Sacramento River is a big river, carrying about 5,000 cubic feet per second, but in flood times it can on occasion swell gigantically to such immense flows as 600,000 cubic feet per second. Indeed, the river's channel could never contain within its natural banks the huge flows of water that almost annually poured out of the canyons of the northern Sierra Nevada. Signs of yearly flooding were everywhere apparent to Ensign Gabriel Moraga, reaching out, he estimated, to cover a band of territory perhaps five miles across on the eastern side and three miles on the west.
>
> In effect, each watercourse on the flat Sacramento Valley floor, from small stream to great river, flowed on an elevated platform, built up by the silt the streams deposited in their own beds. As floodwaters periodically rose to overtop the stream banks and spread out over the valley floor, natural levees were also built up, for as the overflowing waters lost velocity they dropped their remaining burden of silt most heavily on the land immediately bordering the rivers. From these more elevated locations paralleling the watercourses, floodwaters flowed down to pond in wide shallow basins lying between the streams, the broad expanse of these flood-created lakes often leaving nothing dry but the natural levees bordering the rivers and the higher lands next to them. Together, the ponds in the basins annually created a vast inland sea a hundred miles long occupying the centerline of the Sacramento Valley which slowly drained back into the river channels and down through the delta during the spring months. In their lowest elevations, where the water ponded the longest, these basins immense swamps of tules (that is, large bulrushes), standing ten to fifteen feet high. The Indians built not only their homes but their boats and sleeping mats of these tall, woody reeds.

Naturally frequent and sustained flooding of the Colusa Basin Watershed's low-lying lands, the Colusa Basin, was both a blessing and a curse. Hundreds of thousands of years of routine flooding of the watershed's valley flat had built up its surface with fertile soils resting in a fair climate, but tremendous organization and effort was needed to realize much of the watershed's latent agricultural potential. It would take excavating a tremendous length of the deep and wide irrigation and drainage canals and building up higher and higher flood control levees to battle the river flood. The early flood control efforts were decidedly locally driven, pushed forward by social leaders like the *Colusa Sun* editor Will S. Green and the farmers and landowners who invested time and money in the necessary work. However, these early efforts were destined to fail due partly to a lack of organization and physical conflicts with concurrent flood control levee building on the east bank of the river and partly because the local leaders and the national engineering experts continually underestimated what tremendous flood discharges the Sacramento could produce. Ultimately, the hastily shored-up levees were more uniformly bolstered and incorporated into the federal Sacramento River Flood Control Project, a project not substantially completed and deemed largely successful until the flood of February-March 1940. Levee breaks from that flood were shored up again by 1944, and although there had been widespread flooding of the Colusa Basin it was certainly much less than it could have been; the project had given people of the Colusa Basin Watershed some confidence that the major source of damaging floods had been controlled.

Perhaps there is no better account of the broader political and cultural factors entwined in the history of reclamation and flood control efforts than that prepared by Kelley in *Battling the Inland Sea* (1989). Much of the historical summary in this section is taken from that account. We also found maps of some of the early detailed engineering planning studies which viewed over the decades of tried and failed project planning dovetail with Kelley's history of the same. We also review the broadly ranging engineering reports of the DWR (1962, 1964, and 1990) to summarize the watershed's more recent and relevant history of flood management. Even with the problem of Sacramento River overflow substantially solved, the watershed is left with a lesser but still serious and complicated flooding problem referred to in this assessment as the 'residual flooding.' Finally, we briefly review the comprehensive programs the CBDD and USBR have proposed to mitigate the residual flooding.

### Pre-1850 Sources and Patterns of Flood Waters in the Colusa Basin Watershed

Before the Sacramento River Flood Control Project was substantially completed in 1944, general widespread flooding of the Colusa Basin Watershed was dominated by frequent flood overflows from the Sacramento River. The natural levee on the west side of the Sacramento River generally held back its floodwaters at the upstream end of the watershed, but because the slope of the river was changing, these levees weren't enough beginning at Hamilton Bend about 7 mi north of Colusa. The natural geomorphic tendency for the past hundreds of thousands of years was for the Sacramento to drop some of its silt load and flood broadly over its bank, thereby becoming more gradually sloped and narrowing the banks. Large flood flows commonly gushed out onto the upper Colusa Basin from 'seven-mile' slough (also known as Cheney Slough) and generally along that 7-mi stretch. The town of Colusa lay on a somewhat more elevated natural levee deposit protecting it from most flood overflow. Just downstream from Colusa, the Sacramento River almost annually poured floodwaters out to the east into Sutter Basin and out to the west into the lower Colusa Basin via Upper Sycamore Slough and multiple locations downstream from Colusa to Knights Landing. As Kelley (1989) explained:

> Upstream from Colusa the Sacramento River flows with a strong current, for its bed, though relatively flat, has a significant fall: about thirty feet in elevation in the twenty river-miles above town. In this reach, therefore, the Sacramento winds tortuously back and forth within a wide bed, for the river has power enough to cut into the banks on either side, forcing them three quarters of a mile apart. Meandering between these banks, the Sacramento has actively formed loops and

> islands. Because this made steamboating more difficult, the original party of settlers in 1850 chose Colusa's particular site to lay out a town, and named it for the resident Indian tribe, the Co'lus.
>
> Just below town the Valley floor flattens out markedly, its fall moderating to about a foot each river-mile. The river flows more slowly, is unable so sharply to cut into its paralleling banks, and they close in, producing a narrower channel that meanders considerably less. A narrower and straighter channel makes it a better steamboating river, but one that cannot carry so much floodwater. While the Sacramento's wide bed above Colusa is able to enclose volumes that, in flood times, reach 250,000 cubic feet per second, the constricted channel below that point can hold only a flow of 70,000 feet per second. There is, in short, "a strange funnel-shape effect in the natural formation of the river that makes itself felt at Colusa…," as engineer B.A. Etcheverry of the University of California described the situation to a congressional subcommittee in 1927…
>
> …The large inland sea up to a hundred miles long which appeared almost annually in the center-line of the Valley began right here, in the overbank flows in the Colusa vicinity. Local people would try again and again to push the water back into the river's channel and protect themselves from overflow, but it would burst out, first in one location, then in another, to resume its immemorial flooding out over the countryside.
>
> From the point about twenty miles upstream from Colusa where the Sacramento in its natural condition began flowing overbank in both directions, the river runs on an elevated bed, for, having lost some of its volume, it begins dropping silt onto its bed, building it up as a platform. Thus from here to its mouth, the Sacramento runs on a ridge just like the Mississippi River. From the elevated river bed and the stream's natural levees the land on either side falls slowly away for a distance of three or four miles, after which it tilts gradually upward to rise to the foothills. Thus the water that poured out of the river in high water times through slough openings flowed out into these "troughs." Further down the Valley, the troughs eventually widened into great tule basins.

In addition to the Sacramento River flood overflows, there were substantial but lesser contributions of flood waters from the relict Stony Creek alluvial fan area north of Willows and the foothill streams bordering the valley on the west. We shall see that managing these smaller flood waters was partly neglected in the all-consuming struggle to control the more damaging Sacramento River overflows. Also owing to the difficulty of managing these foothill stream flood waters, the watershed has been left with its current residual flooding problem described below in this section. The history of efforts to control of Sacramento River floods is described first.

### Sacramento River Flood Chronology Adapted from Kelley (1989)

It may be difficult to imagine that the Sacramento River, now controlled by several upstream flood control reservoirs and hundreds of miles of levees, weirs, and wide bypass channels, could flood most of the wide flat lands of the Sacramento Valley almost annually. Historical accounts tell us that it did. The best chronology of historical floods on the Sacramento River may be that documented from Colusa, Sacramento, Yuba City, and Marysville newspaper reports by Kelley (1989). Kelley's references to and brief descriptions of individual floods of note are listed in the below chronology. The references generally include more reporting from Marysville and Yuba City than Colusa, but this does not necessarily mean that they were more often flooded. Of course flooding on the Yuba and Feather rivers and the lower Sacramento River is known to have been exacerbated by massive sediment discharges from the hydraulic mining operations in the Sierra Nevada. It's not clear how much the mining debris would have exacerbated flooding in the Colusa Basin Watershed. There have been fewer reports out of Colusa probably reflecting its elevated location on a high natural levee deposit of the Sacramento River. As Kelley (1989) wrote:

> Colusa's site, however, was sufficiently high above the Sacramento so that, unlike Yuba City and Marysville, in its history it has never itself been actually flooded. However, it has been much more likely to be entirely surrounded for long periods by flooded territory. Colusa borders a much larger river, and it sat in the midst of what then were wide tule swamps that encircled it, making the town in floodtimes an island in a sea of floodwaters.

### Failure of Early Privately Constructed Flood Protections

After 1850, the new settlers of the "overflow lands" on the valley flat did what they could to provide adequate irrigation, drainage, and flood protection on their individual and collective parcels, but these relatively small uncoordinated projects were practically failing with each new flood, failing both because they were too small and because they were part of an uncoordinated fabric of small projects dotting a broad floodplain. Flood protection of one small area was generally at the expense of still unprotected or less protected neighboring areas because the facilities typically followed rectilinear property boundaries which tended to cut off natural flow paths and concentrate flood flow to either side.

On 31 May 1861, the state legislature passed AB 54: "An Act to provide for the Reclamation and Segregation of Swamp and Overflowed, and Salt Marsh and Tide Lands, donated to the State of California by Act of Congress." AB 54 was intended to promote organization of "swampland districts" comprising sensibly organized blocks of overflow lands, whose collective landowners would benefit from economies of scale and cooperate to build more capital-intensive and more effective drainage and flood protection facilities. It was thought these facilities would be designed using engineering principles and consistent standards inspired by state supervision to be provided by an elected Board of Swampland Commissioners. Kelley (1989) explained:

> A swampland district was to be created only if it encompassed an area of land "susceptible to one mode or system of reclamation," by which was meant land contained "within natural boundaries" that comprised, in drainage terms, an integrated unit. In practice, the board understood this requirement to mean that a district would usually encompass an entire basin between main channels of the rivers. (Since the Valley's rivers were in a depositional phase, laying down silts in their beds rather than scouring it out, their beds were higher than the lands on either side.) Individual basins could encompass more than a hundred thousand acres.
>
> When a petition came in from at least a third of the landowners in such an area, the commission would proceed to erect the district. Thereafter, it would draw on money held in the Swamp Land Fund (created from the sales of swamplands in that district) and on such additional funds as landowners might themselves have to provide, to build a single system of levees and outfall works for the entire district. Thus, there would be no levees around individual properties; rather, the entire basin would be drained and protected from flood, so that all land would be protected in common. (In 1862, taxing powers were given to the districts for this purpose.) These works, it will be noted, were not simply to be thrown up in the traditional, amateur way, they were to be

> *planned*, and by engineers appointed by the Board of Swamp Land Commissioners, not by the landowners.

But after 5 years of poor results under this program, the state legislature considered passage of AB 591 that would dissolve the Board of Swamp Land Commissioners and pass the same responsibility to the boards of supervisors of individual counties. Will S. Green of Colusa, is credited with representing Colusa and Tehama counties in influencing the legislature to pass a version of AB 591 in 1868: the Green Act or Green's Land Act. According to Kelley (1989):

> In his new legislation Green gave the Republicans' "district" concept a revealing Democratic twist: he radically localized it. That is, when purchasers of half or more of a tract of swamp and overflowed land "susceptible of one mode of reclamation" – in practice, now, this simply meant whatever land the group owned – wished to build protective levees, they needed only to petition their local County Board of Supervisors for creation of a swampland district (which could be limited, now, to a single piece of property), informing them of their desire "to adopt measures to reclaim the same." The board, in its turn, was to make certain that the lands to be included were properly described, after which it had no choice but to authorize formation of the district. It no longer possessed, in short, any authority to examine and approve, or disapprove, proposed levee systems around the property, their alignment or nature, or whether they interfered with the Valley's natural drainage patterns…

Kelley (1989) lamented that:

> . . . the result was that for the most of the next half-century, the Sacramento Valley would be scissored into a crazy-quilt of small reclamation districts whose levees followed property lines, not the Valley's natural drainage pattern. Flood control anarchy, and therefore massive flood control failure, would be the result.

He was correct that an early opportunity to exact a more comprehensive and physically sensible flood control solution for the Sacramento Valley certainly had existed in the 1860s when millions of contiguous acres of overflow and swamp lands were held by the State, an opportunity that vanished with the passage of Green's Land Act in 1868, which saw those millions of acres pass into private landownership within just 3 years, in individual blocks as large as 250,000 acres. Practically, as Kelley lamented, this meant that the ultimate configuration of flood control levees would not necessarily conform to the sinuous boundaries of natural drainage paths. And some of the earliest private levees would block the most common sense 'path of least resistance' pathways for safely directing the inevitable Sacramento River overflows, those pathways where there are today designated flood bypasses.

And flood control anarchy did ensue. As early as 1867 Colusa County dammed off Wilkins Slough along the west bank of the river about 18 mi south of Colusa, but within a week of its completion local people in the Wilkins Slough area destroyed it. This was just the beginning of vigilante violence over flood control.

By 1870, Reclamation District [RD] 108 had been established and completed some 45 mi of levee on the west bank of the Sacramento River from Knights Landing upstream to the vicinity of Upper Sycamore Slough. The first levee was built 60 ft back from the river bluff and just 3-ft-high, 1 ft above the highest river flood level known at the time. It closed 5 major sloughs (Upper

Sycamore, Wilkins, Bear, Lower Sycamore, and Cache Sloughs) and pushed would be Colusa Basin floodwaters over the river's east bank onto RD70 overflow lands lying in the Sutter Basin. Kelley (1989):

> A group of swampland entrepreneurs whose lands lay in Colusa Basin revealed that they had pooled there interests to form Reclamation District 108, a giant organization that is still, more than a century later, in active existence. RD 108's appearance was historically crucial. It did in fact initiate in a major way the building of levees on the Sacramento's banks, and its doing so set the whole process of enclosing that stream rushing swiftly along thereafter in a spiral of hectic construction, each project spurred into being as riposte to prior ones.

Rather than seeking an injunction halting the levee construction, RD70 also sought to reclaim its own overflow lands and so began erecting a similar 40-mi-long levee on the east bank of the river from Knights Landing to the mouth of Butte Slough near Meridian. But closing off Sacramento River flood waters from the RD70 lands practically required closing off flood waters from entering Sutter Basin via the wide natural channel of Butte Slough. William H. Parks established RD5 and with the 3 April 1971 blessing of the Sutter County Board of Supervisors, proceeded to construct a levee-dam across Butte Slough: "Parks Dam" was to be built 6 ft above the high water mark and 8 ft wide on the top (Kelley 1989).

Parks Dam would have pushed Sacramento River flood waters directly into upper Colusa Basin, over the still natural west river bank in the 5-mi long reach between Upper Sycamore Slough and the higher elevation lands at Colusa. By June 1871, RD108 resolved to cut off this gap and so acquired overflow lands to the north by forming RD124. RD108 extended their west bank levee to the north along the border of these newly annexed lands to block off the 5-mile-long and 7-mi-long gaps to the north between Colusa and Hamilton Bend. The RD124 levee was 5-ft-high and 4-ft-wide along the top. By the end of 1871, the west bank levee was 60 mi long, extending from Knights Landing to Hamilton Bend, the entire floodprone eastern border of the Colusa Basin Watershed.

At the same time, Parks would report to the Sutter County Board of Supervisors that his levee-dam was completed across Butte Slough and recommended to the Board that caretakers be placed on the dam to guard it from vandals. Three weeks later during a night when rising river flows were pooling along the face of Park Dam, "masked men arrived at the structure, overpowered the guards, and cut the structure at 2 places between Butte Slough and the highlands bordering Sutter Buttes" (Kelley 1989). Five hundred ft of the dam blew out and Parks immediately committed to rebuilding it, which he did 3 more times over the next 4 years. In a series of events Kelley (1989) described as the "Parks Dam War" it would also fail 3 more times, twice by the river and finally at the hands of angry RD70 residents. RD108's 6-ft high, 60-mi-long west bank levee was saved from the threat of Parks Dam but it was still not enough to protect the Colusa Basin Watershed from frequent damaging floods.

> In 1889, the people of Colusa County flung themselves into an almost desperate outburst of levee building, putting up many miles of costly new levee, but it was all lost labor. In 1892, after a huge storm, the Sacramento reached its highest mark ever at Colusa, there were many levee breaks above and below town on both sides of the river, and thereafter Colusa County people seem to have fallen back exhausted, unable to do more. (Kelley 1989).

Some 20 years after the Parks Dam controversy ended, Kelley (1989) quoted the *Colusa Sun* commenting that "The landowners of 108 expect to be drowned out about two years in five. They fight the water like heroes."

After these years of continually struggling against the river and repairing the west bank levee, one of RD108's largest landowners and leading flood fighters, A. H. Rose, now State Commissioner of Public Works, reported the state of affairs to governor Markham, as told by Kelley (1989):

> Looking out on the Sacramento Valley in 1895, a quarter of a century after he and his fellow investors had launched RD 108, Commissioner Rose saw a discouraging scene. Vast sums of money, he remarked in his first annual report to the governor, had been spent on levees, and much of it had been wasted. The subject of flood control in the Sacramento Valley needed to be treated as a whole, he said, but instead the Valley "is divided into several hundred [independent] Reclamation Swamp Land or Protection Districts." Some of them had natural boundaries, but most were "arbitrarily bounded by property or other lines." Each district was supreme so far as the location and height of its levees were concerned, which in many cases they had built with no attention whatever to their effects on anyone else or on the river, "the prime object being the protection of the lands of their district according to the local objects to be obtained, which generally means the construction of levees powerful enough to overtop or force a break on the other side." Quite out of their concern had been making certain that channelways were of appropriate size, or that there was suitable outfall for floodwaters to flow down valley. How had this happened? Reported Rose: "This unfortunate condition has been the direct outgrowth of the policy of the State to sell lands prior to their reclamation by the State; or even to prescribe the limits and locations of levees and drainage channels."

### Sacramento River Flood Chronology

| | |
|---|---|
| 1850 – January | Two weeks of inundation damaged buildings within a mile from river in Sacramento. Afterwards, first levee in the Sacramento Valley constructed, entirely around the town of Sacramento. |
| 1852 – March | Caused Sacramento ring levee to fail and flooded Sacramento. Marysville also flooded. |
| 1852 – December | Deeper inundation than January 1850. Entire valley south of Colusa under water. Thousands of cattle drowned. |
| 1853 – March | Marysville was inundated 1 ft deeper than March 1852. |
| 1860 – March | flood |
| 1861 – March | widespread overflow in the flatlands |
| 1861 – December | part of "double-flood of 1861-1862 . . . lasting for more than a month…and far exceeding anything people had earlier seen" |
| 1862 – January | "double-flood of 1861-1862 . . . The inland sea had rarely ever spread so widely or had been so deep" |

| | |
|---|---|
| 1864 – December | "heavy and pounding rains" |
| 1866 – December | Will S. Green: "Without doubt, more water passed down the valley [during the flood] than ever before since its settlement by whites in the same length of time. . . . One sheet of water more than 20 miles across was reported to cover the valley floor between Marysville and Colusa. . . . The river tore out several large cuts in its east bank, and torrents of water flowed out into the tule lands." |
| 1867 – February | "'one continuous body of water' many miles across straddling the whole course of the Sacramento River from above Colusa southward. . . from three to eight miles wide on the west side of the river, perhaps half that area being covered on the east." |
| 1867 – December | "Colusa Sun reports that town and its environs were 'now an island; above, below, to the right and left is one vast sheet of water. Between town and the Coast Range the water presents the appearance of an inland sea.'" |
| 1868 – March | "the area downriver from Colusa was experiencing the highest water it had ever known. 'The county … on either side,' wrote Green, 'is completely inundated.'" (p.118) |
| 1872 – January | "Caused winter rains of December 1871 and early January 1872. From Colusa, Green observed that "great oceans of water…are to be seen in every direction from town" First edition of Parks Dam across the opening of Butte Slough was destroyed by "masked men" that "overpowered the guards and cut the structure at 2 places between Butte Slough and the highlands bordering Sutter Buttes." (p. 160); "The Sacramento River reached its highest mark at Colusa since American Settlement." |
| 1874 – January | "the rains continued, sweeping in from the southwest day after day, and the great Sacramento River continued to swell" washing out the second construction of Parks Dam. |
| 1875 – January | "an enormous deluge of storm waters in early January battered the Valley day after day and produced a catastrophic flood" on the Yuba and Feather Rivers. "…for many miles north and south of Colusa the Sacramento poured heavily through openings on the east bank…", causing failure of the third construction of Parks Dam. (p. 169) |
| 1875 – December | "more disastrous flooding" |
| 1876 – January | RD70 levee on east bank of Sacramento River near the head of Butte Slough failed and washed homes away in that district. District members subsequently cut fourth construction of Parks Dam. (p.170) |
| 1878 – February | "the Sacramento, which had been running higher than ever before because of debris in its bed, burst through a levee downstream from the city of Sacramento." (p. 181) |

| | |
|---|---|
| 1881 – January | "a monster flood, one of the greatest in the history of the Sacramento Valley" (p. 217) |
| 1892 | "after a huge storm, the Sacramento reached its highest mark ever at Colusa, there were many levee breaks above and below town on both sides of the river…" (p. 224). |
| 1896 – January | "disastrous" (p. 243) |
| 1902 | "…levees were broken through and floodwaters rushed out widely over the valley floor." (p. 255) |
| 1904 – April | "…disastrous outflow of floodwaters into Sacramento Basin…" (p. 262) |
| 1907 – March | "…at Colusa, the Sacramento was utterly out of control and running wild over the countryside, having burst its bank north as well as south of the community. On the following day the paper carried the familiar words: the "entire east side is a vast sea of water as far as the eye can see." On the west side, below town, the whole Reclamation District 108 was flooded out, there being at least ten breaks in the Sacramento's west bank between Colusa and Sycamore." (p. 276); estimated peak flow of 600,000 cfs at Suisan Bay |
| 1909 | also estimated peak flow of 600,000 cfs at Suisan Bay (p. 277) |

## Reflections on the Outcomes of Early Flood Control Efforts

According to Kelley (1989), effective flood control for the Sacramento Valley and the Colusa Basin Watershed was delayed and limited by uncoordinated, unsupervised efforts made by locals under *laissez faire* policies promoted by Will S. Green and others. But should either the long historical period of Sacramento River flooding or the more recent period of residual foothill stream flooding be blamed on failure of local control? Probably not. When Green's Land Act transferred responsibility for planning and implementing Valley-wide flood control from the state to the individual reclamation districts, it certainly did coincide with a long period of anarchic and failed flood control efforts, but it's not clear that effective flood control would have been accomplished sooner or better under early and sustained supervision by state and federal experts. There were, after all, state and federal experts weighing in on the subject and proposing flood control strategies and plans during the time that the flood control work was left to local control. And from these, a scientific consensus never arose about how large a flood for which the Sacramento River flood system should be designed. Additionally, consensus was not reached about whether the Sacramento River could safely be contained within levees as a "single-channel system" or instead needed to also flood wider floodplain areas through designated bypasses. As Kelley (1989) documents, it took the debating state and federal government experts 40 years to finally put down its attempt to rather heroically control the Sacramento River floodwaters between gigantic levees without land-gobbling bypasses. It was not until after the devastating floods of 1907 and 1909 that scientists and engineers realized that the Sacramento River could produce floods as great as 600,000 cfs. Once the Sacramento River Flood Control Project was finally authorized by state and federal authorities in 1917, it took 2 more decades to build most of the levees, weirs, and bypasses, and then 2 more decades to improve these and declare the project completed. Moreover, the project's flood control successes owe not just to its ultimate configuration of levees, weirs, and bypasses, but equally to its flood control reservoirs. These structures would not have arrived on the California landscape any earlier than they did, having come during a period of dam-building that was facilitated not just by scientific progress but also by the New Deal economic policies.

It is also not as clear as Kelley suggested, that the Colusa Basin was "scissored into a crazy-quilt of small reclamation districts" which blocked natural flow patterns. The Colusa Basin exhibits several very large reclamation districts arranged in a seemingly logical north-south pattern. RD108 lands encompassed nearly the entire floodprone length of the Sacramento River's west bank that discharged to the Colusa Basin: one hydrologic unit. The levee it built along that length of bank was incorporated directly into the Sacramento River Flood Control Project. If anything, perhaps RD2047 should have within its boundaries more of the Lower Colusa Basin lands that were enclosed very early by RD108 and its Back Levee, which may have allowed the construction of a somewhat more effective configuration of the Colusa Basin Drain. Much of the residual flooding problem in the watershed today is due to inadequate flood conveyance capacity along the trace of the Back Levee, but this may be dominated by the backwater effect from high stages in the Sacramento River and the Yolo Bypass, problems related to the basin's natural topography that no early comprehensive Valley-wide flood control project probably could have solved.

If Green's Land Act hadn't passed in 1868, and instead the state and federal government had begun then to supervise the design of a comprehensive Valley-wide flood control project, would a flood bypass like the Sutter Bypass have been constructed through the Colusa Basin? A 1904 plan appears to propose a "West Side Drainage Canal" running approximately along the present Colusa Basin Drain alignment, as would have presumably been dictated in part by the RD108 holdings in the lower Colusa Basin (**Figure 1-Flood**). The 1904 plan shows 2 designated bypass channels running from the Sacramento River's west bank into the West Side Drainage Canal: one about 7 mi north of Colusa at "Caldens Landing" and one about 5 mi south of Colusa at Upper Sycamore Slough, 2 of the dominant natural Sacramento River overflow points. Later flood control planning and design drawings prepared by the California Department of Public Works in 1925 did not show these 2 west bank flood weirs, but did show a proposed 1000-ft-wide right-of-way bordering the early precursor channels of the Colusa Basin Drain, the Old Davis Levee, and the RD108 Back Levee. This continuous 1000-ft-wide drainage right-of-way was labeled "limit of required waterway for west side streams." It would have discharged through a 750-ft-wide version of the Knights Landing Ridge Cut (**Figure 2-Flood**). But would these early proposed drainage canals have worked better to drain the residual flooding from the foothill streams than the existing Colusa Basin Drain and Knights Landing Ridge Cut? DWR (1962, 1990) evaluated the costs and benefits of constructing a widened drainage canal in virtually the same alignment and enlarging the Knights Landing Ridge Cut and improving drainage downstream from its outlet. These evaluations have consistently failed to generate an economic justification.

### Sacramento River Flood Control Project

The State Legislature approved the California Debris Commission plan in 1911 and created the State Reclamation Board to oversee its implementation. This Sacramento River Flood Control Project was thus adopted by the State in 1911 and then authorized by Congress as a federal flood control project in 1917. The project would be designed and built over the next 4 decades to become a largely successful integrated system of levees, overflow weirs, pumping plants, and flood bypass channels. In cooperation with and partially funded by RD108, the project incorporated and improved RD108's west bank levee, such that it is now substantially higher and wider and as much as 80 mi long. Sacramento River flood flows are now largely conveyed by overflow weirs to the Sutter Bypass and the Yolo Bypass. There are no bypass channels passing though the Colusa Basin Watershed.

The integrated project levee improvements, weirs, and bypasses were deemed substantially completed when they were first tested by the flood of February-March 1940 (**Figures 2-Flood** and **3-Flood**). During this flood, there were numerous west bank levee failures north of Princeton which poured floodwaters into the Colusa Basin Watershed and comingled with the floodwaters from the foothill streams on the valley flat lands northwest of Colusa. These flood flows evidently made their slow southerly drainage through the receiving Colusa Basin Drain and Knights Landing Ridge Cut and were presumably impeded by the backwater effect from high stages in the Yolo Bypass, as still occurs today.

Final improvements to the west bank Sacramento River Levee System and the Back Levee were not completed by the project until 1958 (DWR 1990).

### Description of Flood Control and Drainage Facilities

State and Federal governments completed final modifications of the major flood control facilities in the Colusa Basin Watershed by 1958, including reinforcement of the Back Levee System from Knights Landing upstream to high ground in the vicinity of Colusa (**Figure 4-Flood**). The principal flood control and flood-related features in the watershed include the Sacramento River Levee System, the Back Levee, the Colusa Basin Drain, the Knights Landing Outfall Gates (Outfall Gates), and the Knights Landing Ridge Cut (Ridge Cut, **Figure 4-Flood).**

*Sacramento River Levee System.* In 1968, RD108 constructed a 39-mi long levee on the west bank of the Sacramento River between Knights Landing upstream to the town of Sycamore in Colusa County to prevent flooding of district lands between the Sacramento River and the Back Levee. RD108 later contributed most of the funding to extend the west bank levee another 40 mi upstream from Sycamore.

Because the west bank levee blocked natural flooding from returning to the Sacramento River, accumulated flood waters needed to be released to the Sacramento River each spring by cutting and then repairing the west bank levee at Knights Landing. As early as 1883, an automatic gate system was installed to make the releases, but because Sacramento River stage typically remained high through the spring, a pumping plant was installed at lower Sycamore Slough in 1885 to allow districts to pump flood waters to the Sacramento River earlier in the spring to extend the annual planting and growing season.

*Back Levee.* RD108 and others constructed the Back Levee beginning in the late 1800s to provide added flood protection to the flood prone lands between the Colusa Basin Drain (not yet constructed) and the Sacramento River.

*Colusa Basin Drain.* RD2047 formed in 1919 in part to plan and construct the Colusa Basin Drain for collecting and reusing the increasing amount of irrigation return flows in a manner that reduced the then-present flooding problems downstream from the irrigated areas. The Colusa Basin Drain extends from its junction with Willow Creek south to the vicinity of Colusa and then follows the alignment of the RD108 Back Levee, terminating at the Knights Landing Outfall Gates on the Sacramento River in Yolo County **(Figure 4-Flood).** RD2047 excavated the canal channel in an alignment that connected through then-existing borrow pits from earlier RD108 Back Levee construction. The Drain had an original capacity of approximately 1450 cfs with 1 ft freeboard. Its current conveyance capacity is about 2100 cfs at Highway 20 and about 12,450 cfs at Knights Landing (Navigant Consulting, Inc. 2000).

The Colusa Basin Drain was originally designed to carry summer and fall irrigation return flows, not winter and spring flood flows. However, the Colusa Basin Drain incidentally carries some of the watershed's winter and spring floodwaters because it is located along the western edge of the Back Levee (DWR 1990). DWR operates stream flow gages at both locations, but neither is set up to measure out-of-channel flows that occur in the winter and spring.

RD2047 also excavated a branch channel following the common boundary between RD108 and RD787 that connects the Colusa Basin Drain to the Sacramento River. A dual-purpose drainage and irrigation pumping plant at this location has never been used for drainage relief, only irrigation pumping (import). The branch channel is used to convey water pumped from the Sacramento River to irrigate several thousand acres within RD108 and RD787 (DWR 1990).

As the Colusa Basin Drain began to convey higher and more reliable irrigation return flows from increasing Glenn-Colusa Canal deliveries, private irrigation developers constructed several feeder canals and diversion and pumping systems connected to the canal and filed water rights to protect these investments (Navigant Consulting, Inc. 2000).

*Knights Landing Outfall Gates*. The Outfall Gates were installed within a concrete structure separating the Colusa Basin Drain from the Sacramento River in 1913 to allow releases up to 1450 cfs from the Colusa Basin Drain to the Sacramento River during the season when the Sacramento River stage is sometimes lower than the Colusa Basin Drain stage (Navigant Consulting, Inc. 2000).

*Knights Landing Ridge Cut*. The Ridge Cut was constructed to provide an alternate outlet for Colusa Basin Drain and Colusa Basin Watershed flood waters. The Ridge Cut provides drainage down valley to the Yolo Bypass in the winter and spring when releases to the Sacramento River are generally prevented by high stage. The Ridge Cut is composed of 2 dredger-excavated channels, separated by a mid-channel island that was out of reach from the dredgers during construction. It was completed and in operation by the flood of September 1915. The approximately 7 mi-long, 400 ft-wide, and maximum 20-ft deep channel, had an original design conveyance capacity of about 15,000 to 20,000 cfs when the water surface elevations are at the inlet and outlet design stages of 39 ft at Knights Landing and 35 ft at Yolo Bypass (DWR 1990). Preliminary unverified 1983 current meter measurements and calculations suggest that its maximum capacity is about 15,700 cfs (DWR 1990).

The Ridge Cut provides an alternate gravity outlet for lower Colusa Basin floodwaters. It reduces the duration of flooding, but it does not prevent flooding; when the Yolo Bypass stage is high, the backwater effect can extend upstream as far as College City. This also creates an additional backwater effect in the lower reaches of the Colusa Basin Drain (Navigant Consulting, Inc. 2000).

By a 1937 agreement, the floodwater gravity drain outlet elevation of the Ridge Cut was set to 25.5 ft so that floodwaters, ponded in the valley basin lands between the Back Levee and high ground to the west and south, pass unimpeded to the Yolo Bypass while sustaining a pool sufficient for rediversion rights for irrigation with Colusa Basin Drain water entering the Ridge Cut (DWR 1990).

### Structural and Non-structural Projects for Relieving Residual Flooding Problems in the Watershed

The current FEMA 100-year floodplain (**Figure 4-Flood**) shows that almost all of the historically flooded lands of Colusa Basin Watershed would be flooded during a large flood event with the Sacramento River Flood Control Project in place. The project generally prevents Sacramento River flooding during less frequent floods. Black Butte Dam on Stony Creek has eliminated the smaller historical contributions of Stony Creek floodwaters to the watershed north of Willows, but there are substantial areas in the watershed that are subject to relatively frequent flooding from the foothill streams. The FEMA 100-year floodplain map does not describe well the pattern of more frequent flooding in the watershed. DWR (1962) produced a map of "historically inundated areas" that seems to describe the pattern of the more frequent, approximately 5-year floodplain.

**Willows Area.** The FEMA 100-year floodplain map (**Figure 4-Flood**) shows that several foothill streams, including South Fork of Willow Creek, coalesce along a low, broad ridge of land northwest of Willows. These combined flood waters inundate parts of Willows regardless of stage in the Sacramento River or presence of flood overflows from the Sacramento onto the valley flat lands. Alternatives for reducing the frequency and extent of flooding in this area are currently being evaluated by the CBDD and USBR (CH2MHill 2003), and are summarized below.

**Residual Colusa Basin Flooding.** DWR (1962) summarizes the typical pattern of routine flooding occurring along the Colusa Basin Drain resulting from foothill streams runoff in the winter and rice irrigation water releases in the summer:

> Flood conditions, including those arising from poor drainage, impede agriculture and economic development in portions of the Colusa Basin [Watershed]. Problems of flooding exist along Willow Creek, along the Colusa Basin [Drain] and its tributary drainage channels, and in portions of the Yolo Bypass below the Knights Landing Ridge Cut. These problems are caused by improper and insufficient individual farm drainage, inadequate facilities to remove drainage from low lying areas into the Colusa Basin [Drain] and other major drainage canals, insufficient channel capacities of flood and drainage canals tributary to the Colusa Basin [Drain], and inadequate discharge capacity of the Colusa Basin [Drain] into either the Sacramento River or the Yolo Bypass.

> During the winter flood period, roughly October through March, floods are caused by precipitation within the [watershed] and runoff from the foothill region to the west. The magnitude of the discharge in these winter storms is very large when compared with the channel capacity of the Colusa Basin [Drain]. The channel capacity in the upper reaches, for example, is exceeded when the discharge at Highway 20 near Colusa is greater than 2,100 second-feet. The maximum mean daily discharge of record occurred on February 21, 1958, and was 23,900 second-feet at that point. Because the channel is inadequate to handle the discharge, the excess flows flood an extensive area along the channel. In 1958, the flooded area extended continuously from Knights Landing to Orland, a distance of 70 miles. The flooded areas are frequently large at this time of year, but the damages are relatively light since the lands inundated are principally agricultural and idle during the winter. Highways, roads, and public utilities, as well as the limited urban or domestic development within the floodplain are subject to damage.
>
> In the spring months, April through June, flooding is caused principally by irrigation return flows rather than by precipitation. During the spring, precipitation is generally insignificant. The channel capacity of the Colusa Basin [Drain] is usually adequate to handle the irrigation return flows, except in the reach between College City and Knights Landing where flooding of a small area occurs regularly. The resulting damages are large since this flooding occurs in the normal growing season. This spring flooding results from local agricultural practices which cause irrigation return flows that cannot be dissipated by works constructed to relieve winter flood conditions.

According to DWR (1962), releases of water from rice fields typically peaks in May when high stage also typically prevails in the Sacramento River. This prevents the released water from draining though the Outfall Gates, and the outlet of the Knights Landing Ridge Cut is also backed up or otherwise inadequate to pass the released water. There is presumably less summer flooding along the Colusa Basin Drain today than there was at the time of DWR's (1962) characterization of the problem, as would have the resulted from better coordinated releases.

In addition, land has been put into agricultural production up to the western edge of the Colusa Basin Drain [canal], and the levees have been built along the western edge of the canal to protect agricultural lands. These levees may act to constrict the canal's capacity and thereby incrementally raise the canal water surface elevation in places. DWR (1962) reported that between 1 April and 1 June in 15 of the last 40 years, water has overflowed the banks of the drainage canal between College City and Knights Landing.

DWR (1962, 1964) prepared hydraulic models of the Colusa Basin Drain channel to serve as a basis for evaluating the flood benefits in terms of reduced inundation area resulting from a range of management actions: (1) improved drainage facilities from the Knights Landing Ridge Cut through the Yolo Bypass, (2) systems of levees along the Colusa Basin Drain, (3) flood control reservoirs in the western foothills, and (4) watershed management. DWR (1990) updated the evaluation of these alternatives, many of which are still under consideration, and added a fifth evaluation of enlarging the Knights Landing Ridge Cut.

*Yolo Basin Project.* DWR (1962) evaluated the flood management benefits for the lower backwater affected reaches of the Colusa Basin Drain of constructing a new 10,000-ft-long unlined 130-ft-wide trapezoidal drainage canal in the Yolo Basin from the outlet of the Knights Landing Ridge Cut downstream to the Tule Canal and comparably enlarging Tule Canal by addition of 15,300-ft-long levees. DWR (1962) concluded that the project was economically justified (cost-benefit ratio of 1.34:1) even though most of the benefits would accrue to landowners on the downstream end of the watershed. DWR (1990) reevaluated the Yolo Basin Project as having a total project cost of about $8 million, and a 50-yr period cost-benefit analysis of the project at an 8.875% discount rate yielded an updated cost-benefit ratio of 0.25. The reduced cost-benefit ratio compared to DWR (1962) is due to new water quality concerns and the estimated $5 million additional project cost introduced by the need to extend the North Bay Aqueduct's Barker Slough Pumping Plant intake to Miner Slough.

*Enlarge Knights Landing Ridge Cut.* DWR (1990) evaluated various alternative methods and configurations for increasing the conveyance capacity of the Ridge Cut, including a range of design channel base widths up to 1400 ft. DWR (1990) found that the conveyance capacity could be increased by 7300 cfs at a cost of about $12 million. Fifty-year period cost-benefit analysis of the project at an 8.875% discount rate yielded an updated cost-benefit ratio of 0.15. DWR (1990) noted that the evaluated alternative included removal of the heavily vegetated existing islands, the environmental impacts of which would be controversial.

*Colusa Basin Drain Levees.* First, DWR (1962, 1964) considered the potential benefits of constructed new and/or enlarged levees along the existing Colusa Basin Drain to create a maximum channel top width of 450 to 1,000 ft. The levees would range from 18-ft-high in the south to 11-ft-high in the north and would, for example, provide for 27,000 cfs conveyance capacity at the Highway 20 crossing. Pumping stations and flap gates would be used to drain floodprone areas. Cost-benefit analysis of the 50-year protection level project indicated that the levee project was not economically justified, yielding ratio of 0.33 at a 4% interest rate.

DWR (1990) reevaluated the levee project, estimating it then to cost $76 million for protecting 180,000 acres. Fifty-year period cost-benefit analysis of the 100-year protection level project at an 8.875% discount rate yielded an updated cost-benefit ratio of 0.19. The levee protection alternative has generally been abandoned in favor of projects that use reservoirs on the foothill streams to detain floodwaters.

*Foothill Reservoir Project.* DWR (1962) evaluated the potential benefits of constructing flood detention reservoirs on 17 foothill streams, finding it a generally less desirable solution to flooding problems than building levees along the Colusa Basin Drain. DWR (1990) reevaluated the project considering 29 moderate-sized reservoir sites at total cost of $82 million. Seven of the 29 sites ranked highest on a cost per square mile drainage area controlled basis: South Fork Willow Creek, Logan Creek, Hunter Creek, Funks Creek, Stone Corral Creek, Freshwater Creek, and Cortina Creek (generally the larger foothill subwatersheds). These 7 reservoirs were estimated to cost about $27 million. Fifty-year period cost-benefit analysis of the seven reservoir project alternative at an 8.875% discount rate yielded a cost-benefit ratio of 0.65. DWR (1990) found in general that "the limited runoff of Westside tributaries makes it unlikely that significant water supply or recreation benefits could be developed in a multiple-purpose reservoir."

The Colusa Basin Drainage District [CBDD] resumed evaluation of alternatives including different numbers and combinations of 14 foothill reservoirs as part of comprehensive flood control and watershed management alternatives (Navigant Consulting, Inc. 2000).

*Watershed Management.* DWR (1962) did not evaluate the potential benefits of watershed management due to lack of data about the existing conditions of the foothill subwatersheds. As discussed below in this section of the assessment, the CBDD is presently considering watershed management and other non-structural flood reduction measures as part of comprehensive flood control and watershed management project alternatives (Navigant Consulting, Inc. 2000).

**Local Flooding Problems Associated with Transportation Infrastructure.** Road and railroad crossings do not always provide sufficient flood conveyance capacity. Moreover, because most of the crossings are not clear-span bridge decks, they are prone to partial to near complete blockage with vegetation and debris floated from upstream, including large woody debris transported by floods from upper watershed areas.

**Ongoing Efforts to Reduce Residual Flooding**

Many of the project alternatives generally evaluated by DWR (1962, 1964, 1990) have not been implemented due to cost-benefit ratios and other reasons, but continue to be reevaluated in the changing planning and economic context.

Most recently, CBDD has evaluated feasibility of constructing stormwater detention reservoir facilities on two foothill streams in the northern part of the watershed. The South Fork Willow Creek Detention Facility is completely designed and has a construction bid packet ready for distribution should the CBDD secure adequate funds to construct (Gene Massa, CBDD, pers. comm., May 2007). CBDD has all permits secured to construct except the Army Corp's 404(b) permit. The CBDD has not yet completed the feasibility study for the proposed Wilson Creek Detention Facility. The CBDD has completed studies identifying other project sites in Glenn and Colusa Counties targeted for remediation measures including, but not limited to detention facilities.

**Residual Colusa Basin Flooding.** Navigant Consulting, Inc. (2000) evaluated alternatives for the Integrated Resourced Management Plan [IRMP] for Flood Control proposed by the CBDD and USBR. This flood control program and associated programmatic EIR/EIS included structural measures composed of up to 14 stormwater detention reservoirs at foothill stream subwatershed outlets of most of the 32 ephemeral and intermittent streams draining the Eastern Slope of the Coast Range foothills across the watershed flatlands. The feasibility-level designed detention facilities would improve flood control and supplement water supply for multiple uses, including groundwater recharge on the valley flats and incidental habitat enhancement provided by using streams as conveyance facilities from the foothill reservoirs to the groundwater recharge area on the lower fan areas and valley flats.

**Willows Area Flooding.** CH2MHill (2003) then prepared a project-specific EIR for the CBDD’s Integrated Watershed Management Plan [IWMP]. This plan tiers off of the previous watershed-wide IRMP (Navigant Consulting, Inc. 2000) and evaluates alternatives to reduce flooding in the vicinity of Willows (and presumably, to some extent, also reducing flooding south of Willows in areas receiving commingled floodwaters). This watershed-scale analysis evaluated the flood management benefits and other effects of various structural and non-structural flood control measures. While the analysis was specific to the Willow Creek and

Wilson Creek foothill stream subwatersheds which have the most impact on flooding in the vicinity of Willows, the general findings of the flood management analysis are largely transferable to the other 15 or more foothill stream subwatersheds in the Basin by virtue of overall hydrologic-geomorphic setting and land use patterns.

In addressing Willows area flood control, CH2MHill (2003) considered non-structural measures including recommended changes in rangeland management practices and reforestation of upland areas to reduce peak flow and sediment discharged to watershed (or to the proposed detention reservoir), and improved regulatory floodplain management on the valley floor. Structural measures evaluated included the following:

- Two stormwater detention reservoirs receiving peak flows from North and South Fork Willow Creek and Wilson Creek, respectively
- Using existing rice fields on the valley floor as spreading basins
- Restoration of stream sections in the upper watershed and on the valley floor to increase channel conveyance capacity, floodplain connectivity, and temporary storage of floodplain waters
- A ring levee surrounding the City of Willows

The environmental impact analysis and report summarized these measures and utilized hydrologic modeling to estimate their individual flood management benefits. The following is a summary of the CBDD's proposed flood management measures (CH2MHill 2003).

CH2MHill (2003), however, concluded that while rangeland management changes and reforestation would have a measurable impact on peak flow reduction, the potential benefits were limited by the widespread coverage of clayey-soils with naturally high runoff potential in the foothills area.

Additionally, it should be noted that the introduction of Mediterranean annual grasses and forbs is a factor in the replacement of deep-rooted native perennial grasses and forbs by shallow-rooted non-native annuals that is not entirely a result of grazing.

*Changes to Rangeland Management* (*Proposed*). Changes in upper watershed rangeland management practices would increase soil infiltration capacity and soil moisture retention, thereby reducing peak flow discharge reaching the Willows area. Management actions evaluated included grazing management, livestock fencing, riparian buffers, pest and weed management, range plantings, conservation cover, use exclusions, prescribed burning, and/or watershed drainage enhancement and sediment control. The restoration of native perennial grasses over 40,000 acres of rangeland was specifically evaluated.

*Reforestation* (*Proposed*). Reforesting annual grasslands to woodlands increases canopy cover and results in increased groundcover. Increased canopy cover also theoretically reduces rainfall-runoff by intercepting an increment of the initial rainfall and protecting the land surface from rainfall-splash type soil erosion. The primary flood management benefit of reforestation is in increasing soil infiltration capacity and soil moisture retention. The potential flood management benefits of planting oak trees over 4600 acres of woodlands were specifically evaluated.

*Floodplain Management* (*Proposed*). Non-structural floodplain management measures do not provide the direct and immediate flood control benefits of traditional built flood control facilities, but are expected to reduce flood damage over time using policy and regulatory actions to better accommodate expected future flooding. Measures include raising and/or flood-proofing structures, negotiating flood easement areas (including potential to restore and enhance habitat where appropriate), and restricting future development in flood-prone areas.

CH2MHill (2003) estimated that implementing all of the non-structural measures, including rangeland management, reforestation, and floodplain management, would reduce the 5-year flooded area in the vicinity of Willows approximately 26%. Lesser flood benefits are expected during larger, less frequent storms. In general, the potential flood benefits of non-structural measures such as rangeland management are limited by the presence of clayey soils with naturally high runoff potential in the upland watershed areas (CH2MHill 2003). Ancillary benefits of the non-structural measures included increased overall environmental quality, habitat improvements, rangeland productivity, water quality, and seasonal duration of foothill stream baseflow.

*South Fork Willow Creek Detention Basin* (*In Design and Permitting*). The South Fork Willow Creek detention basin has now been designed. It would be located in the foothills approximately 12 mi west of Willows. The basin would detain stormwater from upper Willow Creek, which would then be released after storm flows recede. The proposed embankment (dam) would be approximately 70-ft high, including 10 ft of freeboard above the 100-year water surface elevation. The embankment cross-section would range from 200-550 ft wide at the bottom and up to 20 ft wide at the top. The total length of the embankment would be roughly 600 ft. The detention basin would accommodate up to 5200 ac-ft of storage and would inundate approximately 305 ac during the 100-year storm.

As designed, the South Fork Willow Creek detention basin is anticipated to reduce peak flow in the combined Willow Creek and Wilson Creek channels at Willows (at flood stages, Willow Creek and Wilson Creek are practically combined channels) by approximately 14% for the 100-year flood and 11% for the 5-year flood. Modeling suggests the flooded area would reduce as much as 25% for the 100-year flood and 47% for the 5-year flood.

*Wilson Creek Detention Basin* (*Proposed*). The proposed Wilson Creek detention basin would be located and designed to operate in the same manner as the South Fork Willow Creek detention basin. The embankment would be 55-ft high (10 ft of freeboard above the 100-year water surface elevation), and the cross-section would be approximately 300 ft wide at the bottom and 20 ft wide at the top. The total length of the embankment would be roughly 3500 ft, and the basin would hold up to 2300 ac-ft and inundate approximately 163 ac during the 100-year design inflow. The Wilson Creek detention basin is anticipated to reduce peak flow in the combined Willow Creek and Wilson Creek channels at Willows by approximately 7% for the 100-year flood and 6% for a 5-year flood. Modeling suggests the flooded area in the vicinity of Willows would reduce as much as 13% for the 100-year flood and 26% for the 5-year flood.

*Rice Field Spreading Basins* (*Proposed*). The rice field spreading basins would modify existing rice fields adjacent to or near streams to also serve as a network of small-scale stormwater detention basins. The existing temporary detention effect of suitably situated rice fields would be increased by raising the elevation of existing berms surrounding fields and installing inlet and outlet drainage facilities designed to receive and release storm flows as needed during the winter, while allowing normal rice field production and operation during the growing season. CH2MHill (2003) estimated that adapting existing suitable rice fields as spreading basins would reduce the 100-year peak flow in the combined Willow Creek and Wilson Creek channels (at the City of Willows) by approximately 11%, but have a lesser or negligible effect on more frequent floods, such as the 5-year flood. The corresponding reduction in the 100-year flooded area (in the vicinity of Willows) would be as much as 19%.

*Upper Watershed Stream Restoration* (*Proposed*). CH2MHill (2003) evaluated the potential flood management benefits of reconnecting the generally incised isolated foothill valley stream sections in the upper watersheds with their former floodplains by installing as many as 21 concrete grade control structures designed to raise the bed elevation and planting riparian buffer strips on the thus activated floodplain surfaces adjacent to the stream (along half of the stream length). The grade control structures and more frequent floodplain flows would theoretically reduce the flow velocity and increase temporary flood water storage in the isolated valley sections of the upper watershed areas, estimated to reduce the 100-year peak flow in the combined Willow and Wilson Creek channels at Willows by 5% and the 5-year peak flow by 2%. Ancillary benefits are increased and enhanced aquatic and riparian habitat, improved water quality, improved bank stability, increased groundwater recharge, and reduced channel maintenance costs in most cases borne by private landowners.

The timing of channel incision in the upper watershed areas was not determined by the environmental impact analysis, and it is not clear if most of the incision occurred before or after 1850. CH2MHill (2003) presumed that the incision occurred after Euro-American settlement, as may have resulted from grazing and deforestation. However, it is also plausible that much of the incision may have predated Euro-American settlement, especially considering the naturally high runoff potential of the shallow clayey upland soils and the possibility that Native Americans used fire as a method of vegetation management or hunting in or near the upper watershed area. The possibility that channel incision is less a contemporary land use impact and more a central tendency or an irreversible state needs to be considered carefully before actions are taken to, in effect, reverse presumed land use impacts. This would include proposals to structurally "build back up" the stream bed elevation in incised stream sections using a series of grade control structures and imported coarse sediment.

*Valley Stream Restoration* (*Proposed*). CH2MHill (2003) evaluated the feasibility and flood control benefits of reconfiguring the almost universally straightened and confined valley streams to restore some of their pre-development flood conveyance capacity and temporary floodplain storage capacity. Increasing the sinuosity, reducing the slope, and increasing the width of the channels would essentially allow natural geomorphic processes to restore some of the streams' natural pre-development channel form. Specifically, setting back levees and banks to widen the channels an average of 20 ft was considered along 61,000 linear ft of Willow Creek and 55,000 linear ft of Wilson Creek, also requiring replacement of 21 undersized bridge crossings. Valley stream restoration was anticipated to reduce the 100-year peak flow at Willows by 4% and the 5-year peak flow by 4%. The measure would provide little reduction in the flooded area in the vicinity of Willows. Ancillary benefits are increased and enhanced aquatic and riparian habitat, improved water quality, improved bank stability, and reduced channel maintenance costs borne primarily by private landowners.

*Ring Levee* (*Proposed*). The City of Willows area could be more completely protected from flooding by installing a 2-mi-long ring levee extending approximately from the Glenn-Colusa Canal to Pacific Avenue. An 8-ft-high embankment with 2:1 (vertical:horizontal) side slopes and a 12-ft-wide gravel service road was considered.

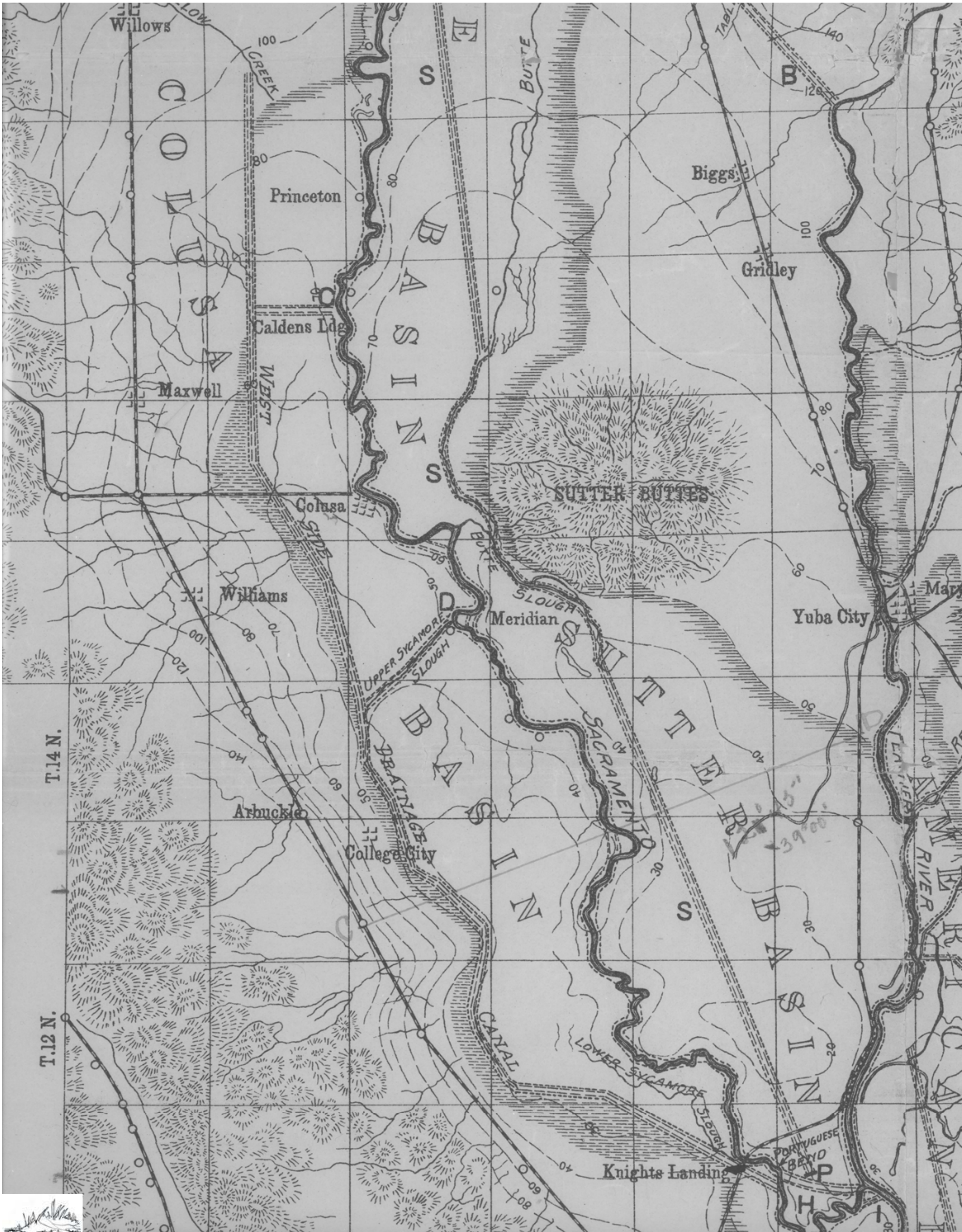
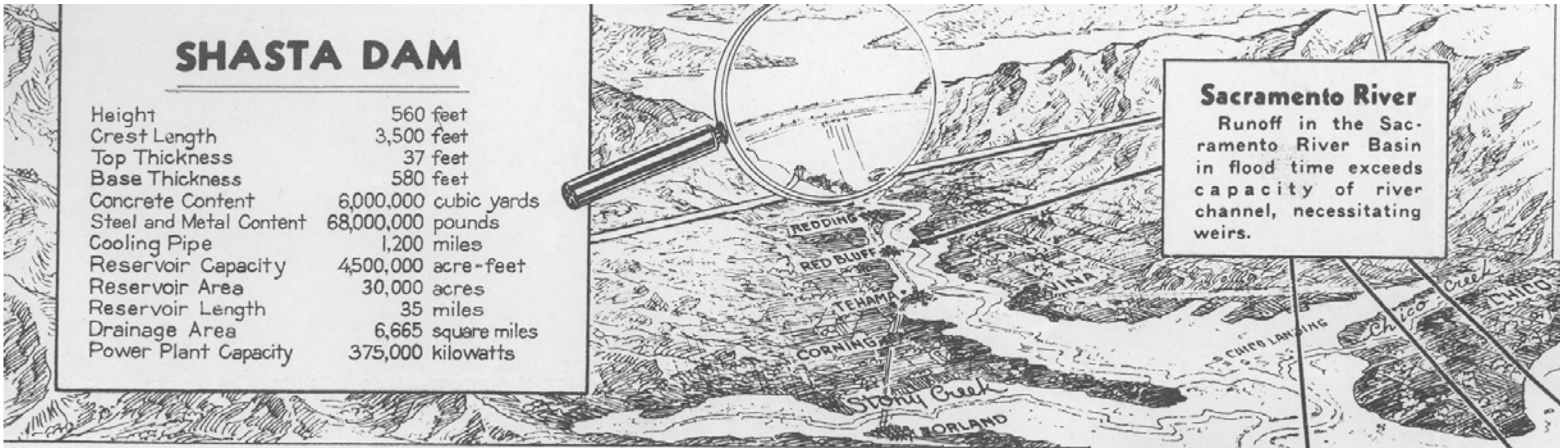



Figure 1-Flood. Detail from 1904 plan for Sacramento valley flood control i




STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

# SACRAMENTO RIVER FLOOD CONTROL PROJECT
AND
# FLOOD OF FEBRUARY-MARCH 1940
IN
# SACRAMENTO VALLEY

**Figure 2-Flood. Detail from 1940 illustration of February-March 1940 flood inur**

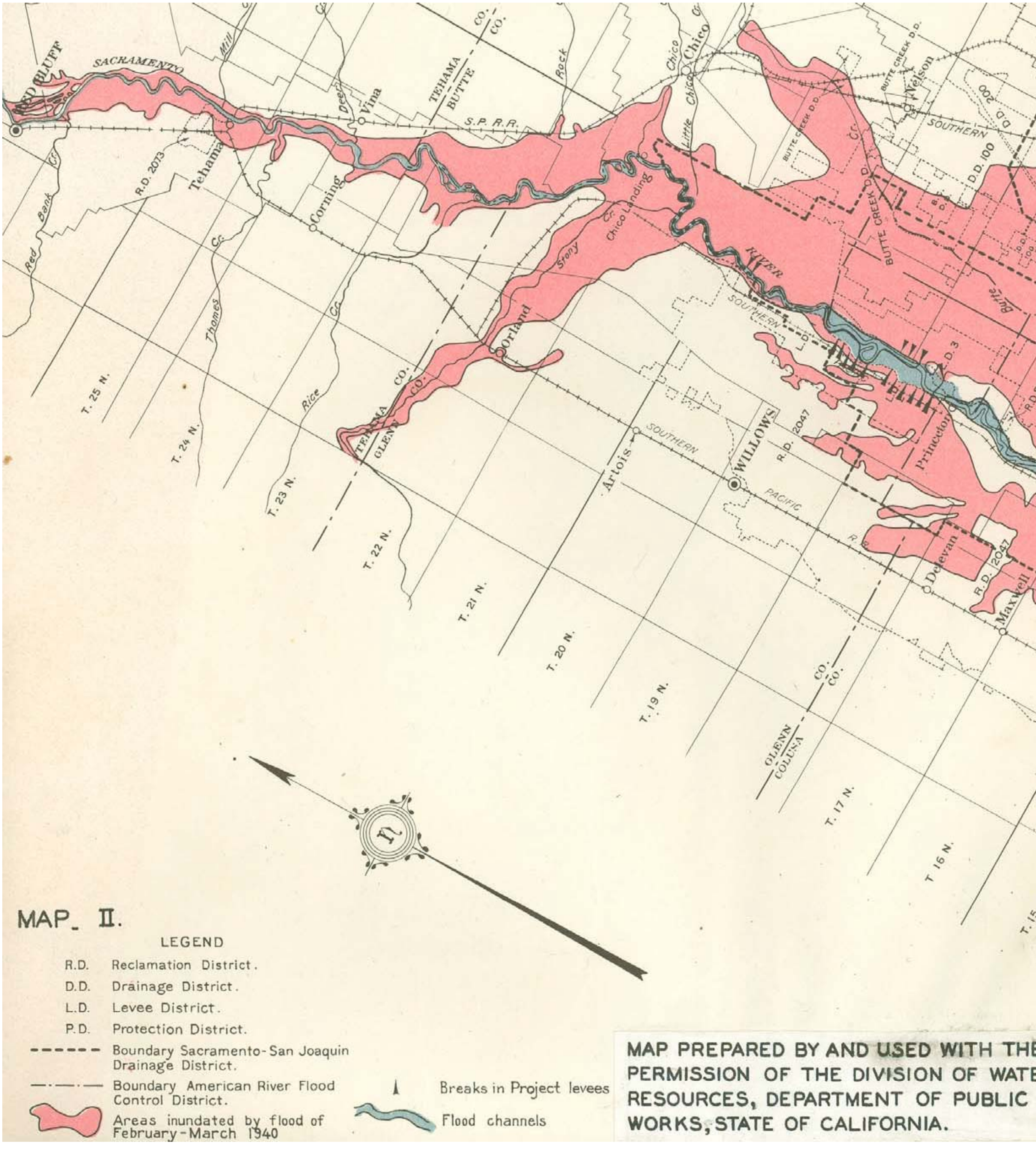
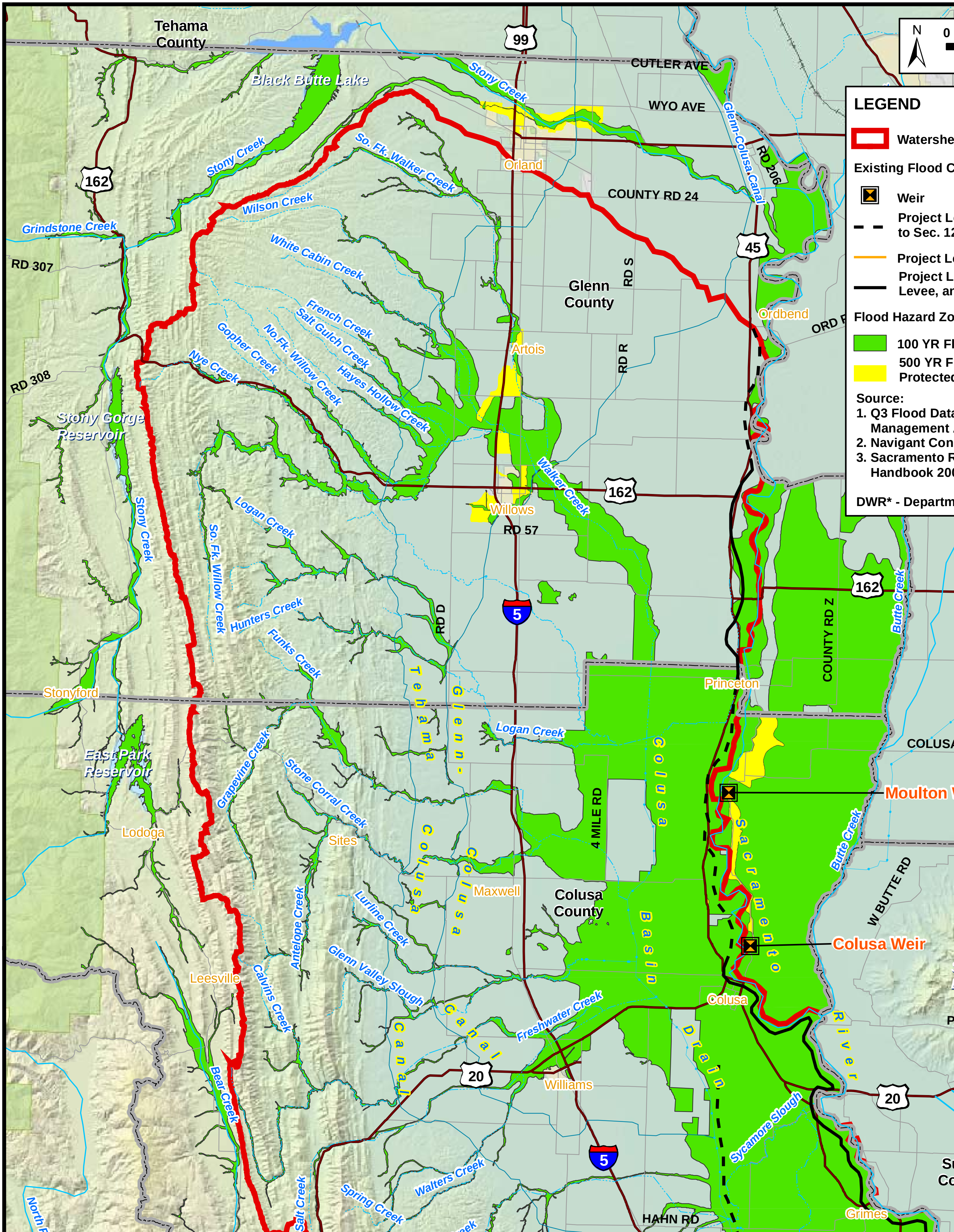



**Figure 3-Flood. Detail from 1940 map of the areas inundated by the flood o**
**Water Resources.**



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Funks Creek
Grapevine Creek
Stone Corral Creek
Antelope Creek
Lurline Creek
Glenn Valley Slough
Calvins Creek
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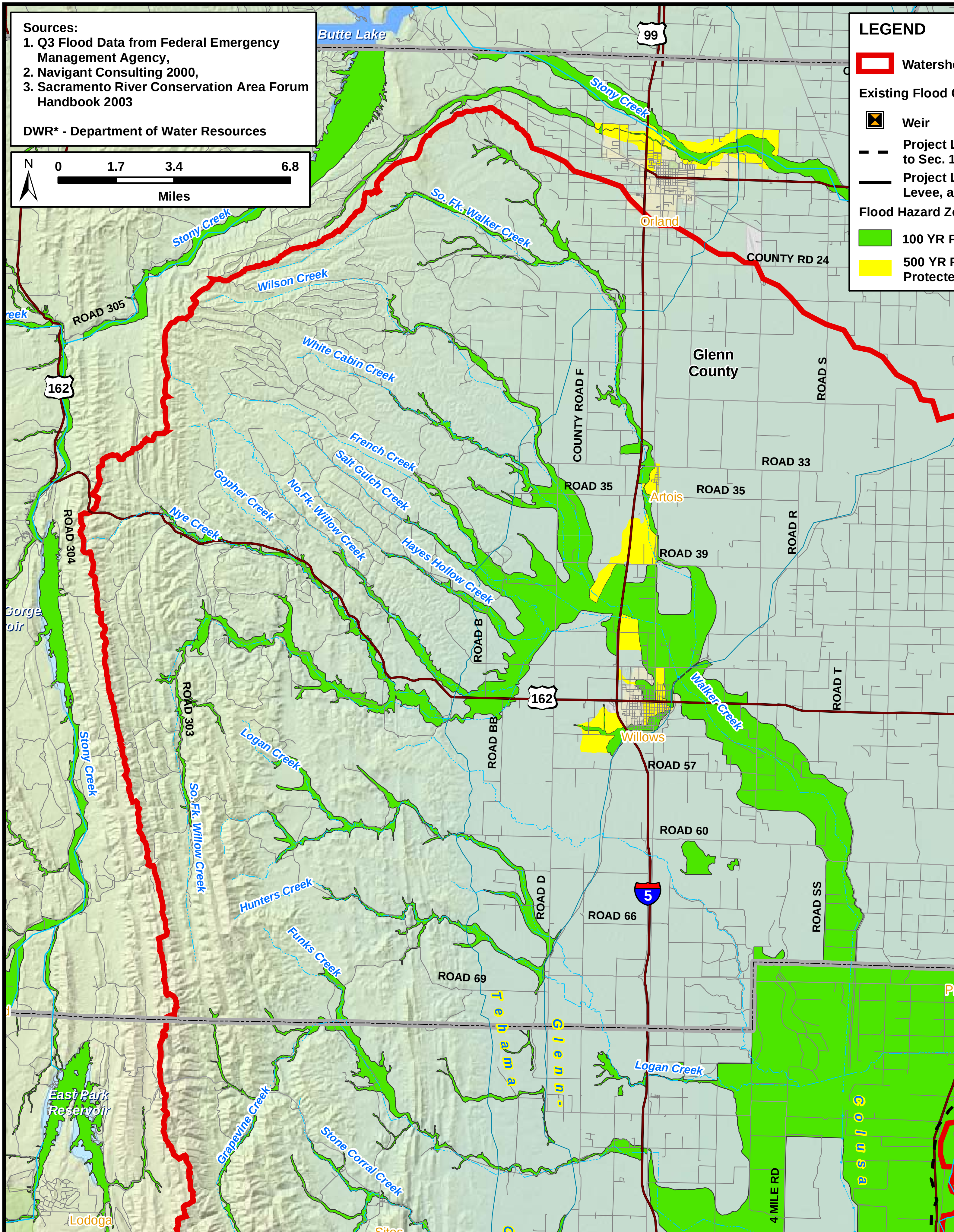

Sources:
1. Q3 Flood Data from Federal Emergency Management Agency,
2. Navigant Consulting 2000,
3. Sacramento River Conservation Area Forum Handbook 2003
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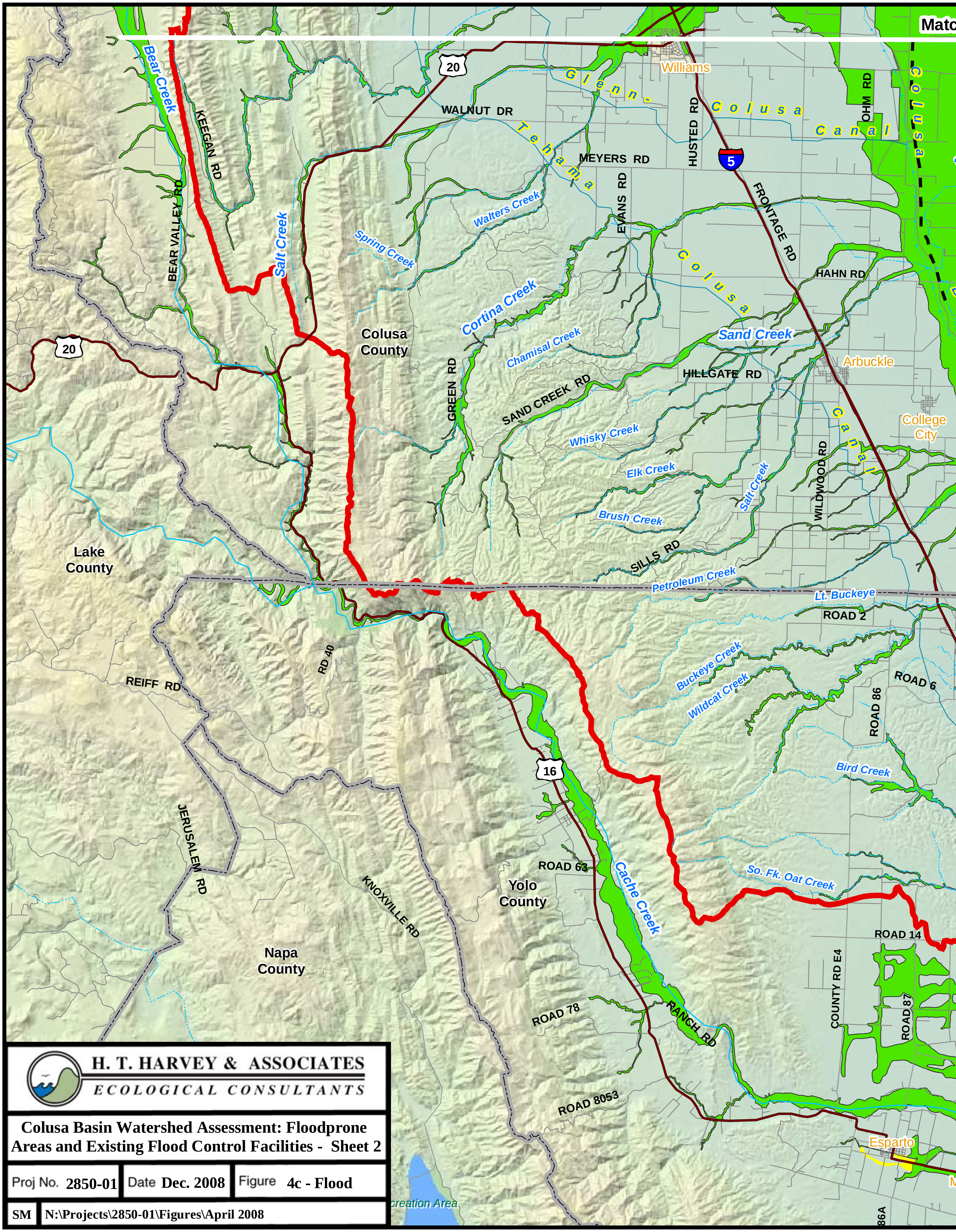


H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

Colusa Basin Watershed Assessment: Floodprone Areas and Existing Flood Control Facilities - Sheet 2

| Proj No. 2850-01 | Date Dec. 2008 | Figure 4c - Flood |
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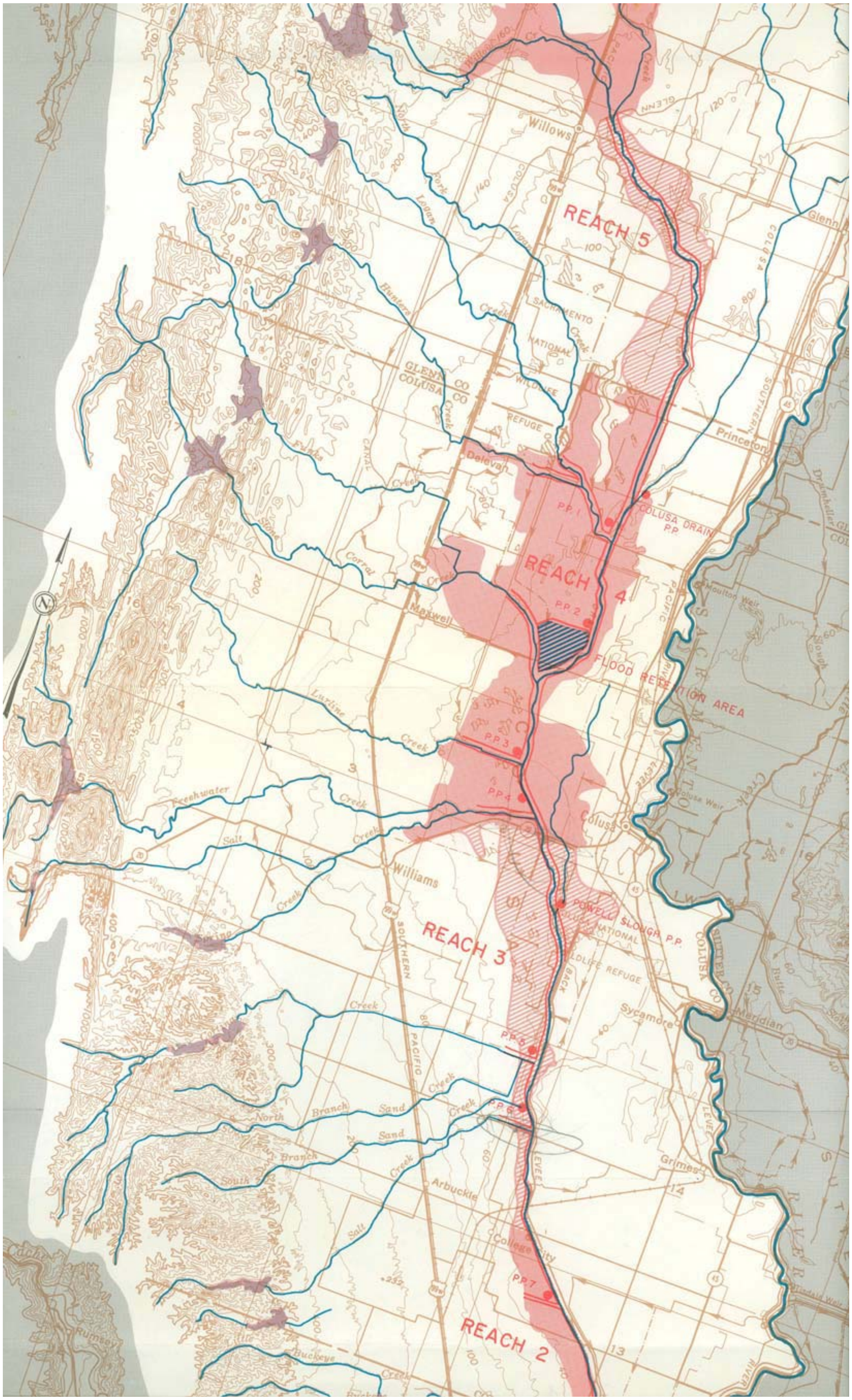



**Figure 5-Flood. Detail from map of existing and possible flood control and drainage features showing historically flooded areas in the Willows area and along the Colusa Basin Drain (adapted from DWR 1962).**

# WATER QUALITY

## HISTORICAL CONDITIONS

### Prior to Euro-American Contact (pre-1850)

As summarized in the hydrology and geomorphology sections, the Colusa Basin (i.e., the lowland area adjacent to the Sacramento River) has been greatly altered from its historical state. Prior to Anglo-American contact, the Colusa Basin likely functioned as a substantial sink for sediments and nutrients flowing from the Sacramento River and various tributaries. Therefore, the Colusa Basin likely served as a nutrient and sediment filter during high flows when flood waters would overtop banks and flow into the once vast riparian and wetland habitats adjacent to waterways. It is likely that these ecosystem processes improved downstream water quality by reducing sediment loads, nutrient concentrations, and peak flows.

### Post Euro-American Contact (post-1850)

The historical data for this assessment is a compilation primarily from Environmental Impact Statements regarding the Tehama-Colusa Canal and the Glenn-Colusa Irrigation District. These sources assess surface and groundwater quality and provide data on the chemical make up and physical properties of the water samples collected. The historical data obtained in this report begin in 1952. There is limited data on pesticide analyses prior to 1977; however, pesticide information post-1980 is reported. Specific data and historical information regarding surface water and groundwater from 1952 to the mid-1980s is described below.

### Surface Water

**Non-rice Pesticides.** Data on pesticides prior to 1980 in the Colusa Basin Drain were not readily obtainable. Therefore, the following summary of water quality data on non-rice pesticides begins in 1980. Although DDT was banned by the U.S. Environmental Protection Agency [EPA] in 1972, it was detected in fish of the Colusa Basin Drain between 1980 and 1984 at levels greater than fish from other waters of the state and was also detected in small amounts in the Colusa Basin Drain as late as 1987 (EPA 1972). Pesticide concentrations were lower in the water and sediment; however, they tended to accumulate in the tissues of the organisms living in the Colusa Basin Drain. Endrin, Dieldrin, Aldrin, Kelthane, or their breakdown products were detected in the Colusa Basin Drain (Turek 1990).

From 1980 to 1984, the following organic chemicals were detected in fish from the Colusa Basin Drain: Chlordane, Dachthal, DDT, Dieldrin, Endosulfan, alpha HCH (hexachlorocyclohexane), Nonachlor, PCB , (polychlorinated biphenyls), toxaphene, and chemical group A. Toxaphene exceeded National Academy of Sciences (NAS) guideline of 100 parts per billion (ppb) for the protection of aquatic life and their predators. Between 1980 and 1984, 3 fish were found to exceed the NAS guidelines for toxaphene. Simazine, diazinon, and endosulfan sulfate were found in 1987 (Turek 1990).

**Rice Pesticides.** We found little information and data on pesticide levels prior to 1977 in the Colusa Basin Drain after an extensive literature search. Between 1977 and 1982, molinate and thiobencarb applications spiked resulting in elevated concentrations in the Colusa Basin Drain and Sacramento River. Studies by the DWR indicated that fish kills, primarily carp, in the Colusa Basin Drain and Reclamation Slough between 1976 and 1983 resulted from a high concentration of molinate (Turek 1990). The DFG found thiobencarb at elevated concentrations as well (Turek 1990). High concentrations of molinate cause anemia and death in carp. In 1980 and 1981 molinate peaked at 374 µg/L in the Colusa Basin Drain. In 1982, levels peaked to 700 µg/L in the Colusa Basin Drain and 42 µg/L in the Sacramento River. In 1983 rice farmers were required to have a 4-day holding period after application of the pesticides before they could discharge, resulting in lower levels in the Colusa Basin Drain. Over the next few years the molinate holding time was extended to 14 days, resulting in very low concentrations of the pesticides reaching the Sacramento River (Turek 1990).

Bentazon use increased in the 1980s and concentrations of 16 µg/L were detected in major agricultural drains and the Sacramento River in 1985 and 1986 (Turek 1990). It was also detected in finished tap water for the City of Sacramento in 1986. Bentazon use doubled from 1987 to 1988 resulting in a peak concentration of 5.5 µg/L in the Colusa Basin Drain and 0.8 µg/L in Sacramento River (Turek 1990).

**Mercury.** Mercury is a trace metal that occurs naturally in the environment. It can be toxic to humans and other organisms even at low concentrations. In California, mercury can be found throughout many watersheds due to both natural occurrence and human influences redistributing it through activities such as mining or use of fossil fuels (Gassel et al. 2005). In the environment, mercury cycles through soil, water, and organisms. The Sacramento River Basin has mercury from both natural geologic deposits and as a legacy from mercury and gold mining in the Sierra Nevada and Coast ranges. Mercury is currently considered the most serious water quality problem in the Sacramento River, some tributaries of the Sacramento River, and downstream locations including the San Francisco Bay (Domagalski 1998).

Regulatory agencies have implemented maximum concentrations of mercury to protect aquatic life and human health. The EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection recommended 4-day average concentration for total mercury is 770 ng/L (Marshack 2003). The California Toxics Rule Inland Surfacewater 30-day average for human health drinking water sources (consumption of water and of aquatic organisms like fish) is 50 ug/L. (Marshack 2003, Domagalski et al. 2000, EPA 1999)

Depending on environmental conditions, mercury in aquatic systems may be transformed into methylmercury. Methylmercury is more able to bioaccumulate than elemental mercury in fish and other organisms. Either elemental or methylmercury may be present in water, sediment and aquatic biota. For example, more than 95% of the mercury found in fish occurs as methylmercury (Domagalski et al. 2000). Bioaccumulation and biomagnification increase the concentration of mercury found in organisms along the food chain; the higher on the food chain, the higher the amount of mercury in the organism. Consumption of fish is the major route of human exposure to methylmercury.

Dissolved mercury analyses showed that no mercury was detected within the Colusa Basin Drain in Colusa County. However, in 1974 0.9 µg/l of mercury was detected north of Colusa County at a site within the drainage area of the Colusa Basin Drain (USGS 1975). The precise location of sample collection is not known.

**Trihalomethanes (THMs).** During the 1980s, trihalomethanes (THMs) were detected in the City of Sacramento's drinking water (Turek 1990). No concentrations were reported by the author. The source for this drinking water was at the time primarily surfacewater from the Sacramento River. THMs are considered a water treatment disinfection by-product and are formed by the chlorination of organic material and some are considered carcinogenic. A study carried out in 1987 by DWR indicated that the Colusa Basin Drain had a higher THM formation potential than the Sacramento River, and the river had a higher potential for THM formation below the Colusa Basin Drain outfall than upstream. This finding suggested that agricultural drainage waters were in part increasing the THM formation potential of the river.

Analysis of data presented in Bay Delta and Tributaries [BDAT] Project site (BDAT 2008) presents limited data on THMs. Specifically, data on the THMs chloroform, dibromochloromethane (DBCM) and bromodichloromethane (BDCM) collected at the Colusa Basin Drain between 1993 and 2001 indicate that the concentration of these THMs has decreased over time. For example, the concentration of DBCM was 17 ug/L in 1994 and dropped to non-detect in 2001. The concentration of these THMs at no time exceeded the drinking water maximum contaminant level for total THMs of 100 ug/L.

**Conventional Water Quality Parameters (dissolved oxygen, pH, turbidity, conductivity, trace elements).** DWR studies from 1952 to 1964 provide data on conventional water quality parameters for the Colusa Basin Drain (DWR 1964). The sampling locations in the Colusa Basin Drain extended from Highway 20 to Knights Landing. Over a period of 9 years the lower area of the Colusa Basin Drain mostly met standards of Class I water, only 2 of 63 collected samples exceeded standards. This classification of the water likely uses the USDA Agricultural Handbook #60 qualitative standard for irrigation water. In particular, Class I water is suitable for irrigation under most circumstances with equivalent total dissolved solids (TDS) less than approximately 175 mg/L.

Furthermore, the USBR reported in an EIS the levels of dissolved oxygen (DO), pH, turbidity, electrical conductivity (EC), TDS, and trace elements including Ca, Mg, K, Na, $CO_3$, etc., between 1962-1971 (Bureau of Reclamation 1975). Throughout this sampling period at Highway 20, the DO held constant ranging from 8.4-10.2 mg/L with the peak in 1970, and pH remained fairly constant with values ranging from 7.7-8.2. Turbidity was only measured from 1969-1971 and had a decreasing trend of 181 NTU (Nephelometric Turbidity Units) to 121 NTU. EC ranged from 612 µmhos/cm to a peak of 807 µmhos/cm in 1967. TDS was measured starting in 1965 and ranged from 386-495 mg/L with a peak in 1967. Most trace elements held fairly constant; however, Na had a decreasing trend falling from 102 mg/L to 76 mg/L. Samples from Knights Landing took place from 1967-1971. Data are similar to those taken at Highway 20 with fairly steady values. However, the only difference is an increasing trend of DO: levels increased from 8.8-11.0mg /l from 1968-1971. The Sacramento River above the Colusa Basin Drain and below Knights Landing were also sampled from 1962-1971 and reported in the impact statement. DO and pH held constant between the 2 sampling regions. Average turbidity was lower below Knights Landing with values averaging 34 NTU, EC was also lower with values averaging 175 µmhos/cm, TDS was not measured and Na was higher with averaging values of 11 mg/L. Boron was measured in both regions and was detected at no more than 0.1 mg/L. No data was available on nitrogen or phosphorus values. The results of this study indicate suggest that the water is of good quality throughout, and the input of the Colusa Basin Drain at Knight's landing did not significantly impact water quality. Increased sodium values do suggest a slight increase in salts, possibly due to leaching from cultivated land upstream of the drain.

Reports regarding the Tehama-Colusa Canal Project present that TDS increase in return flows to the Sacramento River, which includes collector drains such as the Colusa Basin Drain (USBR 1972). The Colusa Basin Drain also accepts drain water and irrigation run off from the Glenn Colusa Irrigation District. According to the Return Flow Water Quality Appraisal by Low et al. (1974) compiled for the calendar year of 1973, the water quality parameters (EC, TDS, turbidity and Suspended Solids [SS]) were typical of irrigated waters. Flow weighted averages of EC in the Colusa Basin Drain was 402 µmhos/cm, TDS was 220 mg/L, turbidity was 31 NTU, and SS was 36 mg/L. These values are averages of samples taken during the April-October irrigation season.

### Groundwater

Data on groundwater analysis from 1969 to 1971 from various wells within Colusa County was taken from near Williams and Maxwell (USBR 1975). Average pH held fairly constant between Maxwell and Williams but EC was higher in Maxwell at 1050 µmhos/cm and 792 µmhos/cm in Williams. TDS and sodium (Na) levels were also slightly higher in Maxwell with respective values of 630 mg/L and 134 mg/L. Williams had average TDS of 444 mg/L and Na of 92 mg/L. Sulfate ($SO_4$) levels were also higher in Maxwell, 142 mg/L; but $NO_3$ levels were higher in Williams with an average of 7.8mg/L.

Chemical analysis of the groundwater within the Tehama-Colusa Canal Service Area is available for the years 1974 and 1977 (USGS 1975 and 1977). Groundwater was sampled from wells throughout the service area and included regions near the Colusa Basin Drain. Analytes measured in the 1975 report were sampled from August-October in 1974 and include dissolved silica, Al, Fe, Mn, Ca, Mg, Na, K, bicarbonate, alkalinity, sulfate, Cl, F, N (nitrate and nitrite), P, dissolved solids, hardness, specific conductance (SC), pH, temperature, As and B. Dissolved constituents sampled and analyzed were ammonium, Cd, Cr, Co, organic C, Pb, Li, Hg, Mo, Ni, Se, Sr, V, and Zi. The SC of samples within the range of the Colusa Basin Drain in Colusa County varied from 257-1710 µmhos. Dissolved Boron ranged from 0-2900 µg/l within the same area.

The 1977 USGS document states that the groundwater from over 200 well samples was suitable for most agricultural and domestic uses. Typical for the area, dissolved solids ranged from 150-1000 mg/L and there were negligible levels of toxic or phytotoxic compounds. However, it was found that near the city of Arbuckle and Williams there were relatively high concentrations of B, Cl, Na, and dissolved solids. According to the report it was assumed that the sources of these compounds were saline springs and seeps.

The following 5 documents were reviewed and no relevant information was found:

- Battling the River – a History of Reclamation District 108 (Bayse 2003)
- Colusa Basin Study: Environmental Appraisal (USBR 1974)
- Colusa Basin Investigation (DWR 1964)
- Return Flow Water Quality Appraisal, Glenn-Colusa Irrigation District, Calendar Year 1973 (Low et. al 1974)
- Water Quality Data of the Sacramento River, California: May 1972 to April 1973 (USGS 1974)

## EXISTING CONDITIONS

### Background

This section covers the time period from the mid-1980s to 2007. As summarized in the hydrology section, irrigation water is supplied to the Colusa Basin Watershed primarily by a variety of water suppliers who pump from the Sacramento River. These include, but are not limited, to the Glenn-Colusa Irrigation District, Tehama Colusa Canal Authority, RD108, Princeton Codora Glenn Irrigation District, and the Princeton Irrigation. This water is considered of excellent quality (CH2MHill 2003). Impacts to water quality are thought to occur in the upper watershed from erosion and subsequent downstream sedimentation (CH2MHill 2003). The above geomorphology section provides a summary of the existing information regarding potential sources of erosion in the Colusa Basin Watershed. In contrast, water quality in the valley and lower watershed is influenced by agricultural field drainage and reuse of irrigation water. Both drainage and reuse cause increases in salt and sediment loading and in some cases, pesticide and fertilizer impacts. Municipal wastewater treatment plant discharge and stormwater discharge from Willows, Williams, Maxwell, Dunnigan, and Colusa also contribute to degradation of water quality. The Arbuckle Public Utilities District is not listed by the Regional Water Quality Control Board [RWQCB] as holding a National Pollutant Discharge Elimination System permit for discharge of municipal wastewater. Therefore the quality of water discharged from the wastewater treatment plant and its impacts, if any, to surface water quality in the Colusa Basin are not known.

### Surfacewater

**Non-rice Pesticides.** The organophosphate pesticide Diazinon is a pollutant that is of particular concern in the Colusa Basin Drain. Between 1994 and 2006, of the 118 samples collected by various programs from the Colusa Basin Drain, 30 samples, or approximately 25%, exceeded the DFG threshold of 0.05 ug/L (RWQCB 2007).

In 2002, the Colusa Basin Drain was listed as impaired by the State Water Resources Control Board [SWRCB] as required by Section 303(d) of the Federal Clean Water Act Rationale for 303(d) listing was as a result of the presence of several constituents potentially from agricultural sources. The Colusa Basin Drain was listed for the following insecticides and herbicides: Azinphos-methyl, Carbofuran, Diazinon, Malathion, Methyl Parathion, Molinate, Group A pesticides, and unknown toxicity, while Jack Slough was listed for Diazinon (Larry Walker & Associates 2005, RWQCB 2007). An "unknown toxicity" designation is given to a sample or as rationale for listing if toxicity is noted and attempts using EPA Toxicity Identification Evaluations [TIEs] procedures do not identify a causative agent(s). As a result of these 303(d) listings, Total Maximum Daily Loads [TMDLs] are being developed for the listed constituents that are currently assigned a low to medium priority (Jones & Stokes 2006).

In 2002, the Sacramento Valley Water Quality Coalition [Coalition] formed to comply with the RWQCB's Conditional Waiver for Irrigated Lands, often referred to as the "Ag Waiver" or Irrigated Lands Regulatory Program [ILRP]. Since 2005, the Coalition has executed a water quality Monitoring and Reporting Program Plan. The ILRP requires the implementation of management plans to mitigate water quality problems in specific areas in sub-watersheds where water quality monitoring reveals exceedences that are attributed to irrigated agricultural practices. The Coalition monitors water quality at the following locations in and around the Colusa Basin:

- Colusa Basin Drain above Knights Landing
- Freshwater Creek at Gibson Road
- Logan Creek at 4 Mile-Excelsior Road
- Lurline Creek at Interstate 5
- Walker Creek at County Road 48
- Colusa Basin Drain near Maxwell Road

The Coalition makes a variety of water column and sediment measurements including the following analytes:

- General Chemistry: pH, Conductivity, DO, Temperature, Color, Hardness, Turbidity, TDS, Total Suspended Solids, Total Organic Carbon
- Pathogen Indicators: *E. Coli* bacteria
- *Water Column and Sediment Toxicity*: Ceriodaphnia, 96 hour acute; Pimephales, 96 hour acute; Selenastrum, 96 hour short-term chronic; Cell Growth; Hyalella 10 day short-term chronic
- Pesticides: Carbamate, Organochlorine, Organophosphorus, Pyrethroid, and Chlorinate Herbicides
- Trace Elements: Arsenic, Boron, Cadmium, Copper, Lead, Nickel, Selenium, Zinc
- Nutrients: Total Kjeldahl Nitrogen, Phosphorus, Soluble Orthophosphate, Nitrate as N, Nitrite as N, Ammonia as N

The Coalition recently reported results from sampling in 2007 (Larry Walker & Associates 2007).

Complete mortality was observed in toxicity tests conducted with Ceriodaphnia on samples collected in December 2006 at Colusa Basin Drain above Knight's Landing. Use of TIE indicated that a metabolically activated pesticide (which includes organophosphate pesticides such as Diazinon and Chlorpyrifos) was a significant cause of toxicity. No organophosphate, organochlorine, triazine, or pyrethroid pesticides were detected in the sample, but a low concentration (0.26 µg/L) of Diuron, a pre-emergent herbicide, was detected (Larry Walker & Associates 2007). Follow-up samples collected at the Colusa Basin Drain and did not cause any

*Ceriodaphnia* toxicity, indicating the toxicity was not persistent at the site 6 days after the original samples were collected. No specific cause of the toxicity was determined.

In 2007, the Coalition reported 2 detections of the insecticide Diazinon (0.0088 to 0.0475 µg/L) and one each of the herbicide Simazine (0.0595 ug/L) and the insecticide Dimethoate (0.0352 µg/L) in the Colusa Basin Drain at Knights Landing in February and March 2007. Both reported detections of Diazinon were below the Colusa Basin Plan water quality goal of 0.05 µg/L (RWQCB 1998). No applicable water quality objective currently exists for Dimethoate. The detection of Simizine was below the drinking water Maximum Contaminant Level [MCL] of 4 µg/L (Marshack 2003).

The detection of trace concentrations of a variety of pesticides in the Colusa Basin Watershed is not unexpected given the intensity and history of production agriculture in the area. The concentration of some of these pesticides are in excess of regulatory limits, and a variety of regulatory programs, such as the Irrigated Lands Program and 303(d) listing, are in place to address this issue. In general, in spite of detected water quality impacts from the presence of these pesticides, the surface water quality in the Colusa Basin Watershed is adequate to support existing uses which are predominantly agricultural. The quality of surface water in the Sacramento River appears to be largely unaffected by the presence of pesticides and as a result is of high quality.

**Legacy Pesticides.** The USGS National Water Quality Assessment [NAWQA] data also suggest that Dichlorodiphenyldichloroethylene concentrations in the Colusa Basin Drain were 2-100 times higher in biota than other sample sites in the Sacramento River watershed (Domagalski et al. 2000). Although DDE was detected in the Knights Landing Ridge Cut and Willow Slough Bypass, only 3 of 12 samples reported detectable levels in 2005 (Larry Walker & Associates 2005). Monitoring results presented by Larry Walker & Associates in 2004-2005 indicate that water quality of the Colusa Basin Drain is similar to water found currently in the Willow Slough Bypass (Larry Walker & Associates 2005).

**Rice Pesticides.** Some of the major pesticides that have been historically used on rice are Molinate, Thiobencarb, and Carbofuran. Rice farming requires that fields be flooded with water throughout the growing season. Molinate and Thiobencarb are applied to control aquatic grasses and weeds, whereas Carbofuran was applied to control insects. During the late 1970s, the levels of rice pesticides in the Colusa Basin Drain were sometimes toxic to fish such as carp as a result of the presence of Molinate. In addition, the concentration of some of these pesticides, particularly Thiobencarb, caused taste and odor problems at the cities of Sacramento and West Sacramento in the late 1970s and early 1980s due to interactions with chemicals at the water treatment plant.

As a result of these problems, a management program was enacted to reduce the levels of these pesticides in streams. The plan requires that rice-field water be retained on fields for one month following pesticide application to allow concentrations in water to be reduced through mechanisms such as volatilization, biological processes, or sunlight-induced degradation. Sampling of rice pesticides during this period showed that concentrations occasionally were in excess of management objectives in agricultural streams, but always were very low in the Sacramento River (Domagalski et al. 2000).

The concentrations of Molinate and other pesticides used in rice farming measured between 1994 and 1998 in the Colusa Basin Drain or in the Sacramento River represent a significant improvement over concentrations measured in previous years (Domagalski 2000). Declining maximum Molinate concentrations found in the Colusa Basin Drain from 1993 to 2000 reflect a trend of decreasing use of Molinate over that time period (Orlando and Kuivila 2004)

As result of improved water and weed management techniques (particularly the increased rice-field retention time), the CRC reports that the total herbicide load (Molinate and Thiobencarb) carried by the Sacramento River dropped from approximately 40,000 lbs in 1982 to less than 125 lbs in 1992 (CRC 2007). The concentration of Thiobencarb in the Sacramento River has been below the secondary public health level since 1986. The concentration of rice herbicides in the Colusa Basin Drain has also declined to less than 10% of pre-1985 levels. Since 1982, the concentration of Molinate in the Colusa Basin Drain decreased from a peak of 357 ug/L in 1981 to 25 ug/L in 1995 (CRC 2007). According to the latest reports from the CRC, Carbofuran use on rice has been cancelled since 2000 and Molinate will no longer be registered after August 31, 2009 (Pers. Comm. R. Firoved 2008 based on actions by USEPA and the California Department of Pesticide Regulation (DPR)).

**Mercury Monitoring.** Mercury and methylmercury readily adhere to particles of sediment and organic matter. As such, mercury is transported downstream from upstream watershed sources with suspended sediment loads. Streambed sediment samples taken within the Colusa Basin Watershed have concentrations close to the typical amount of mercury present in rocks found on the earth's surface. MacCoy and Domgalski (1999) found average mercury concentrations in sediment of 0.07 µg/kg in the Sacramento River at Colusa and 0.06 µg/kg in the Colusa Basin Drain and detected mercury in aquatic biota at the same sites at concentrations of 0.1 µg/g and 0.24 µg/g, respectively.

The Central Valley RWQCB reviewed existing data on mercury monitoring in the Sacramento Valley and recently prepared a TMDL for mercury in the Delta. In characterizing the total mercury input from upstream sources to the Delta, the TMDL study calculated that between 1984 and 2003, the Colusa Basin Drain contributed 2.7% of the total mercury to the Delta. Monitoring data for 2000-2003 resulted in a calculated mercury load from the Colusa Basin Drain of 3.6% of the total mercury load to the Delta (Wood et al. 2005). A TMDL for mercury is also being considered for the entire Sacramento River Basin.

Sampling by USGS done between February 1996 and April 1998 at the Colusa Basin Drain reported median methylmercury concentrations of 0.19 ng/L (Domagalski et al. 2000; Domagalski 2001). During the same time period, the Sacramento River at Colusa had a median methylmercury concentration of 0.102 ng/L (Domagalski 2001). While there is not a water quality standard for methylmercury, Rudd suggests that a concentration at or below 0.1 ng/L is representative of water in pristine condition (Rudd 1995).

The concentration of mercury in water correlates well with the concentration of mercury adhered to suspended sediment. Domagalski and others correlated high mercury concentrations in sediment in the Colusa Basin Drain with the heavy rains and related elevated sediment loads during the winter of 1997 (Domagalski et al. 2000).

The Sacramento River Watershed Program found mercury concentrations in the Sacramento River at Colusa to be 4.4 ng/L during 1999 and 2000. Levels at the Colusa Basin Drain site were between 7.1 and 19.27 ng/L (CALFED 2003).

Generally speaking, mercury is not a significant problem in the Colusa Basin, and the Colusa Basin Drain has not been identified as a significant source for mercury inputs to the Sacramento River. The presence and concentration of mercury in sediment and surface water in the Colusa Basin Drain appears to be consistent with the average amount of mercury in rock. The most significant sources of mercury in California are as a result of historical mining for both mercury and gold. Because the locations for mining are in either the Coast Range foothills or the Sierra Nevada, and drainages from these areas do not directly empty into the Colusa Basin Drain, significantly elevated concentrations of mercury are not found there.

### Groundwater

DPR has conducted extensive investigations of groundwater quality in the Colusa Basin since 1983 (Schuette et al. 2003). Every year, up to 91 pesticides were sampled in up to 161 wells in the Colusa Basin. A total of 14 verified detections were reported over this time period, none above the drinking water MCL. Bentazon accounted for 7 (50%) of the reported detections (Schuette et al. 2003). Bentazon is currently used on dry beans. This pesticide was formerly used on rice, however, rice use of Bentazon was cancelled in approximately 1988 (Pers. Comm. R. Firoved 2008). In 2002-2003, the RWQCB took action in Colusa County as a result of minor (<100 $ft^2$) groundwater contamination by Simazine that was adequately addressed by soil remediation.

USGS installed and sampled 28 shallow (< 45 ft) wells in rice growing areas of the Sacramento Valley in 1997 (Dawson 2001). At least one health-related state or federal drinking-water standard (maximum contaminant or long-term health advisory level) was exceeded in 25% of the wells for Ba, B, Cd, Mo, or sulfate. At least one state or federal secondary MCL was exceeded in 79% of the wells for chloride, iron, manganese, or TDS. Nitrate and nitrite were detected, but at concentrations below primary drinking water MCLs. Eleven pesticides and one pesticide degradation product were reported in groundwater samples. Four of the detected pesticides were rice pesticides (Bentazon, Carbofuran, Molinate, and Thiobencarb). Pesticides were detected in 89% of the wells sampled, and rice pesticides were detected in 82% of the wells sampled. The most frequently detected pesticide was Bentazon, detected in 20 out of 28 wells (Dawson 2001). No pesticide concentration exceeded its respective drinking water MCL. Bentazon use was suspended in 1989 and banned by DPR in 1992. The environmental fate characteristics of Bentazon suggest that it may migrate and persist in groundwater for extended periods.

In the early 1990s, the ground-water quality in the Colusa Basin area was not entirely suitable for human or agricultural use because of the presence of elevated concentrations of boron, fluoride, chloride, nitrate, sulfate, and volatile organic chemicals ([VOCs] Domagalski 2000; Jones &

Stokes 2006). Recently (Domagalski 2000), reported analysis of samples from 31 existing domestic wells in the greater Colusa Basin Drain area. Only one sample exceeded the drinking water MCL for nitrate and one for the drinking water MCL for arsenic. One or more pesticides were detected in 9 of 31 (29%) of the wells. All detections were below applicable drinking water MCLs. VOCs were not widely detected in the shallow aquifer. However, in one well downgradient from a known point source, 8 different VOCs were detected. One of those VOCs (Trichloroethylene, measured at 5.5 μg/L) exceeded current drinking-water standards (primary MCL is 5 μg/L, Marshack 2003). Trichloromethane [TCA] was the most frequently detected volatile organic chemical (16 of 19 wells). The concentration of TCA did not exceed its MCL and its presence may be attributed to lawn irrigation using water treated by chlorination.

Groundwater quality in the Colusa Basin is generally acceptable for agricultural uses (CH2MHill 2003). With the exception of boron, no naturally occurring groundwater constituent prevents the use of groundwater for irrigation. Throughout most of the Basin, areas may exist where groundwater has salt concentrations high enough to adversely affect yields of commonly grown crops. For example, TDS values range from 120- to 1220-mg/L, averaging 391 mg/L (DWR 2006.) High EC, TDS, adjusted sodium absorption ratio [ASAR], nitrate, and manganese impairments occur near Colusa. High TDS and boron occur near Knights Landing. Localized areas have high manganese, fluoride, magnesium, sodium, iron, ASAR, chloride, TDS, ammonia, and phosphorus.

# BIOLOGY

## HISTORICAL CONDITIONS AND TEMPORAL CHANGE

### Overview

Prior to Euro-American contact, the historic vegetation in the Colusa Basin Watershed was generally determined by the patterns of soil texture, soil moisture, flooding cycles, and to some extent anthropogenic management by American Indian inhabitants. The Sacramento River typically flooded its banks and the banks of adjacent slough channels annually or twice annually, depositing coarse textured alluvial sediment along its banks and finer textured sediments farther out in the valley. This depositional process created wide, gently sloped, natural levees running parallel to the watercourse. The coarse textured sediments deposited along the adjacent slough channels created natural levees perpendicular to the overall southerly slope of the Colusa Basin Watershed, which further contained the sheeting flood flows within natural basins where finer textured sediment settled out (**Figure 1-Biology**). Therefore, the broad natural levees adjacent to the Sacramento River and its distributary sloughs comprised regularly flooded, yet well-drained, fertile soils (i.e., loams). In contrast, the intervening basin soils were poorly drained and seasonally flooded for extended periods. Within the natural levees of the Sacramento River corridor, riparian forests of willow, cottonwood, sycamore, and alder developed (**Figure 1-Biology**). Valley oak riparian forests grew atop the river and slough levees and emergent freshwater marsh dominated by tule (*Scirpus* spp.) grew within the basins (**Figure 1-Biology**). Along the western foothills of the Coast Range, intermittent streams flowed eastward, depositing their alluvial sediments upon the western side of the valley basins. These streams supported less extensive riparian vegetation than the perennial flows of the Sacramento River and adjacent sloughs, yet they still supported some narrow bands of riparian vegetation. Beyond the riparian corridor of these foothill streams, native grasslands, chamise chaparral, and patches of blue oak woodland formed a mosaic of habitats along the western foothills varying with aspect, soil moisture, and soil depth.

Following Euro-American contact, flood control and drainage projects rapidly and dramatically altered hydrologic cycles and pathways, which in turn eliminated or converted vegetation. Tree species were felled for firewood and construction, woodlands on levees were cleared for cropland, tule marshes were drained for agricultural use, and grasslands were cleared for crops. **Figure 1-Biology** through **Figure 3-Biology** illustrate the changes in vegetation in the basin that took place from pre-1900 to 1995 (GIC 2003). The history of vegetation change closely parallels the history of innovations in flood control, drainage, and irrigation methods.

### Data Sources and Methods

Spatial information prior to 1900 is virtually nonexistent, and it was not until 1926 that the region was fully surveyed and mapped (GIC 2003). Nonetheless, **Figure 1-Biology** represents the best available historic vegetation information for the pre-1900 period reconstructed from the earliest source available (GIC 2003). The historic map series (**Figures 1-Biology** through **Figure 3-Biology**) has some inherent limitations owing to the fact that it was created from multiple sources, each created at various scales over a range of timeframes, and source data frequently only covered portions of the Central Valley region with varying levels of detail applied to each portion. As such, it should only be regarded as a reasonable, generalized view of vegetation cover and change from the time of Euro-American contact to the modern era (1995, GIC 2003). **Appendix 1-Biology** shows the source, scale, and date of each source of information used to derive the historic maps according to habitat type for each of the timeframes shown in **Figures 1-Biology** through **Figure 3-Biology** (GIC 2003). The later-era maps (**Figures 2-Biology** and **Figure 3-Biology**) increasingly incorporate significant advances in spatial data technology and methodology (e.g., GIS, land surveys, and landcover satellite technologies) and caution must be exercised when attempting to draw highly specific correlations between these maps and the pre-1900 map and between the 1945 and 1995 maps due to changes in scale and resolution. However, despite these caveats, general conclusions about historic vegetation change are clearly illustrated by this series, and are further corroborated by historical narrative sources. The general trend of increasing extent of developed landscapes, including both agricultural development and urbanized development, at the expense of native habitats such as riparian forest, wetlands, and native grasslands, is clearly evident (GIC 2003). **Appendix 1-Biology** provides the definitions and characteristic species for each habitat classification category used in **Figures 1-Biology** through **Figure 3-Biology**.

### Vegetation at Time of Settlement

The general picture of vegetation structure in the Colusa Basin Watershed prior to Euro-American contact included 3 main types: the prairie grassland with scattered valley oaks, the freshwater marshes in the lowest elevation areas of the floodplain, and the riparian forests that lined the banks of rivers and streams on natural levees (Thompson 1961, Green 1880). Based on accounts from the early 1800s by the earliest Spanish explorers of the Sacramento Valley, the riparian forest along the Sacramento River was about 1 mi wide and composed of oaks, sycamore, cottonwood, willow, and ash (Kelley 1989). Other accounts describe the natural levees that supported riparian forest as several (2-5) miles wide and approximately 25 ft high (Thompson 1961, Green 1880). Beyond the edge of the riparian forest existed 6-ft tall grasslands that “stretched as far as the eye could see” (Kelley 1989). The annual flooding of the Sacramento River spread out an estimated 3 mi to the west depositing flood water in low lying depressions, which were filled with tule marsh (Kelley 1989). Lieutenant Charles Wilkes of the U.S. Navy reported that the tule marsh extended for miles adjacent to the riverbanks (Kelley 1989).

The original riparian forest species included California sycamore, Fremont cottonwood, valley oak, Oregon ash, alder, buckeye, red willow, and California walnut in the upper canopy and box elder, Gooding’s willow, arroyo willow, and sandbar willow in the mid-story canopy. Vines of wild grape, poison oak, and clematis cloaked the tree canopy and low-growing shrub, and herbaceous species included mugwort, California blackberry, mulefat, and wild rose (Thompson 1961, Katibah 1981). The cottonwood, sycamore, and willows typically grow on the streambanks, while the valley oak tended to grow on the natural river levees farther out from the channel (Thompson 1961).

Some estimates of the original extent of riparian vegetation along the Sacramento River suggest that its boundary followed the 100-yr floodplain boundary (Katibah 1981, **Figure 4-Flood**, **Figure 1-Biology**). Specific accounts by early explorers describe the valley oak riparian forest along the Sacramento River as extending 900 ft wide (Thompson 1961). Some of the individually measured oaks were massive: 19-27 ft in circumference (6-9 ft diameter, Thompson 1961). Other accounts describe the extent of valley oak riparian forest as 1 mi wide on average (Green 1880). The riparian forest along the intermittent foothill streams was much narrower than that of the Sacramento River and would also have had a different species composition. The riparian forest along foothill streams would have been composed of live oak woodlands rather than valley oak. Writing in 1891, Rogers describes the riparian forest that occurred along natural levees of the foothill tributaries as being one-eighth to one-quarter mile wide growing on levees that were 10-15 ft high (Rogers 1891).

Grassland was perhaps the most predominant original vegetation cover throughout the watershed; however, this vegetation type was never mapped extensively or accurately (GIC 2003). Native grass species of this habitat included 2 species of needlegrass, California oatgrass, tufted hairgrass, three-awn, hairgrass, fescues, reedgrass, rye, junegrass, melicgrass, and bluegrass. Numerous wildflower species occurred within the native grassland such as: lupine, clover, gilia, baby blue eyes, red maids, cream cups, gold fields (*Lasthenia* formerly *Baeria*), tarweed, and gumweed (Thompson 1961). Early accounts describe the grassland vegetation of wild oats as 4-7 ft tall and so dense it was difficult to traverse, while additional bunch grasses grew on the red lands near the historic northern boundary of Colusa County, which was probably the present-day northern boundary of Glenn County, since Glenn County was established at a later date than this account (Green 1880). It has been theorized that tree establishment was limited within the grassy plains due to unfavorable soil characteristics such as areas of sandy texture, heavy texture (shrink-swell clays), patches of high alkalinity, as well as frequent flooding and periodic drought (Thompson 1961). Burning of the grasslands by American Indian groups also might have limited tree establishment in the grassy plains (Thompson 1961). Nonetheless, occasional singular valley oak trees once dotted the prairie and occasional closed-canopy stands of valley oak woodland were scattered about the plain.

A vast expanse of freshwater emergent marsh (i.e., tule marsh) occurred within the Colusa Basin Watershed. The freshwater marshes were dominated by tule and cattail (Katibah 1981). The original extent of tule marsh within the Colusa Basin has been estimated at 6 mi wide and 18 mi long (Green 1880). Other sources also depict a “trough” that was 2 mi wide and 22 mi long that probably received annual overflows from the west bank of the Sacramento River and waters from the foothill tributaries (Rogers 1891). An 1880 map by Charles Hughes indicates the locations of the upper and lower basins in Colusa County (and portions of Yolo County) that were tule marshlands (**Figure 1-Biology**, Green 1880). The upper basin, located 2 mi south of the town of Colusa and immediately north of Sycamore Slough was estimated to be 16 $mi^2$ in size and covered in tule marsh (Green 1880). Sycamore Slough itself emptied into the lower basin approximately 11 mi further south from the upper basin and the lower basin extended down to Knights Landing (Green 1880, **Figure 1-Biology**).

Two additional types of seasonal wetland habitat were also present, though less extensive than the tule marsh: vernal pool habitats and alkali sinks. Both of these seasonal wetlands occurred in depressions within the landscape underlain by soils with poor drainage capacity. They tended to retain water from rainfall (and sometimes overland flooding) in winter and dried during the springtime. Depending on the rates of evaporation, groundwater elevation, and alkalinity of the surface soils, freshwater vernal pools or alkaline sinks were formed. Species composition varied between these 2 seasonal wetland types, the former being dominated by annual forbs and grasses, the latter dominated by perennial halophytic (salt tolerant) vegetation. Typical plant species of freshwater vernal pools include the goldfields, coyote thistle, pincushion plant, tidy tips, and popcorn flower. Typical species in the alkali sinks included saltgrass, saltbush spp., pickleweed spp., seablite, alkaliweed, rabbitbrush, tarweed, and clover (ARP CSU 2005, Calfora 2008).

Chaparral vegetation dominated by chamise also occurred in portions of the Colusa Basin Watershed along the western foothills. Relict stands of chaparral extend into regions otherwise dominated by grassland (Thompson 1961). Repeated burning of chaparral may have favored grassland development over chaparral development (Thompson 1961).

Portions of the foothills along the western boundary of the Watershed also included blue oak and gray pine (Green 1880). A 200 ac relict stand of blue oak woodland is located southwest of College City, outside Arbuckle (Casey, pers. comm.2008)

### Anthropogenic Changes to Vegetation

Anthropogenic changes to the vegetation in the Colusa Basin Watershed reflect the same general pattern exhibited throughout California's Great Central Valley, a dramatically engineered and modified rural landscape (GIC 2003). Extensive flood control measures, wide scale drainage of wetlands, and conversion of native habitats to agricultural and urban uses have all occurred across large spatial scales in the Colusa Basin Watershed between 1850 and the present.

Based on early USGS maps, as late as 1886, tule marsh extended up to 5 mi wide from the riverbanks (though set back from the natural levees, Kelley 1989). Around 1850, tule swamps extended along both sides of the Sacramento River from "at least 25 mi north of Colusa southward to the Sacramento-San Joaquin delta islands, seventy mi down-valley from that town" (Kelley 1989). Around 1869-1870 RD108 and RD124 were formed and constructed levees along the Sacramento River and adjacent sloughs to reclaim large portions of the tule marsh located in the lower (RD108), and upper (RD124) basins (Green 1880). RD108 was 74,000 ac in size in 1870 and had reclaimed 20,000 ac of area in the lower basin for agricultural purposes by 1880 (Green 1880). RD124 encompassed 14,000 ac in 1870, and by 1878 approximately half (7000ac) of this area was under cultivation (Green 1880).

The expanding population in the Valley in response to the Gold Rush initiated cutting and burning the riparian forest and valley oak woodlands to fuel steamships and to clear the land for agriculture (Kelley 1989). Accounts dating to the 1860s indicate that the majority of the previous extent of the riparian forest had been cut, cleared, and removed by this point (Thompson 1961). The swift removal of the riparian forest was thought to be due to the demand for wood for steam vessels, construction lumber, and firewood coupled with limited local supplies in the adjacent basins (Thompson 1961). Furthermore, the natural levee lands beneath the riparian forest were among the first to be cleared and cultivated for agriculture because the soils here were free from extended flooding inundation and were better drained than lowland basin soils (Thompson 1961). From the late 1800s onward, the natural hydrologic cycles were so thoroughly altered through flood control projects and drainage development that some areas could no longer support the historic extent of riparian vegetation that once existed (Katibah 1981).

By 1910, Willis Jepson described the riparian forests of the Central Valley as "thin and limited in extent," constrained to the levees along streams and rivers and consisting mainly of valley oak and interior live oak (Thompson 1961). Contrast **Figure 1-Biology** with **Figure 3-Biology** to see this graphic representation of the reduction in riparian forest extent post 1900 compared to pre-1900 (GIC 2003). However, where there were perennially moist soils along stream banks and river bottoms, Jepson described communities of willow and cottonwood riparian forest and along the largest rivers the complete suite of species included black willow, yellow willow, red willow, Oregon ash, interior live oak, valley oak, and box elder (Thompson 1961).

By 1961, Thompson describes the extent of the riparian forest as discontinuous, often less than 300 ft wide and confined to stream banks and the inboard side of constructed levees (Thompson 1961). A few relict stands of valley oak riparian woodland still exist in Yolo County, near Knights Landing and Elkhorn Ferry, and in Tehama County near Woodson Bridge, which could serve as reference communities for restoration planning within the Colusa Basin Watershed (Thompson 1961). Additional examples could be found in adjacent watersheds along portions of Cache Creek and Putah Creek (Thompson 1961).

Altered fire-dynamics (including frequency, intensity, and suppression), grazing, cultivation, and invasion by non-native grass species have essentially destroyed the original grasslands of the Central Valley (Thompson 1961, Hall 1975). Contrast **Figures 1-Biology** and **2-Biology** and **3-Biology** in order to view the conversion of historic grassland to urban and agricultural uses (GIC 2003). Some research suggests that the invasion of the native grassland by wild oats pre-dated Euro-American settlement in the Colusa Basin and resulted from the species own rapid rate of spread after originating from earlier Spanish missions in the coastal regions of California (Hall 1975). This view helps explain why Will Green reported seeing the Colusa plains covered in wild oat as early as 1852 (Green 1880). Therefore, by the time the Euro-American explorer-settlers observed the vegetation of the region and began recording their observations in the historical sources, the original landscape may well have already been changed from its form prior to all Euro-American contact on the continent. Today, relicts of original grassland species assemblage can be found among the patches of chaparral in the western foothills (Alderson, pers. comm.).

Between 1937 and 1962 the Sacramento, Delevan, and Colusa NWRs were established to provide wetland habitat for migrating waterfowl (**Table 1-Land Use**, DWR 1990). In 1937, the Federal Bureau of Biological Survey (predecessor to the USFWS) acquired the Spalding Ranch for approximately $150,000, which became the Sacramento NWR (Hall 1975). The refuge's primary mission from inception was to convert the marginal agricultural lands of the former ranch to intensively managed waterfowl food production areas. The impetus for this mission was tied both to a broad scale goal to recover western waterfowl populations impacted by the dust bowl conditions of the 1930s and to provide alternate foraging habitat to protect nearby commercial rice fields from decimation by waterfowl. Much of the infrastructure was constructed in the summer of 1937 by the Civilian Conservation Corps including the present pond system, the dam on Logan Creek that diverts water into the ponded areas, and many of the major dikes and roadways (Hall 1975). These wetlands receive water from the Central Valley Water Project via the Glenn-Colusa Irrigation District in the course of their ongoing management (DWR 1990). Consequently, an increase in wetland acreage occurred after the refuges were established and this is reflected in **Figures 2-Biology** (1945), and **Figure 3-Biology** (1995, GIC 2003). Wetland acreage further increased when farmers started flooding ricelands in lieu of burning to decompose rice stubble (see existing conditions section for acreage and timeframe of this change).

**Wildlife**

Based on accounts from the early 1800s by the earliest Spanish explorers of the Sacramento Valley, thousands of tule elk, antelope (pronghorn), and deer browsed the valley floor (Kelley 1989). Will Green wrote of his first trip up the Sacramento River towards Colusa that there were "myriads of ducks and wild fowl…deer…and even grizzly bear," along the banks of the river (Kelley 1989). In his hypothetical account of the pre-settlement environment of the Sacramento NWR and surrounding area, Hall (1975) included tule elk, pronghorn, grizzly bear and coyote as the dominant megafauna, and northern pintail, green-winged teal, mallard, American wigeon, northern shoveler, tundra swan, greater white-fronted goose, snow goose, ross goose and Canada goose as the dominant wintering waterfowl. A few of these species had smaller breeding populations. Conversely, fulvous whistling-duck, cinnamon teal and redhead were thought to have had larger breeding populations than wintering populations.

Trappers apparently ignored sections of the Colusa Basin Watershed due to the probable lack of wetland habitats for otter, beaver, and mink, and the upland plains were described as dry and covered with non-native oats by early explorers. John Bidwell described the Stony Creek area in late summer of 1844 as "a country dry and parched….with countless herds of wild horses, elk and antelope (pronghorn)." However, similar to the rapid decimation of riparian habitat after Anglo-American contact, by 1870 pronghorn, grizzly bear, tule elk, coyote, and badger were eliminated or greatly reduced within the watershed due to competition from domestic livestock grazing, hunting, and loss of habitat to wheat farming (Hall 1975).

Geese, however, probably increased in population due to the increased food found in the newly established wheat fields. Because of this large population and the concomitant loss of elk and pronghorn, waterfowl hunting grew in importance for local settlers as well as for market hunters supplying the San Francisco Bay Area from 1880 until 1918 when the Federal Migratory Bird Treaty Act [MBTA] went into effect and outlawed market hunting. The majority of the 49,000 geese sold at market in San Francisco in the winter of 1895-96 were shot in the Colusa Basin Watershed. When rice cultivation was introduced to the Colusa Basin Watershed through the Sacramento Valley Irrigation Company in the early 20$^{th}$ Century, waterfowl habitat increased, especially for ducks that were more dependent upon wetlands for habitat. Many acres that had been dryland wheat farms and pasture were quickly transformed to rice thereby increasing the proportion of ducks in the waterfowl population. This creation of prime waterfowl habitat was dramatic, as from 1913 to 1919 the acreage increased from 750 to 71,550 (Hall 1975).

During the fall of 1937 when the first wintering waterfowl appeared at the newly established Sacramento NWR, peak numbers were counted at 36,811 ducks and 72,320 geese. These numbers were eclipsed in 1938 following the planting of rice and millet on the refuge which attracted over 500,000 waterfowl that completely devoured these crops within 3 days in mid-October, and attracted over 1,250,000 in mid-December. These numbers fluctuated over the next few years as barley and other crops were added to the mix on the refuge and peaked in late

December 1947 with 3,380,000 ducks and 450,000 geese. In the late 1940s, the Colusa NWR was formed partly as a way to attract some of these waterfowl away from the private rice fields in the vicinity of the Sacramento NWR as waterfowl depredation of private rice crops was creating a great deal of concern amongst the region's rice farmers. Around this time, millet was to become a major waterfowl feed crop grown on the refuges because it was easier and less expensive to grow (Hall 1975).

In 1937 a large portion of the southern half of the Sacramento NWR was inventoried for habitat and wildlife (Hall 1975). Ring-necked pheasant (an introduced species) was recorded in large numbers (278). Baseline inventory surveys at this time also recorded a high number of burrowing owls (60).

### Invasive Plants

Eucalyptus was planted abundantly throughout the Central Valley in the late 1800s (Thompson 1961). It was introduced to California in 1853 by Captain Robert Waterman and advertised as a fast-growing ornamental (Bean and Russo 1986). Its fast rate of growth results in poor quality timber, but it has been used for firewood, rough hewn timbers for mining, paper pulp, shelterbelts, and ornamental uses (Bean and Russo 1986). Wild oats (*Avena sativa*) and filaree (*Erodium cicutarium*) had invaded the watershed prior to Spanish settlement from Mexico where these Eurasian species had rapidly expanded its range into California (Hall 1975). Giant reed escaped cultivation in California as early as 1820 in the Los Angeles River (Hoshovsky 1987). Early records of saltcedar date to 1776 in the southwestern U.S., and it was commercially available in California in 1850 (Carpenter 1998). It was found to be invading waterways in 1877 (Carpenter 1998). Yellow starthistle was originally from southern Europe, but was introduced from Chile to California during the gold rush (DiTomaso 2001). Medusahead was first introduced into the United States in the 1880s (Maurer et al. 1988). Specific information about the introduction of ludwigia, purple star thistle, and perennial pepperweed was not readily available.

## EXISTING CONDITIONS

### Biotic Habitats (Vegetation and General Wildlife Use by Habitat Type)

**Vegetation.** Biotic habitats within the Colusa Basin Watershed were characterized using the Wildlife Habitat Relationships [WHR] system for habitat classification along with previous studies and reports (Mayer and Laudenslayer 1988). The WHR categorizes habitats into different types according to dominant vegetation and characteristics that are important to wildlife. **Figure 4-Biology** illustrates the distribution of biotic habitats in the watershed based upon a composite of information from the California Gap Analysis Program [CA-GAP] Map and the California Department of Forestry and Fire Protections' Fire and Resource Assessment Program [FRAP]. We selected these sources because they provide the only comprehensive vegetation map data that covers the study area at a level of detail that is appropriate for this relatively broad-scale assessment. The FRAP vegetation map data were utilized in **Figure 4-Biology** for the western (foothill) portion of the watershed because the FRAP map provides a higher resolution compared to the CA-GAP Map for the foothill region. The CA-GAP Map data were utilized for the lowland portions of the watershed (central and eastern) since this source provides higher resolution than the FRAP maps for the low-lying areas.

**Appendix 2-Biology** provides the scientific names for the plant species included below.

Patterns of vegetation within Colusa Basin Watershed generally correspond to the watershed's major topographic features and current land-use activity. The habitats of Colusa Basin Watershed can be grouped broadly into the following 6 types according to vegetation and landscape position:

- Riparian habitats along the Sacramento River, its tributary sloughs, and foothill streams
- Emergent Wetland habitats in the central portion of the Colusa Basin
- Developed and Cultivated habitats located in the central portion of the Colusa Basin
- Annual Grasslands along the western foothills
- Woodlands along the western foothills
- Shrub lands along the western foothills

These general categories can be sorted out further according to the more localized effects of soils, elevation, aspect, and disturbance history.

Historically, the Sacramento River along with its tributary sloughs flooded their banks saturating the lowest portions of Colusa Basin and depositing first coarse textured sediments along the waterways' natural levees and fine textured sediments at the farther extents of their floodplains (USDA/NRCS 1998). This condition sometimes occurred twice annually, once during winter rains, and a second time during spring from the melting Sierra Nevada snow pack. Extensive flooding such as this created the patterns of soil development throughout the eastern and central portion of Colusa Basin up to the outwash plains of the western foothills. Consequently, the historic vegetation of this area included riparian forest along the river and streams' natural levees along with vast expanses of emergent marshes throughout the low-elevation of the Colusa Basin on the finer textured soils. Beginning in 1860 major flood control and irrigation development projects altered this historic hydrologic/sedimentation regime (Kelley 1989).

The foothill habitats have been shaped by a different set of conditions. Rather than forming from alluvial deposits from the Sacramento and its tributary sloughs, the foothills soils formed from weathered sandstone, shale, and schist. Although the foothill streams have historically flooded, the scale never approached that of the major river basin. Soil erosion rather than deposition, has shaped the landforms of the foothills. Foothill soils may be shallow or deep and drain more easily along steeper slopes than the basin lowlands. Consequently, the foothill habitats include grasslands, shrublands, and woodlands. The mosaic of these 3 habitats has been shaped further by aspect, elevation, and patterns of anthropogenic fire and grazing.

### *Aquatic Habitats*

**Emergent Wetland Habitats in the Central Portion of the Colusa Basin.** Emergent Wetland habitat comprises 3% of the Colusa Basin Watershed (31,392 ac; **Figure 4-Biology**). As noted above, the historic extent of emergent wetlands has been reduced significantly due to drainage and conversion to agriculture (Mayer and Laudenslayer 1988). The largest patches of emergent marsh still existing are located in the Sacramento Valley at the Sacramento NWR Complex. Emergent wetlands are formed in frequently flooded depressions or seeps, usually on fine sediment (clay or silt soils) or organic soils (peat). They are dominated by perennial monocots where the standing water is usually less than 4 ft deep (Mayer and Laudenslayer 1988). Species known to occur within freshwater marsh habitats in the Colusa Basin Watershed include Coulsa grass, tufted hairgrass, mannagrass, spikerush, and rushes. More alkaline sites include saltgrass, saltbush, gumweed, big bulrush, pickleweed, and alkali weed. Wetter sites include multiple species each of cattail, bulrush, and arrowhead. They often form a series of concentric rings, following the contours that determine depth and duration of flooding. Their perennial vegetation is relatively stable from year to year, though they can be become open water in some high-water years. Marshes usually accumulate sediment and organic material unless erosion forces exceed rates of accretion and are known for their very high rates of primary productivity. This productivity becomes the basis of productive food webs as they provide food, cover and water for numerous faunal species including 160 species of birds (Mayer and Laudenslayer 1988).

Vernal Pools are wetlands found within grasslands in depressions that are underlain by hardpan soil layers. These habitats are isolated, seasonal wetlands set within the annual grassland habitat. Typical plant species include the goldfields, coyote thistle, pincushion plant, tidy tips, and popcorn flower. Vernal pools are rare habitats that host numerous rare species of plants, amphibians, and invertebrates. Both the habitats themselves and certain species within vernal pools are subject to regulatory protection. The Colusa Basin IRMP draft project EIS/EIR reports that there are 11,920 ac of high-density vernal pool habitat and 4,220 ac of medium density vernal pool habitat within the Colusa Basin Watershed Navigant Consulting, Inc. 2000). Some indication of the spatial distribution of this habitat can be gleaned from the California Natural Diversity Data Base [CNDDB] plant occurrence records for the Colusa Basin Watershed (**Figures 5-Biology** and **Figure 6-Biology**).

### *Riparian Habitats*

Riparian woodlands perform essential ecological functions in a watershed. They provide nesting and feeding sites for wildlife, host a high diversity of flora and fauna, improve water quality, facilitate groundwater recharge, and reduce erosion. Fifty-five species of mammals, 147 species of birds and at least 50 species of reptiles or amphibians are known to use riparian habitats for some portion of their life-history (Mayer and Laudenslayer 1988).

Valley-Foothill Riparian habitat comprises 0.5% of the watershed (4715 ac, **Figure 4-Biology**) This habitat type primarily occurs along the Sacramento River where frequent flooding and/or high groundwater tables support this water-loving, flood-tolerant plant community. Valley-foothill Riparian habitat is dominated by cottonwood, sycamore, willows (Goodings, narrow-leaved, red, arroyo, and shining) and valley oak trees (Mayer and Laudenslayer 1988). Additional tree species include white alder, boxelder, and Oregon ash. The understory typically includes wild grape, wild rose, California blackberry, blue elderberry, poison oak, buttonbrush, and willow spp. among the shrub layer and sedges, rushes, grasses, mugwort, and nettle among the herbaceous layer. Cottonwood and willows dominate the immediate stream banks and valley oaks spread out from the levees outward. This habitat occurs on coarse textured soils with more or less permanently moist topsoils, a high water table, and low-velocity stream flows. Valley-Foothill Riparian habitat in California has been vastly reduced from its historic extent; 12,000 ac of original 800,000 ac remain today having been diminished by cultivation of the floodplain, alteration of the river (flood control and channelization), and tree harvesting (Mayer and Laudenslayer 1988). Altered hydrologic conditions no longer can support this habitat in its historic range.

Patches of sycamore alluvial woodland still occur along remnant reaches of Sycamore Slough, south of Colusa (Alderson, pers. comm.). Mature California sycamore and valley oak are abundant with California wild grape and California rose abundant in the understory. Northern California black walnut, blue elderberry, and Himalayan blackberry (a non-native, invasive understory species) also occur along Sycamore Slough.

In contrast to the obligate-riparian plant communities along the Sacramento River and Sycamore Slough, the habitats along the ephemeral foothill streams of the watershed are likely dominated by relatively drought-tolerant plant communities. However, the FRAP and CA-GAP Maps do not capture the distribution of streamside woody vegetation along many of the foothill tributaries due to the coarse-scale resolution of these mapping efforts (**Figure 4-Biology**).

### *Developed and Cultivated Habitats Located in the Central Portion of the Basin of the Watershed*

Developed and cultivated habitats in the WHR database include Cropland, Irrigated Row and Field Crops, Rice, Hayfields, Deciduous Orchards, and Vineyards (606,737 ac), and Urban areas (2974 ac, **Figure 4-Biology**). Cultivated habitats comprise 58% of the Colusa Basin Watershed and urban areas comprise <1%. Rice is the primary crop occupying 20% of the Colusa Basin Watershed. Generally crops are located on level or gently rolling terrain. Soils and microclimate dictate which crops are planted and alkali soils must be leached to support some crops. In general, orchards are established on coarser textured soils along the former natural river levees and foothills. Rice is generally grown on the finest textured soils.

Since 1992 the Rice Straw Burning Reduction Act has restricted burning rice straw. In response, farmers have dramatically increased the amount of rice fields that are flooded during the winter months after the rice straw is incorporated into the soil. This results in a huge increase in open water wetland habitat for migratory birds (mostly ducks and geese). Farmers flail mow the straw into small pieces (~4 inches), then disk the field to bury the pieces 4-5 inches deep in the soil, and then flood the soil to promote decomposition of this organic matter. Farmers either depend on adequate precipitation or irrigation district water to flood their fields in the winter. Fields may remain flooded for 8 months, providing wintering habitat for ducks and geese. Sudangrass is often planted on levees to conceal duck blinds (Cline 2005). It has also been reported that some people plant giant reed to conceal duck blinds. The planting of giant reed in the Colusa Basin Watershed poses some potential problems since it is an invasive, non-native plant species (see *Invasive Plants* section below, Singh pers. comm.).

Irrigated Row and Field Crops are mostly annuals, but a few are perennials (asparagus and strawberries). Examples of Irrigated Row Crops include tomatoes, cotton, asparagus, broccoli, carrots, cauliflower, celery, cucumbers, melons, onions, peppers, strawberries, potatoes, beets, and lettuce. They are usually grown in rows and may either have significant bare ground between rows or provide 100% canopy cover. Often they are planted in spring and harvested in summer or fall. Sometimes they are planted in rotations (multi-cropping) or alternated with dryland farmed barley or winter wheat after fall harvest. Crop rotation conserves soil nutrients, soil productivity, and breaks up pest life-cycles.

Hayfields refer to alfalfa hay or irrigated native hay fields. Alfalfa is grown between crop cycles in order to fix nitrogen in the soil and is planted for approximately 3 yrs within 7-8 yr rotations (Mayer and Laudenslayer 1988). In the absence of management, alfalfa fields may revert to patchy saltgrass, salt-tolerant shrubs, exotic invasive vegetation, or unvegetated alkaline flats. Grassy hayfields are mowed, managed hayfields, which may be sedge meadow, wet meadow, or perennial grassland habitat in their unmanaged state. These areas can be inundated for a month or more during winter and will sometimes support cattails and bulrushes.

Deciduous Orchards refer to almonds, walnuts, apples, apricots, cherries, figs, nectarine, pears, pecans, pistachios, plums, pomegranates, and peaches. The understory is usually managed herbaceous cover of annuals or perennials. Orchards often endure for 20-40 yrs until productivity declines and they must be renewed. They can be grown on flat alluvial soils, rolling foothills, or even steep slopes and benefit from the good drainage afforded by coarser soil types. They can be irrigated using flood-irrigation, sprinklers, or drip.

### *Annual Grasslands along the Western Foothills*

Annual grasslands comprise 18% of the Colusa Basin Watershed (185,143 ac; **Figure 4-Biology**). This habitat type includes a small percentage of Vernal Pools discussed below. Annual grassland is an open habitat composed of annual herbaceous plant species such as wild oat, soft chess, ripgut brome, red brome, wild barley, and foxtail fescue. Forbs within annual grassland include filaree, turkey mullein, clovers, bur-clovers, and popcorn flower. Annual grasslands tend to occur where there was formerly pristine native grassland that has been lost due to disturbance, grazing, and introduction of non-native annual grass species (Mayer and Laudenslayer 1988). The former native grasslands consisted of perennial bunchgrasses in wetter sites and annual species on drier alluvial plains. Annual grasslands can be located on lower elevation flood plains and swales as well as in higher elevation, drier sites, and they often occur as an understory component of Oak Woodlands.

The structure and composition of annual grassland habitats can be affected by climate and livestock grazing patterns (Mayer and Laudenslayer 1988). Fall rains stimulate germination, growth occurs during cool winter months, then warmer spring months stimulate rapid growth and most plants mature between April and June. Species composition shifts throughout the growing season according to plant phenology. Precipitation strongly affects species composition. Perennial grasses are more common when precipitation is above 60 inches/yr (average precipitation in Sacramento is 17 inches, Mayer and Laudenslayer 1988). Grazing timing and intensity affects species composition and the quantity of standing dead material. Grazing results in more low-growing spring-maturing forbs; absence of grazing results in more dense tall grass stands.

Native perennial grasses can be found within moist remnant prairies or lightly grazed areas, and may include purple needle grass and Idaho fescue. One location of remnant perennial grassland can be found along Salt Creek 10 mi west of Williams (Sedway Cooke Associates 1989).

### *Woodlands along the Western Foothills*

Blue oak and Blue Oak-Foothill Pine forms a mosaic with annual grassland habitats in the foothills along the western edge of Colusa Basin Watershed in shallow, rocky, well-drained, infertile gravelly loam or clay loam soils. This habitat intergrades with Valley Oak Woodlands and Annual Grasslands at lower elevations and with Pine Woodlands at higher elevations. Blue Oak Woodland comprises 12% of the Colusa Basin Watershed (128,194 ac; Figure **4-Biology**). Blue Oak-Foothill Pine habitat comprises 6% of the Colusa Basin Watershed (60,874 ac; Figure **4-Biology**). Blue oaks are adapted to hilly terrain where the water table is unavailable (in contrast to Valley Oak Woodland). Blue Oak Woodlands are generally found between 500-3000 ft elevation in nearly a continuous ring around the Central Valley foothills east and west, and in the Colusa Basin Watershed a 200 ac remnant stand is located southwest of College City, outside Arbuckle (Masters, pers. comm.). The canopy closure can range from widely scattered to closed canopy, depending on available water supply (Mayer and Laudenslayer 1988). The understory is typically composed of annual grassland habitat. Blue oak may comprise 80-100% of the tree species present within this woodland type. They are slow growing long-lived trees (100-300 yrs old, Mayer and Laudenslayer 1988). Shrubs are generally absent, or occur only along rock outcrops. Shrub species include poison oak, California coffeeberry, buckbrush, redberry, and manzanita species.

Most stands consist of mature trees with few or no young trees present. Few areas have been found where successful recruitment has occurred since the turn of the century. This is thought to be due to land-use conversion; increased consumption of acorns and seedlings by insects, livestock or native animals; and competition between annuals species and seedlings for soil moisture and nutrients (Mayer and Laudenslayer 1988). The absence of livestock does not generally result in greater regeneration because numerous native species consume the acorn crop and seedlings (Mayer and Laudenslayer 1988). Some ecologists suggest that savannas will become more widely spaced as older trees die leaving sparser canopy coverage.

Where blue oak intermixes with foothill pine both species and structural diversity is higher than in purely Blue Oak Woodlands (Mayer and Laudenslayer 1988). Blue Oak-Pine Woodland usually includes a shrub component and Blue Oak Woodland typically only includes annual grassland understory. Associated species include live oaks, valley oak, and California buckeye. If pine becomes more dominant it will shade out the blue oak (Mayer and Laudenslayer 1988). The understory may be either patches of shrubs or annual grassland. Shrubs species include ceanothus species, manzanita species, coffeeberry, blue elderberry, gooseberry, and redbud.

Just 229 ac of remnant valley oak woodland remain at the southern, low elevation (<2000 ft) portions of the western foothills of the Colusa Basin Watershed southwest of Dunnigan (**Figure 4-Biology**). Valley oak grows along drainages, in deeper alluvial soils, within reach of permanent ground water supply. Valley oak may form more of a savanna structure in drier, less fertile sites or more of a closed canopy structure in moister, more productive sites. Shrub understory also increases with greater moisture and productivity while annual grasslands dominate the understory of higher-drier sites. In the absence of grazing shrub species include poison oak, toyon, and coffeeberry. Valley oak is long-lived species (100-300 yrs old) that suffers the same limitations as blue oak concerning regeneration. Valley oaks are somewhat tolerant of flooding and fire (Mayer and Laudenslayer 1988).

### *Shrublands along the Western Foothills*

A patch of chaparral classified as chamise-redshank in WHR occurs along the western most edge of the watershed boundary in the Coast Range foothills (**Figure 4-Biology**). However, redshank is not found in Northern California, so this landcover type is more appropriately named herein as chamise chaparral. Chamise chaparral typically includes a continuous 3-6 ft shrub layer lacking an herbaceous ground cover layer and a tree layer. In addition to chamise, other typical chaparral shrubs include numerous species of manzanita and buckbrush, together with mountain mahogany, serviceberry, yerba santa, and buckwheat. Among the mosaic of shrub cover and canopy gaps, chaparral habitat includes a great diversity of annual and perennial herbs and grasses that are also common among the foothill woodland habitats. Drier sites may have lower levels (<80%) of canopy cover. Soils are usually thin and low in organic matter, along ridges and steep slopes. Fire reinitiates secondary succession during which time more herbs and subshrub species (deerweed, buckwheat) may be present initially (1-3 yrs following fire, Mayer and Laudenslayer 1988). These early succession post-fire herbaceous/subshrub species are important for capturing and retaining nutrients within this habitat type (Mayer and Laudenslayer 1988). As the chamise chaparral grows, these other species are gradually excluded (10-30 yrs after fire). Chaparral species sprout from the root crown and/or from seed following fires; herbs and subshrubs sprout from the seedbank. However, too frequent or high intensity fire may limit chaparral's continued existence. Chamise chaparral senesces after about 60 yrs, so prescribed burning may be a useful management technique, since fire suppression leads to stand senescence, which in turn lowers wildlife habitat (Mayer and Laudenslayer 1988).

### *Sensitive Plant-communities*

Six sensitive plant communities are indicated on the CNDDB records as occurring in the Colusa Basin Watershed (Figures 4-Biology, 5-Biology, and 6-Biology). They are:

- (Coastal and) Valley Freshwater Marsh
- Great Valley Cottonwood Riparian Forest
- Great Valley Mixed Riparian Forest
- Great Valley Willow Scrub
- Valley Needlegrass Grassland
- Northern Claypan Vernal Pool

Two additional communities are shown on the CA-GAP/WHR vegetation map that are also considered sensitive according to the DFG list of communities (DFG 2003b, **Figure 4-Biology**). These include Valley Oak Woodland and Great Valley Valley-Oak Riparian Forest and Blue Oak Woodland.

Each sensitive plant community is described briefly below in terms of its abiotic habitat requirements, dominant and typical species, degree of rarity, and general location and extent in the watershed. The degrees of rarity are conveyed by the rating provided after each community type heading (e.g., G3 S2.1). The degrees of rarity ratings are defined at the end of this section.

**Valley Freshwater Marsh G3 S2.1.** Freshwater marsh habitats are dominated by emergent perennial herbaceous species that tolerate seasonal, frequent, or permanent flooding. In the

Colusa Basin Watershed this habitat is most likely to be found along the bottomland margins of rivers, creeks, ditches, and sloughs as well as in natural depressions with fine textured or organic soils (Sawyer and Keeler-Wolf 1995). Typical species include bulrushes (tule), cattail, saltgrass, and sedges. These plants usually form a continuous canopy that is <12 ft tall. This habitat can be found in the central portion of the Colusa Basin Watershed between Willows and Colusa along the Colusa Drain and in the Sacramento NWR complex (**Figure 4-Biology**).

**Great Valley Cottonwood Riparian Forest G2 S2.1.** This habitat occurs along floodplains, stream and river banks, levees, and terraces subject to seasonal or intermittent flooding. This habitat is dominated by tree cover <82 ft tall consisting of Fremont cottonwood, though California sycamore, Oregon ash, box elder, walnut, and willow species (narrowleaf, Pacific, red, etc.) are frequently present as well (Sawyer and Keeler-Wolf 1995). The understory often includes wild grape vines and may include a shrub layer consisting of willow species, blue elderberry, and/or California blackberry, along with an herbaceous layer including mugwort and blue wildrye (Vagheti 2003). Surface soils may be moderately coarse (loamy sand) to moderately fine (silt loam). This habitat can be found along the Sacramento River north of Colusa (**Figure 4-Biology**).

**Great Valley Mixed Riparian Forest G2 S2.2.** This habitat is similar to Great Valley Cottonwood Riparian Forest, except that it is not dominated by a single species (Fremont cottonwood), but rather is composed of a number of co-dominant tree species. Additional tree species may include big leaf maple, white alder, California sycamore, Oregon ash, box elder, valley oak, Pacific willow, or red willow (Sawyer and Keeler-Wolf 1995). Understory species composition and abiotic factors such as flood frequency, soil type, and soil moisture are comparable to Great Valley Cottonwood Riparian Forest. This habitat can be found along the Sacramento River north of Colusa (**Figure 4-Biology**).

**Great Valley Willow Scrub G3 S3.2.** This habitat is composed of thicket-forming small (<32.8 ft) trees and shrubs dominated by willow species. Typical willow species include shining, arroyo, Gooding's, narrowleaf, dusky, and red willow. The groundcover layer is sparse or absent due to shading and disturbance (flooding). Willow scrub occurs along seasonally flooded, relatively young (<30 yrs) floodplains or other low-gradient depositional areas along rivers and streams (Sawyer and Keeler-Wolf 1995, Vagheti 2003). Once established it may persist on older (100 yrs) floodplain surfaces (Vagheti 2003). Surface soil texture may be relatively coarse (loamy sand) to quite fine (silty clay, Vagheti 2003). This habitat can be found along the Sacramento River north of Colusa (**Figure 4-Biology**).

**Valley Needlegrass Grassland G1 S3.1.** Valley Needlegrass grasslands are open grassland habitats dominated by native perennial bunchgrasses such as nodding needlegrass or purple needlegrass and may be a dominant understory component of oak woodlands. Additional native grass species that may be present include California fescue, California melic, creeping wildrye, or hooked three-awn. Frequently this habitat is invaded by non-native annual herbs and grasses such as ripgut brome, soft chess, wild oats, and Italian ryegrass. Needlegrass grasslands are found on deep, fine textured soils. Patches of this habitat occur west of Williams according to CNDDB records (Figures 5 and 6 - Biology).

**Northern Claypan Vernal Pool G1 S1.1.** This habitat occurs on silica-cemented hardpan soils, which retard drainage. These depressions are flooded or saturated seasonally during winter, drying out by late spring. The soil may be fresh or slightly saline, neutral to alkaline. The dominant vegetation consists of a mixture of annual and perennial herbs and grasses such as goldfields (California and Fremont), coyote thistle, Fremont tidytips, and blenosperma and saltgrass. Vernal pool habitats host numerous plant, amphibian, and invertebrate species, many of which are rare. This habitat occurs in the Colusa Basin Watershed around Willows, southwest of Maxwell, and in the Sacramento NWR complex (Figures 5-Biology and 6-Biology).

**Valley Oak Woodland G3 S2.1 and Great Valley Valley Oak Riparian Forest G1 S1.1.** Valley oak woodlands occur in both riparian settings and valley bottomlands where they are able to root into groundwater. When they occur along riparian areas they are found on older (>100 yr) floodplains that are flooded intermittently or seasonally. Soil textures range from loamy sand to silty clay (Sawyer and Keeler-Wolf 1995). Associated tree species include box elder, California sycamore, Oregon ash, and walnut. Wild grape vines are commonly found in the understory along with California dutchman's pipe and poison oak (Vagheti 2003). Frequently the ground layer is grass, which may be composed of native bunchgrasses, non-native annual grasses, or a mixture of both. Small remnant patches of valley oak woodland are shown on the CA-GAP/WHR map just west of Dunnigan (**Figure 4-Biology**).

**Blue Oak Woodland G3 S3.2.** Blue oak woodland occurs on the slopes of the foothills and valley bottom where soils are moderately to excessively well-drained. The habitat structure can be savannah or continuous closed canopy. The tree canopy is dominated by blue oak, but may include foothill pine, coast live oak, interior live oak, valley oak, or western juniper. Blue oak woodland and blue oak-foothill pine occur along the entire western edge of the watershed from north to south in the foothills (**Figure 4-Biology**).

**Rarity Ratings.** Rarity Ratings are given as global rankings and state rankings with threat-level codes appended to the state ranking. The global rank is a reflection of the overall condition of an element throughout its global range. Global rank codes are defined as follows:

- G1 = Less than 6 viable element occurrences [EOs] OR less than 1000 individuals **or** less than 2000 ac.
- G2 = 6-20 EOs **or** 1000-3000 individuals **or** 2000-10,000 ac.
- G3 = 21-80 EOs **or** 3000-10,000 individuals **or** 10,000-50,000 ac.
- G4 = Apparently secure, but factors exist to cause some concern; i.e., there is some threat or somewhat narrow habitat
- G5 = Population or stand demonstrably secure to ineradicable due to being commonly found in the world

The state rank is assigned much the same way as the global rank, except state ranks in California often also contain a threat designation attached to the S-rank. State rank codes are defined as follows:

- S1 = Less than 6 EOs or less than 1000 individuals **or** less than 2000 ac
- S2 = 6-20 EOs OR 1000-3000 individuals **or** 2000-10,000 ac
- S3 = 21-80 EOs or 3000-10,000 individuals **or** 10,000-50,000 ac

S4 = Apparently secure within California; this rank is clearly lower than S3 but factors exist to cause some concern; i.e., there is some threat or somewhat narrow habitat
S5 = Demonstrably secure to ineradicable in California

California's threat level gradations are shown as decimal suffixes to the state ranking numbers. The threat levels are defined as follows:

0.1- Seriously threatened in California (high degree/immediacy of threat)
0.2- Fairly threatened in California (moderate degree/immediacy of threat)
0.3- Not very threatened in California (low degree/immediacy of threats or no current threats known)

### *General Wildlife Use by Habitat Type*

The following section provides an overview of general wildlife use within the Colusa Basin Watershed by WHR Habitat Type. **Appendix 3-Biology** provides the scientific names for the wildlife species discussed below. The special-status wildlife species that could potentially occur is also listed under each Habitat Type. Special-status wildlife species are then treated in more detail in the Special-Status Species section below.

The landcover types of the watershed vary widely in their habitat and biodiversity values. **Table 1-Biology** provides lists of wildlife species that inhabit these landcover types. This list was compiled based upon internal review by H. T. Harvey & Associates wildlife ecologist as well as review of published lists of birds for Glenn, Tehama, and Colusa counties (Sterling 2007). From these lists, a Biodiversity Index was developed and defined as species richness: number of species occurring within each Habitat Type (**Table 2-Biology**). **Appendix 3-Biology** provides the scientific names for the wildlife species noted herein.

**Table 1. Biology. Wildlife Species in Each WHR Landcover Type in the Colusa Basin Watershed.**

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| **Invertebrates** | | | | | | | | | | | | | | | |
| **Vernal Pool Tadpole Shrimp** | | | | B | | | | | | | | | | | |
| **Conservancy Fairy Shrimp** | | | | B | | | | | | | | | | | |
| **Vernal Pool Fairy Shrimp** | | | | B | | | | | | | | | | | |
| **Valley Longhorn Elderberry Beetle** | | | | | | | | | B | | | | | | |
| **Amphibians** | | | | | | | | | | | | | | | |
| **California Tiger Salamander** | | | | B | V | | | | | | | | | | |
| Western Toad | | B | B | B | V | | V | B | B | B | B | | B | | |
| **Western Spadefoot Toad** | | | | B | V | | | | | | | | | | |
| Pacific Treefrog | | | B | B | | | V | B | B | B | B | | V | | |
| *Bullfrog* | | | B | | | | | | V | | | | | | |
| **Reptiles** | | | | | | | | | | | | | | | |
| **Northwestern Pond Turtle** | V | V | B | B | | | | B | B | B | B | | B | | |
| Western Fence Lizard | | | | | B | V | V | B | B | B | B | B | B | | |
| **California Horned Lizard** | | | | | | | | | | | | B | B | | |
| Western Skink | | | | | B | | V | B | B | B | B | B | B | | |
| Western Whiptail | | | | | B | V | | B | B | B | B | B | B | | |
| Southern Alligator Lizard | | | | | V | | V | B | B | B | B | B | B | | |
| Racer | | | | | B | V | V | B | B | B | B | B | B | | |
| Coachwhip | | | | | B | | | B | B | B | B | B | B | | |
| California Whipsnake | | | | | V | | V | B | B | B | B | B | B | | |

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Gopher Snake | | | | | B | V | V | B | B | B | B | B | B | | |
| Common Kingsnake | | | | | B | V | V | B | B | B | B | B | B | | |
| Common Garter Snake | | | V | V | B | V | V | B | B | B | B | B | B | | |
| **Giant Garter Snake** | | | B | B | | | | | | | | | | | |
| Western Terrestrial Garter Snake | | V | | | B | V | V | B | B | B | B | B | B | | |
| Western Aquatic Garter Snake | | B | | | | V | V | B | B | B | B | | | | |
| Western Rattlesnake | | B | | | B | V | V | B | B | B | B | B | B | | |
| **Birds** | | | | | | | | | | | | | | | |
| Pied-billed Grebe | V | | B | | | | | | | | | | | | |
| Eared Grebe | V | | | | | | | | | | | | | | |
| Western Grebe | V | | | | | | | | | | | | | | |
| Clark's Grebe | V | | | | | | | | | | | | | | |
| **American White Pelican** | V | | | | | | | | | | | | | | |
| Double-crested Cormorant | V | | | | | | | | | | | | | | |
| American Bittern | | | V | | | | | | | | | | | | |
| Great Blue Heron | V | V | V | | | | | | B | B | | | | V | V |
| Great Egret | V | V | V | | | | | | B | B | | | | V | V |
| Snowy Egret | V | V | B | V | | | | | | | | | | V | V |
| Cattle Egret | V | | B | | | | | | | | | | | V | V |
| Green Heron | V | | V | V | | | | | B | B | | | | | |
| Least Bittern | | | B | | | | | | | | | | | | |
| Black-crowned Night-Heron | V | V | B | V | | | | | B | B | | | | V | V |
| White-faced Ibis | | | B | V | | | | | | | | | | V | V |

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Turkey Vulture | | | V | V | V | V | V | V | B | B | B | V | B | V | V |
| Tundra Swan | | | | | | | | | | | | | | | |
| Greater White-fronted Goose | | | | | | | | | | | | | | | |
| Snow Goose | | | | | | | | | | | | | | | |
| Ross' Goose | | | | | | | | | | | | | | | |
| Canada Goose | V | V | B | V | | | | | | | | | | | |
| Wood Duck | V | V | V | V | | | | | B | | | | | | |
| Gadwall | V | | B | V | | | | | | | | | | | |
| Eurasian Wigeon | V | | V | V | | | | | | | | | | | |
| American Wigeon | V | V | V | V | | | | | | | | | | | |
| Mallard | V | B | B | B | | | | | B | | | | | | |
| Blue-winged Teal | V | | V | V | | | | | | | | | | | |
| Cinnamon Teal | V | | B | B | | | | | | | | | | | |
| Northern Shoveler | V | | B | V | | | | | | | | | | | |
| Northern Pintail | V | | B | V | | | | | | | | | | | |
| Green-winged Teal | V | | V | V | | | | | | | | | | | |
| Ring-necked Duck | V | | B | | | | | | | | | | | | |
| Canvasback | V | | V | | | | | | | | | | | | |
| **Redhead** | V | | B | | | | | | | | | | | | |
| Greater Scaup | V | | V | | | | | | | | | | | | |
| Lesser Scaup | V | | V | | | | | | | | | | | | |
| Common Goldeneye | V | V | V | | | | | | | | | | | | |
| Bufflehead | V | V | V | | | | | | | | | | | | |

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Develo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Hooded Merganser | V | | V | V | | | | | | | | | | | |
| Common Merganser | V | B | | | | | | | | | | | | | |
| Ruddy Duck | V | | B | | | | | | | | | | | | |
| Osprey | V | V | | | | | | | B | B | | | | | |
| **White-tailed Kite** | | | | V | V | V | V | V | B | B | B | V | B | V | V |
| **Bald Eagle** | | V | V | V | | | | | V | | | | | | |
| **Northern Harrier** | | | B | V | B | | | | | | | V | | V | V |
| Sharp-shinned Hawk | | | | | V | V | V | V | V | V | V | V | V | | |
| Cooper's Hawk | | | V | V | V | V | V | V | B | B | B | V | V | | |
| Red-shouldered Hawk | | | | V | V | V | V | V | B | B | B | | B | | |
| **Swainson's Hawk** | | | | | V | | | V | B | B | B | | B | V | V |
| Red-tailed Hawk | | | V | V | V | | | V | B | B | B | V | B | V | V |
| Ferruginous Hawk | | | | | V | | | | | | | | | V | V |
| Rough-legged Hawk | | | | | V | | | | | | | | | V | V |
| **Golden Eagle** | | | | | V | | | | V | | | V | | | |
| American Kestrel | | | | | V | V | V | V | B | B | V | B | B | V | V |
| Merlin | | | | | V | | | | V | | | V | V | V | V |
| **Peregrine Falcon** | | | V | V | V | | | | | | | | | | |
| **Prairie Falcon** | | | | | V | | | | | | | V | | | |
| *Ring-necked Pheasant* | | | | | B | V | V | V | | | V | | | B | B |
| *Wild Turkey* | | | | | | | | | B | | | B | | | |
| California Quail | | | | | V | B | B | B | B | B | B | B | B | | |
| Virginia Rail | | | B | | | | | | | | | | | | |

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Sora | | | B | | | | | | | | | | | | |
| Common Moorhen | | | B | | | | | | | | | | | | |
| American Coot | V | | B | V | | | | | | | | | | | |
| **Greater Sandhill Crane** | | | V | V | | | | | | | | | | V | V |
| Lesser Sandhill Crane | | | V | V | | | | | | | | | | V | V |
| Black-bellied Plover | V | | | V | | | | | | | | | | | |
| Semipalmated Plover | V | | | V | | | | | | | | | | | |
| Killdeer | V | B | | B | | | | | | | | | | V | V |
| Mountain Plover | | | | | V | | | | | | | | | V | V |
| Black-necked Stilt | V | | | V | | | | | | | | | | | |
| American Avocet | V | | | V | | | | | | | | | | | |
| Greater Yellowlegs | V | | | V | | | | | | | | | | | |
| Lesser Yellowlegs | V | | | V | | | | | | | | | | | |
| Solitary Sandpiper | V | | | V | | | | | | | | | | | |
| Spotted Sandpiper | V | V | | V | | | | | | | | | | | |
| Whimbrel | | | | V | V | | | | | | | | | | V |
| Long-billed Curlew | | | | V | V | | | | | | | | | | V |
| Western Sandpiper | V | | | V | | | | | | | | | | | |
| Least Sandpiper | V | | | V | | | | | | | | | | | |
| Pectoral Sandpiper | | | | V | | | | | | | | | | | |
| Dunlin | | | | V | | | | | | | | | | | |
| Short-billed Dowitcher | V | | | V | | | | | | | | | | | |
| Long-billed Dowitcher | V | | | V | | | | | | | | | | | |

| Species Name | Aquatic Habitats: Lacustrine (Unvegetated Ponds) | Aquatic Habitats: Riverine | Aquatic Habitats: Freshwater Emergent Wetland | Aquatic Habitats: Seasonal Wetland/Vernal Pool | Annual Grassland | Shrubland: Tamarisk | Shrubland: Blackberry Scrub | Riparian Habitats: Great Valley Riparian Scrub | Riparian Habitats: Great Valley Mixed Riparian Forest | Riparian Habitats: Great Valley Cottonwood Riparian Forest | Riparian Habitats: Mixed Willow species | Woodlands: Blue Oak Savanna | Woodlands: Valley Oak Woodland | Devel[...]: Irrigated Row and Field Crops | Devel[...]: Irrigated Hay (Alfalfa) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wilson's Snipe | V | | V | V | | | | | | | | | | | |
| Red-necked Phalarope | V | | | V | | | | | | | | | | | |
| Wilson's Phalarope | V | | | V | | | | | | | | | | | |
| Bonaparte's Gull | V | | | | | | | | | | | | | | |
| Ring-billed Gull | V | | | V | | | | | | | | | | V | V |
| California Gull | V | V | | V | | | | | | | | | | V | V |
| Herring Gull | V | V | | V | | | | | | | | | | V | V |
| Caspian Tern | V | V | | | | | | | | | | | | | |
| Forster's Tern | V | | V | V | | | | | | | | | | | |
| **Black Tern** | V | | B | B | | | | | | | | | | | |
| *Rock Dove* | | | | | V | | | | | | | | | V | V |
| Mourning Dove | | | | | V | B | B | B | B | B | B | B | B | V | V |
| **Yellow-billed Cuckoo** | | | | | | | V | V | B | B | B | | V | | |
| Greater Roadrunner | | | | | V | | | | | | | B | | | |
| Barn Owl | | | V | V | V | V | V | V | B | B | B | B | B | V | V |
| Western Screech-Owl | | | | | | V | V | V | B | B | B | B | B | | |
| Great Horned Owl | | | V | V | V | | | V | B | B | V | B | B | V | V |
| **Burrowing Owl** | | | | | B | | | | | | | | | V | V |
| **Long-eared Owl** | | | | | V | | | | B | | | | | | |
| **Short-eared Owl** | | | V | | V | | | | | | | | | | V |
| Lesser Nighthawk | V | B | V | V | B | | | | | | | | | | |
| **Vaux's Swift** | V | | V | | | | | | V | | | | | | |
| White-throated Swift | V | | V | | | | | | | | | | | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Develo… | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| Black-chinned Hummingbird | | | | | | V | V | B | B | B | B | | V | | |
| Anna's Hummingbird | | | | | | V | V | B | B | B | B | B | B | | |
| Rufous Hummingbird | | | | | | V | V | V | V | V | V | | V | | |
| Belted Kingfisher | | B | | | | | | | B | B | | | | | |
| Lewis's Woodpecker | | | | | | | | | V | V | | V | V | | |
| Acorn Woodpecker | | | | | | | | | B | V | | B | B | | |
| Red-breasted Sapsucker | | | | | | | | | V | V | V | V | | | |
| Nuttall's Woodpecker | | | | | | | | | B | B | B | B | B | | |
| Downy Woodpecker | | | | | | | | | B | B | B | V | V | | |
| Northern Flicker | | | | | | V | V | V | B | B | B | B | B | | |
| **Olive-sided Flycatcher** | | | | | | | | V | V | V | V | V | V | | |
| Western Wood-Pewee | | | | | | | V | V | V | V | V | V | V | | |
| **Willow Flycatcher** | | | | | | V | V | V | V | V | V | | | | |
| Hammond's Flycatcher | | | | | | | V | V | V | V | V | V | V | | |
| Dusky Flycatcher | | | | | | | V | V | V | V | V | V | V | | |
| Pacific-slope Flycatcher | | | | | | V | V | V | B | B | V | V | V | | |
| Black Phoebe | V | B | B | V | V | V | V | B | B | B | B | B | B | | |
| Say's Phoebe | | | | | V | V | | | | | | V | | | V |
| Ash-throated Flycatcher | | | | | V | | V | V | B | B | B | B | B | | |
| Western Kingbird | | | V | V | B | V | V | B | B | B | B | B | B | B | B |
| Northern Shrike | | | | | V | | | | | | | | | V | V |
| **Loggerhead Shrike** | | | V | V | B | V | V | B | | | B | B | | B | B |
| Cassin's Vireo | | | | | | | V | V | V | V | V | V | V | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| Hutton's Vireo | | | | | | | V | V | B | B | V | B | | | |
| Warbling Vireo | | | | | | | V | V | B | B | V | V | V | | |
| Western Scrub-Jay | | | | | | V | V | V | B | B | B | B | B | | |
| Yellow-billed Magpie | | | | | V | V | V | V | B | B | V | B | B | V | V |
| American Crow | | V | | | V | V | V | V | B | B | V | V | B | V | V |
| Common Raven | | | | | V | V | | V | V | V | V | V | V | V | V |
| Horned Lark | | | | | B | | | | | | | | | V | V |
| Tree Swallow | V | V | V | V | V | V | V | V | B | B | V | V | B | V | V |
| Violet-green Swallow | V | V | V | V | V | V | V | V | V | V | V | V | V | V | V |
| Northern Rough-winged Swallow | V | B | V | V | V | | | | B | B | | V | V | V | V |
| **Bank Swallow** | V | B | V | V | V | | | V | | | | | | | |
| Cliff Swallow | V | B | V | V | V | | | | V | | | V | V | V | V |
| Barn Swallow | V | B | V | V | V | | V | V | V | V | V | V | V | V | V |
| Oak Titmouse | | | | | | | | | B | V | | B | B | | |
| Bushtit | | | | | | V | V | B | B | B | B | B | B | | |
| Red-breasted Nuthatch | | | | | | | | | V | V | | V | V | | |
| White-breasted Nuthatch | | | | | | | | | B | B | V | B | B | | |
| Brown Creeper | | | | | | | | | V | | | V | V | | |
| Rock Wren | | | | | | | | | V | | | V | | | |
| Bewick's Wren | | | | | | B | B | B | B | B | B | B | B | | |
| House Wren | | | | | | B | B | B | B | B | B | V | B | | |
| Winter Wren | | V | | | | | V | V | V | V | | | | | |
| Marsh Wren | | | B | | | | V | V | | | V | | | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| Golden-crowned Kinglet | | | | | | | | | V | V | | V | V | | |
| Ruby-crowned Kinglet | | | | | | V | V | V | V | V | V | V | V | | |
| Blue-gray Gnatcatcher | | | | | | V | V | V | V | V | V | B | | | |
| Western Bluebird | | | | | V | V | V | V | B | B | V | B | B | | |
| Mountain Bluebird | | | | | V | | | | | | | | | | |
| Swainson's Thrush | | | | | | | V | V | V | V | V | | V | | |
| Hermit Thrush | | | | | | | V | V | V | V | V | V | V | | |
| American Robin | | V | | | V | V | V | V | B | B | B | B | B | | |
| Varied Thrush | | | | | | | V | V | V | V | V | | V | | |
| Wrentit | | | | | | | B | B | B | B | V | B | | | |
| Northern Mockingbird | | | | | | V | V | V | B | B | B | B | B | | |
| California Thrasher | | | | | | | V | V | V | V | V | B | | | |
| *European Starling* | | | | | V | V | V | V | B | B | B | B | B | V | V |
| American Pipit | | | | | V | | | | | | | V | | V | V |
| Cedar Waxwing | | | | | | | | | V | V | | V | V | | |
| Phainopepla | | | | | | | | | V | V | | B | V | | |
| Orange-crowned Warbler | | V | | | | V | V | V | B | B | B | B | V | | |
| Nashville Warbler | | | | | | | V | V | V | V | V | V | V | | |
| **Yellow Warbler** | | | | | | | V | V | B | B | B | V | V | | |
| Yellow-rumped Warbler | | V | | | | V | V | V | V | V | V | V | V | | |
| Black-throated Gray Warbler | | | | | | | V | V | V | V | V | V | V | | |
| Townsend's Warbler | | | | | | | V | V | V | V | V | V | V | | |
| Hermit Warbler | | | | | | | | | V | V | V | V | V | | |

| Species Name | Aquatic Habitats | | | | Annual Grassland | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| MacGillivray's Warbler | | | | | | | V | V | V | V | V | V | V | | |
| Common Yellowthroat | | | B | B | | V | V | B | B | B | B | V | V | | |
| Wilson's Warbler | | | | | | | V | V | B | B | V | V | V | | |
| **Yellow-breasted Chat** | | | | | | | B | B | B | B | B | V | | | |
| Western Tanager | | | | | | | V | V | V | V | V | V | V | | |
| Spotted Towhee | | | | | | V | B | B | B | B | B | B | B | | |
| California Towhee | | | | | | V | B | B | B | B | B | B | B | | |
| Rufous-crowned Sparrow | | | | | V | | | | | | | B | | | |
| Chipping Sparrow | | | | | | | | V | V | V | V | V | V | | |
| Vesper Sparrow | | | | | V | | | | | | | | | | |
| Lark Sparrow | | | | | V | V | V | V | V | V | V | B | V | V | V |
| Savannah Sparrow | | | | | B | | | | | | | V | V | V | V |
| **Grasshopper Sparrow** | | | | | B | | | | | | | | | | |
| Fox Sparrow | | | | | | | V | V | V | V | V | V | V | | |
| Song Sparrow | | | B | V | | V | B | B | B | B | B | | B | | V |
| Lincoln's Sparrow | | | V | | | | V | V | V | V | V | V | V | | V |
| White-throated Sparrow | | | | | | | V | V | V | V | V | V | V | | |
| Golden-crowned Sparrow | | | V | V | V | V | V | V | V | V | V | V | V | | |
| White-crowned Sparrow | | | V | V | V | V | V | V | V | V | V | V | V | V | V |
| Dark-eyed Junco | | | | | V | | V | V | V | V | V | V | V | | |
| McCown's Longspur | | | | | V | | | | | | | | | V | V |
| Lapland Longspur | | | | | V | | | | | | | | | V | V |
| Chestnut-collared Longspur | | | | | V | | | | | | | | | V | V |

| | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species Name** | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Black-headed Grosbeak | | | | | | | V | V | B | B | B | B | B | | |
| Blue Grosbeak | | | | | | V | B | B | V | V | B | | | | |
| Lazuli Bunting | | | | | | V | B | B | B | B | B | B | B | | |
| Red-winged Blackbird | | | B | B | V | V | B | B | V | V | B | | V | V | V |
| **Tricolored Blackbird** | | | B | B | V | | B | B | B | B | B | | V | V | V |
| Western Meadowlark | | | | | B | | | | V | | | B | V | V | V |
| Yellow-headed Blackbird | | | B | V | | | | | | | | | | | |
| Brewer's Blackbird | | | V | V | V | V | V | V | B | B | B | B | B | V | V |
| Great-tailed Grackle | V | V | B | V | V | | | | | | | | | V | V |
| Brown-headed Cowbird | | | | | V | V | B | B | B | B | B | B | B | | |
| Hooded Oriole | | | | | | | | | B | B | V | | | | |
| Bullock's Oriole | | | | | | | V | V | B | B | B | B | B | | |
| Purple Finch | | | | | | | V | V | V | V | V | V | V | | |
| House Finch | | | | | V | V | B | B | B | B | B | B | V | V | V |
| Pine Siskin | | | | | | | | | V | V | | V | V | | |
| Lesser Goldfinch | | | | | V | V | B | B | B | B | B | B | B | | |
| Lawrence's Goldfinch | | | | | V | | | | V | | | B | V | | |
| American Goldfinch | | | | | V | V | V | V | B | B | B | V | B | | |
| *House Sparrow* | | | | | | | | | | | | V | | | |
| **Mammals** | | | | | | | | | | | | | | | |
| *Virginia Opossum* | | B | | | | B | B | B | B | B | B | B | B | | |
| Vagrant Shrew | | | B | | | | | B | B | B | B | | | | |
| Ornate Shrew | | B | B | V | B | | V | B | B | B | B | | B | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| Broad-footed Mole | | | | | B | | B | B | B | B | B | B | B | B | B |
| Yuma Myotis | V | V | V | V | V | V | V | V | B | B | V | | V | V | V |
| California Myotis | V | V | V | V | V | V | V | V | B | B | V | | V | V | V |
| Western Pipistrelle | V | V | V | V | V | V | V | V | V | V | V | | V | V | V |
| Big Brown Bat | V | V | V | V | | V | V | V | V | V | V | | V | V | V |
| Hoary Bat | V | V | V | V | V | V | V | V | V | V | V | | V | V | V |
| **Townsend's Big-eared Bat** | | | V | V | | V | V | V | V | B | V | | V | | |
| **Pallid Bat** | V | V | V | V | | V | V | V | B | B | V | | B | | |
| Brazilian Free-tailed Bat | V | V | V | V | V | | V | V | V | V | V | | B | | |
| Brush Rabbit | | V | V | V | V | V | B | B | B | B | B | | B | | |
| Desert Cottontail | | V | | | | V | B | B | B | B | B | B | B | V | V |
| Black-tailed Jackrabbit | | | | | B | V | B | B | B | B | B | B | B | V | V |
| California Ground Squirrel | | | | | B | | | | | | | B | B | V | V |
| Western Gray Squirrel | | | | | | | | | B | | | B | B | | |
| Botta's Pocket Gopher | | | | | B | | B | B | B | B | B | B | B | B | B |
| Beaver | | B | B | | | | | | B | | | | | | |
| Western Harvest Mouse | | | | | B | | | B | B | | | | B | B | B |
| Brush Mouse | | | | | | | | | B | | | | B | | |
| Deer Mouse | | | | | B | V | B | B | B | B | B | B | B | V | V |
| Pinyon Mouse | | | | | | | B | B | B | B | B | | B | | |
| Dusky-footed Woodrat | | | | | | | B | B | B | B | B | B | B | | |
| California Vole | | | | | B | | | | B | | | | B | | |
| *Muskrat* | | B | B | V | | | | | B | | | | | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Devel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| *Black Rat* | | V | | | | V | B | B | B | B | B | | B | | |
| *Norway Rat* | | V | | | | V | B | | | | | | | | |
| *House Mouse* | | V | | | B | V | B | B | B | B | B | B | B | B | B |
| Coyote | | V | V | V | B | V | V | V | B | B | B | B | B | V | V |
| Gray Fox | | V | | | B | V | B | B | B | B | B | B | B | V | V |
| *Red Fox* | | V | V | V | B | V | V | B | B | B | B | | B | | V |
| **Ringtail** | | B | | | | | | | B | B | | B | | | |
| Raccoon | V | V | V | V | V | V | B | B | B | B | B | B | B | | |
| Long-tailed Weasel | | V | V | V | B | V | V | V | B | B | B | B | B | V | V |
| Mink | V | B | V | V | | | | | B | B | V | | | | |
| **American Badger** | | | | | B | | | | | | | B | B | | |
| Striped Skunk | | | | | V | V | B | B | B | B | | B | B | B | B |
| River Otter | V | B | | | | | | | B | | | | | | |
| Black Bear | | | | | | | V | V | V | V | | V | V | | |
| Bobcat | | V | | V | | V | V | V | B | B | V | B | V | | |
| Mountain Lion | | | | | V | | V | V | V | V | V | V | V | | |
| Mule Deer | | V | | | V | | V | V | B | V | V | B | B | V | V |

Italicized Names = Introduced Species
Boldfaced Names = Special-status Species
B = Breeding in Habitat
V = Non-Breeding Visitor in Habitat

**Table 2. Biology. Biodiversity Indices, Species Richness, for Each Landcover Type in the Colusa Basin Watershed.**

| Landcover Types | Total # of Breeders | Total # of Visitors | Total # of Species |
|---|---|---|---|
| **Aquatic Habitats** | | | |
| Lacustrine (Unvegetated Ponds) | 0 | 80 | 80 |
| Riverine | 20 | 44 | 64 |
| Freshwater Emergent Wetland | 38 | 57 | 95 |
| Seasonal Wetland/Vernal Pool | 12 | 84 | 96 |
| **Annual Grassland** | 34 | 74 | 108 |
| **Shrubland** | | | |
| Tamarisk | 5 | 79 | 84 |
| Blackberry Scrub | 31 | 96 | 127 |
| **Riparian Habitats** | | | |
| Great Valley Riparian Scrub | 57 | 81 | 138 |
| Great Valley Mixed Riparian Forest | 117 | 60 | 177 |
| Great Valley Cottonwood Riparian Forest | 104 | 52 | 156 |
| Mixed Willow species | 79 | 61 | 140 |
| **Woodlands** | | | |
| Blue Oak Savanna | 77 | 61 | 138 |
| Valley Oak Woodland | 83 | 66 | 149 |
| **Developed and Cultivated Habitats** | | | |
| Irrigated Row and Field Crops | 8 | 63 | 71 |
| Irrigated Hay (Alfalfa) | 8 | 70 | 78 |
| Rice | 1 | 179 | 180 |
| Pasture | 11 | 68 | 79 |
| Deciduous Orchard | 14 | 51 | 65 |
| Eucalyptus | 44 | 52 | 96 |
| Urban/Suburban | 30 | 47 | 77 |

### *Aquatic and Riparian Habitats*

**Riverine.** Riverine is not well represented in the Colusa Basin Watershed as the Sacramento River itself lies just outside of the watershed boundary. However, there are special-status species that are known to occur on the Sacramento River that may visit areas within the watershed boundary adjacent to the river. They include bald eagle, osprey and northwestern pond turtle. Other common wildlife species that frequent the Sacramento River include common merganser, wood duck, greater yellowlegs, spotted sandpiper, and belted kingfisher.

According to a report by California Department of Fish and Game (DFG 2003a) the conditions in the Colusa Basin Drain provide little habitat for fish although samples taken during their investigation revealed the presence of ten game and 17 non-game species. The Colusa Basin Drainage Canal is a major contributor of warm water into the Sacramento River, which has a detrimental affect on salmonids. The Colusa Basin Drain "attracts adult fish into an area where survival is unlikely and returns agricultural drain water of high temperature and poor quality into the Sacramento River" at Knights Landing (DFG 2003a).

Because fish were not identified as a resource of concern to the Colusa Basin stakeholders and to keep the costs associated with development of the watershed assessment for the Colusa Basin Watershed within the budget a decision was made to omit further discussion of them in the Biological Resources Section. A large body of information exists on the state of fisheries in the Central Valley.

**Valley Foothill Riparian.** Special-status wildlife species that are known to or that may occur in the valley foothill riparian woodlands in the Colusa Basin Watershed include Cooper's hawk, Swainson's hawk, long-eared owl, yellow-billed cuckoo, yellow warbler, western pond turtle, and valley elderberry longhorn beetle. Common wildlife species found in this habitat include brush rabbit, dusky-footed woodrat, black rat, raccoon, Virginia opossum, gray fox, coyote, red-shouldered hawk, great horned owl, black-chinned hummingbird, western scrub-jay, Nuttall's woodpecker, downy woodpecker, American crow, yellow-billed magpie, bushtit, oak titmouse, white-breasted nuthatch, black-headed grosbeak, blue grosbeak, lazuli bunting, Bullock's oriole, house finch, and American goldfinch.

### *Emergent Wetland Habitats in the Central Portion of the Colusa Basin*

**Freshwater Emergent Marsh (Including Ponds).** Special-status wildlife species that are known to or that may occur in freshwater emergent wetlands in the Colusa Basin Watershed include giant garter snake, northwestern pond turtle, least bittern, northern harrier, short-eared owl, black tern, and tricolored blackbird. Other common wildlife species found in these marshes include aquatic garter snake, western pond turtle, bullfrog, California newt, great blue heron, great egret, snowy egret, black-crowned night-heron, pied-billed grebe, wood duck, cinnamon teal, Virginia rail, common moorhen, American coot, marsh wren, song sparrow, and red-winged blackbird. Many mammals such as river otter, raccoon, and deer will visit these ponds as an important source of drinking water or prey.

**Lacustrine.** The lacustrine areas in the Colusa Basin Watershed are very limited in size and number; however, several sewage ponds and other artificial, unvegetated ponds in the watershed attract species typically associated with much larger lakes. Of these are special-status species such as bald eagle, osprey, American white pelican, and northwestern pond turtle, along with common birds including eared grebe, pied-billed grebe, common goldeneye, bufflehead, ruddy duck, and American coot.

**Seasonal Wetland.** Special-status wildlife species that are known to or that may occur in seasonal wetlands in the Colusa Basin Watershed include giant garter snake, northwestern pond turtle, northern harrier, short-eared owl, black tern, and tricolored blackbird. Other common wildlife species found in these wetlands include aquatic garter snake, western pond turtle, western toad, California newt, great blue heron, great egret, Canada goose, greater yellowlegs, least sandpiper, killdeer, and Brewer's and red-winged blackbirds. Many mammals such as skunks, coyote, and deer will visit these ponds as an important source of drinking water.

### *Developed and Cultivated Habitats Located in the Central Portion of the Colusa Basin*

**Rice.** Rice fields dominate much of the eastern Colusa Basin and provide important habitat for much of the wildlife in the region (Sterling and Buttner 2005). Most of the waterfowl, egrets, herons, white-faced ibis, American avocets, black-necked stilts, raptors, blackbirds, and migrant shorebirds rely on rice fields to provide food and habitat. In fact, 235 wildlife species have been documented inhabiting rice fields for breeding, foraging, and/or roosting (Sterling and Buttner 2005).

**Pasture.** Special-status wildlife species that are known to or that may occur in pastures in the Colusa Basin Watershed include white-faced ibis, northern harrier, Swainson's hawk, ferruginous hawk, burrowing owl, and tricolored blackbird. Other common wildlife species in pastures include mallard, killdeer, western kingbird, Say's phoebe, western meadowlark, red-winged blackbird, coyote, black-tailed jackrabbit, Botta's pocket gopher, and California vole.

**Irrigated Row and Field Crops.** Special-status wildlife species that are known to or that may occur in irrigated row and field crops in the Colusa Basin Watershed include white-faced ibis, northern harrier, Swainson's hawk, ferruginous hawk, mountain plover, and burrowing owl. Other common wildlife species in irrigated row and field crops include American kestrel, horned lark, American pipit, western meadowlark, red-winged blackbird, house finch, California meadow vole, house mouse, brown rat, and black-tailed jackrabbit.

**Irrigated Hay (Alfalfa).** Special-status wildlife species that are known to or that may occur in irrigated hay fields in the Colusa Basin Watershed include white-faced ibis, northern harrier, Swainson's hawk, ferruginous hawk and burrowing owl. Other common wildlife species in hay fields include mallard, western meadowlark, red-winged blackbird, Botta's pocket gopher, and California vole.

**Deciduous Orchard.** Special-status wildlife species that are known to or that may occur in deciduous orchards in the Colusa Basin Watershed include yellow-billed cuckoo and tricolored blackbird. The yellow-billed cuckoo has been documented nesting and foraging in English walnut orchards near extensive cottonwood gallery riparian woodlands along the Sacramento River adjacent to the watershed boundary. Other common wildlife species in orchards include western scrub-jay, yellow-billed magpie, American crow, American robin, western bluebird, house finch, black-tailed jackrabbit, and black rat.

**Eucalyptus.** Special-status wildlife species that are known to or that may occur in eucalyptus groves in the Colusa Basin Watershed include Swainson's hawk and long-eared owl. Other common wildlife species that are found in these groves include barn owl, red-tailed hawk, red-shouldered hawk, Cooper's hawk, Anna's hummingbird, western scrub-jay, yellow-billed magpie, American crow, yellow-rumped warbler, and white-crowned sparrow.

**Urban/Suburban.** Special-status wildlife species that are known to or that may occur in urban/suburban areas in the Colusa Basin Watershed include Cooper's hawk, white-tailed kite, and Swainson's hawk. Other common wildlife species in these developed areas include Nuttall's woodpecker, barn swallow, western scrub-jay, ruby-crowned kinglet, northern mockingbird, American robin, cedar waxwing, yellow-rumped warbler, white-crowned sparrow, dark-eyed junco, house finch, house mouse, brown rat, and roof rat.

### *Annual Grassland along the Western Foothills*

Special-status wildlife species that are known to or that may occur in annual grasslands in the Colusa Basin Watershed include western spadefoot toad, northern harrier, Swainson's hawk, ferruginous hawk, golden eagle, prairie falcon, merlin, short-eared owl, burrowing owl, grasshopper sparrow, tricolored blackbird, pallid bat, and badger.

Other common wildlife that inhabit grasslands in the Colusa Basin Watershed include raptors such as wintering Rough-legged hawk, and resident white-tailed kite, red-tailed hawk, American kestrel, and common barn-owl. Western kingbird, Say's phoebe and resident loggerhead shrike frequent fence posts, barbed wire, and electrical lines where they search for insect prey. Common birds that forage on the ground for insects, worms, and seeds include mourning dove, American crow, horned lark, American pipit, lark sparrow, savannah sparrow, western meadowlark, Brewer's blackbird, and brown-headed cowbird. Several species of swallows forage over the grasslands for flying insects. Representative reptiles and mammals of annual grasslands include gopher snake, garter snakes, racer, western fence lizard, side-blotched lizard, black-tailed jackrabbit, California ground squirrel, Botta's pocket gopher, western harvest mouse, California vole, and coyote.

Annual grasslands of the Colusa Basin Watershed provide important foraging habitat for golden eagle, red-tailed hawk, prairie falcon, merlin, American kestrel, common barn-owl, and wintering rough-legged and ferruginous hawks.

### *Northern Claypan Vernal Pool*

Several special-status wildlife species are associated exclusively or primarily with vernal pools within the Colusa Basin Watershed. These include vernal pool tadpole shrimp, vernal pool fairy shrimp, Conservancy fairy shrimp, California tiger salamander, and western spadefoot toad. A few species nest within or around the pools including horned lark and savanna sparrow, but most wildlife are associated with the pools during spring migration, especially shorebirds such as black-necked stilt, greater yellowlegs, killdeer, least and western sandpipers, long-billed dowitcher, dunlin and Wilson's snipe; herons such as green heron, great egret, great blue heron; and ducks such as American wigeon, green-winged teal, cinnamon teal, gadwall and mallards.

### *Woodlands along the Western Foothills*

**Valley Oak Woodland.** Special-status wildlife species that are known to or that may occur in valley oak woodlands in the Colusa Basin Watershed include pallid bat, badger, Swainson's hawk, northwestern pond turtle, and valley elderberry longhorn beetle. Many common wildlife species are found in these woodlands including Nuttall's woodpecker, yellow-billed magpie, oak titmouse, white-breasted nuthatch, and western bluebird.

**Blue Oak Woodland/Savanna.** Special-status wildlife species that are known to or that may occur in blue oak woodlands in the Colusa Basin Watershed include valley elderberry longhorn beetle, foothill yellow-legged frog, western pond turtle, golden eagle, pallid bat, and badger. Representative raptors found in blue oaks in the Colusa Basin Watershed area include red-tailed hawk, American kestrel, common barn-owl, great horned owl, and western screech-owl. Other common wildlife species found in blue oak woodlands include western fence lizard, gopher snake, California quail, mourning dove, greater roadrunner, acorn woodpecker, Nuttall's woodpecker, northern flicker, white-breasted nuthatch, ash-throated flycatcher, blue-gray gnatcatcher, orange-crowned warbler, Bullock's oriole, Hutton's vireo, western scrub-jay, oak titmouse, bushtit, Bewick's wren, western bluebird, lark sparrow, brown-headed cowbird, california towhee, house finch, lesser goldfinch, white-crowned sparrow, golden-crowned sparrow, California ground squirrel, coyote, gray fox, raccoon, striped skunk, and mule deer.

### *Shrublands along the Western Foothills*

Many species are primarily associated with the chamise chaparral and other shrublands in the Colusa Basin Watershed including reptiles such as western fence lizard, western rattlesnake; mammals such as desert cottontail, brush rabbit, California pocket mouse, Botta's pocket gopher, California ground squirrel, spotted skunk, mule deer, coyote, and bobcat; and birds such as greater roadrunner, wrentit, California thrasher, rufous-crowned sparrow, and sage sparrow (summer). Many of these species are resident and are rarely found outside of chaparral. Tule elk from the greatly expanding, introduced herds in the region probably visit the shrublands within the watershed. Other species that occur in chaparral in the watershed are also found in a variety of upland habitats including many mammals such as ringtail, northern raccoon, striped skunk, gray fox, bobcat, and puma [mountain lion] as well as birds such as mountain quail, California quail, Anna's hummingbird, western scrub-jay, Bewick's wren, hermit thrush (winter), orange-crowned warbler (summer), black-headed grosbeak (summer), lazuli bunting (summer), spotted towhee, California towhee, fox sparrow (winter), golden-crowned sparrow (winter), white-crowned sparrow (winter), dark-eyed junco (winter), house finch, Lawrence's Goldfinch (summer), and Lesser Goldfinch.

## Special-status Species (Plants and Wildlife)

**Special-status Species Criteria.** H. T. Harvey & Associates' plant and wildlife ecologists conducted an assessment of the potential for occurrence of special-status plant and animal species within the Colusa Basin Watershed. This assessment was based upon a review of CNDDB records for the Colusa Basin Watershed and adjacent quadrangles, review of federal and state threatened and endangered species lists, review of California Native Plant Society [CNPS] Lists 1A, 1B, 2 and 3, and ecologists' knowledge of species habitat requirements. Field reconnaissance and species-specific surveys were not conducted as such surveys were beyond our scope of work. An assessment of special-status fish species was also beyond our scope of work and is not included. The following criteria were used to determine which species should be included:

- Animal species listed, or proposed for listing, as threatened or endangered under the Federal Endangered Species Act ([FESA] 50 CFR 17.11 [listed animals], and various notices in the Federal Register [proposed species])
- Plant and animal species that are candidates for possible future listing as threatened or endangered under the FESA (61 FR 40: 7596-7613, February 28, 1996)

- Plant species included on CNPS List 1A, 1B or 2
- Plant and animal species listed, or proposed for listing, by the State of California as threatened or endangered under California Endangered Species Act ([CESA] 14 CCR 670.5);
- Plant and animal species that meet the definitions of rare and endangered under California Environmental Quality Act ([CEQA] Guidelines, Section 15380);
- Plant and animal species of special concern to DFG (in preparation [birds], Williams 1986 [mammals], and Jennings and Hayes 1994 [amphibians and reptiles])
- Animal species fully protected in California (California Fish and Game Code, Section 3511 [birds], Section 4700 [mammals], Section 5050 [reptiles and amphibians], and Section 5515 [fish])
- Animal species included in DFG's list of special animals and monitored by the CNDDB **California Natural Diversity Database. Figure 7-Biology** and **Figure 8-Biology** show the locations of special-status animal records and **Figures 4-Biology** and **5-Biology** show the locations of special-status plant records within the CNDDB in the Colusa Basin Watershed.

### *Special-status Wildlife Species*

The special-status wildlife species known to occur or that could potentially occur in the Colusa Basin Watershed are summarized in **Table 3-Biology**. These summary species accounts provide information on their legal status, habitat requirements, and occurrence and abundance status within the watershed. The occurrences of documented records from the CNDDB are illustrated in **Figures 7-Biology** and **8-Biology**. Special-status wildlife species distribution by landcover type is provided in **Table 4-Biology**.

**Special-status Wildlife and Associated Watershed Management Issues.** The following section provides a general overview of the relationship between the emerging stakeholders watershed management concerns (summarized in introduction) and special-status wildlife. Several watershed management issues are at the forefront of concern for the Colusa Basin Watershed stakeholders. These can be divided broadly as they relate to 1) livestock production, 2) agricultural production, and 3) biotic resource management. The primary concern for livestock production is the degradation or loss of rangeland due to invasive weeds, erosion, tree removal in oak woodland habitat, and development. Concerns for agricultural production include water quality, quantity and conveyance, soil erosion, flood control, and loss of land through development. Overlying these concerns are issues of maintaining both economic viability and wildlife populations, especially those of waterfowl that bring economic benefits to the watershed through hunting and tourism, and those of special-status species that are managed by state and federal regulatory and land management agencies.

**Table 3. Biology. Special-Status Wildlife Species, Their Status, and Potential Occurrence in the Colusa B**

| NAME | *STATUS | HABITAT | POTENTIAL FOR OCCURR |
|---|---|---|---|
| **Federal or State Endangered Species** | | | |
| Vernal pool tadpole shrimp<br>*Lepidurus packardi* | FE | Grass or mud-bottomed swales in grasslands on old alluvial soils underlain by hardpan. | **Moderate.** Within species' range; suita in the lower watershed. |
| Yellow-billed Cuckoo<br>*Coccyzus americanus* (nesting) | SE | Large stands of gallery riparian forest. | **Present.** No optimal habitat exists in th the species' population center in the Ce to the watershed, so it may potentially b riparian habitat. |
| Conservancy fairy shrimp<br>*Branchinecta conservatio* | FE | Seasonally astatic pools<br><br>Found in northern two-thirds of Central Valley at a few disjunct areas of vernal pools within grassland complexes | **Present.** Known from the Sacramento Refuge – one of the few locations know |
| Willow Flycatcher<br>*Empidonax trailii* (nesting) | SE | Riparian woodland and wet meadow systems. | **Present.** Does not nest in watershed, a regular migrant; extirpated as a breeder outside of species' current breeding ran |
| American Peregrine Falcon<br>*Falco peregrinus anatum* (nesting) | SE, Fully protected | Nests on cliff faces; forages on wetland birds. | **Present.** No suitable nest structures in Occurs regularly in winter and migratio breeding visitor. |
| Bald Eagle<br>*Haliaeetus leucocephalus* (nesting and wintering) | SE, FPD, Fully protected | Rivers, reservoirs, lakes, riparian forests, rice and other agricultural fields, grasslands. | **Present.** Occurs as a non-breeding visi nest within the watershed. |
| **Federal or State Threatened Species** | | | |
| Vernal pool fairy shrimp<br>*Branchinecta lynchi* | FT | Grassed or mud-bottomed swales, earth slump or basalt-flow depression pools in grasslands. | **Present.** Within species' range; suitabl the lower watershed. |
| Valley elderberry longhorn beetle<br>*Desmocerus californicus dimorphus* | FT | Associated with elderberry trees, *Sambucus* spp., during entire lifecycle. | **High.** Within species' range; suitable h lower watershed. |

**Table 3. Biology. Special-Status Wildlife Species, Their Status, and Potential Occurrence in the Colusa B**

| NAME | *STATUS | HABITAT | POTENTIAL FOR OCCURRE |
|---|---|---|---|
| California tiger salamander *Ambystoma californiense* | FT, CSC | Vernal pools, stock ponds and grasslands. | **Present.** A few records in the northern Critical habitat was designated in the D Yolo County in the southern section of Watershed. |
| California red-legged frog *Rana aurora draytonii* | FT, CSC | Springs, stock ponds, freshwater wetlands. | **Low.** Known to have occurred in the C historically, but may be extirpated from |
| Giant garter snake *Thamnophis gigas* | ST, FT | Freshwater marshes and low gradient streams. Also found in drainage canals and irrigation ditches. | **Present.** Within species' range; potenti watershed. |
| Swainson's Hawk *Buteo swainsoni* (nesting) | ST | Riparian woodland, grasslands; some agricultural crops (especially alfalfa, tomato, hay), urban trees near foraging habitats. | **Present.** Within species' breeding rang Valley; suitable nesting and foraging ha watershed. |
| Greater Sandhill Crane *Grus canadensis tabida* (wintering) | ST, Fully protected | Agricultural fields in winter: corn, sorghum, rice. | **Present.** Within species' wintering ran Valley. |
| California Black Rail *Laterallus jamaicensis coturniculus* | ST, FSC, Fully protected | Freshwater emergent marshes. | **Low.** Outside of species' known breedi nearby on the eastern edge of the Sacran |
| Bank Swallow *Paria riparia* (nesting) | ST | Vertical, exposed banks along rivers and creeks. | **Present.** Within species' breeding rang habitat probably occurs in the watershed |
| **Federal or State Proposed Endangered or Threatened Species** | | | |
| Mountain Plover *Charadrius montanus* (wintering) | FPT, CSSC | Annual grasslands, bare agricultural fields. | **Present.** Occasional wintering flocks o the watershed. |
| **Federal/California Species of Special Concern** | | | |
| Western spadefoot toad *Spea hammondii* | CSSC | Vernal pools and seasonal wetlands in grasslands. | **Present.** Known occurrences near Wils north Dunnigan Hills in the southern po Basin Watershed. |
| Western pond turtle *Clemmys marmorata* | CSSC | Permanent or nearly permanent water in a variety of habitats. | **Present.** Within species' range; suitabl watershed. |
| San Joaquin coachwhip *Masticophis flagellum ruddocki* | FSC | Shrublands and grasslands. | **Present.** An isolated population occurs Arbuckle, and this species could occur i grasslands of Dunnigan Hills. |

**Table 3. Biology. Special-Status Wildlife Species, Their Status, and Potential Occurrence in the Colusa B**

| NAME | *STATUS | HABITAT | POTENTIAL FOR OCCURR |
|---|---|---|---|
| Tule White-fronted Goose<br>*Anser albifrons elgasi* | CSSC | Freshwater emergent marshes, rice and sometimes other agricultural fields | **Present.** A small wintering population<br>the federal wildlife refuges within the C |
| American White Pelican<br>*Pelecanus erythrorhynchus* (nesting) | CSSC | Nests on islands in lakes and reservoirs. | **Present.** Only as a non-breeding visito<br>Central Valley or within the Colusa Bas |
| Western Least Bittern<br>*Ixobrychus ex ilis hesperis* (nesting) | FSC/CSSC | Freshwater emergent marshes. | **Present.** Uncommon in the wildlife ref<br>summer, and a rare winter resident. |
| Golden Eagle<br>*Aquila chrysaetos* (nesting and wintering) | CSSC<br>DFG: Fully protected | Nests on cliff faces and large trees. | **Moderate during breeding season.** Su<br>foraging habitat occurs in the watershed<br>nesting in the foothills outside of the wa<br><br>**Present during non-breeding season.**<br>grasslands and agricultural fields in the |
| Black Tern<br>*Chlidonias niger* (nesting colony) | FSC/CSSC | Large freshwater emergent marshes and rice fields. | **Present.** Suitable breeding habitat occu |
| Northern Harrier<br>*Circus cyaneus* (nesting) | CSSC | Annual grasslands, agricultural landscapes, freshwater emergent marshes. | **Present.** Within species' breeding rang<br>habitat occurs within the watershed. |
| Merlin<br>*Falco columbarius* (wintering) | CSSC | Oak savanna, annual grasslands, agricultural landscapes, urban development near agriculture or grasslands. | **Present.** A small population winters ar<br>watershed. |
| Prairie Falcon<br>*Falco mexicanus* (nesting) | CSSC | Nests on cliff faces. | **Present.** No suitable nesting structures<br>but regularly occurs as a non-breeding v<br>agricultural fields in the lower watershe |
| Lesser Sandhill Crane<br>*Grus canadensis canadensis* | CSSC | Winters in grain fields and seasonal wetlands. | **Present.** Small population winters with<br>Watershed, but larger population migrat<br>Basin Watershed during fall and spring. |
| Long-billed Curlew<br>*Numenius americanus* | FSC | Grasslands, wetlands, row crops, grain fields, and rice. | **Present.** Does not breed in watershed,<br>resident in the watershed during the non<br>July to May. |

**Table 3. Biology. Special-Status Wildlife Species, Their Status, and Potential Occurrence in the Colusa B**

| NAME | *STATUS | HABITAT | POTENTIAL FOR OCCURR |
|---|---|---|---|
| Short-eared Owl<br>*Asio flammeus* (nesting) | CSSC | Fallow fields and grasslands. | **Present.** Rare and local breeder, but m<br>visitor on the Sacramento Valley floor;<br>habitat may occur in the watershed. |
| Long-eared Owl<br>*Asio otus* (nesting) | CSSC | Dense riparian forests near freshwater marshes or fallow fields and grasslands. | **Low.** Very rare breeder, but more sligh<br>winter visitor on the Sacramento Valley<br>riparian breeding habitat occurs in isola |
| Burrowing Owl<br>*Athene cunicularia hypugea* (burrow sites) | FSC/CSSC | Oak savanna, annual grasslands, agricultural landscapes. | **Present.** Increasingly rare breeder in th<br>Valley; suitable habitat occurs in the wa |
| Vaux's Swift<br>Chaetura vauxi | CSSC | Breeds in hollow snags and artificial chimneys (rarely) in coniferous forests and rarely in adjacent urban areas. Migrates throughout the state over all habitats. | **Present.** Only as a spring and fall migr<br>Central Valley or within the Colusa Bas |
| Olive-sided Flycatcher<br>*Contopus cooperi* | CSSC | Breeds in coniferous forests, but can occur in migration throughout the state in a variety of habitats. | **Present.** Only as a rare spring and fall<br>in the Central Valley or within the Colu |
| Loggerhead Shrike<br>*Lanius ludovicianus* | FSC/CSSC | Oak savanna, annual grasslands, agricultural landscapes. | **Present.** Breeding pairs occur in the w |
| Purple Martin<br>*Progne subis* (nesting) | CSSC | Gallery riparian forest, large snags in coniferous forest. | **Low.** Presumed extirpated from the Sa<br>except for the metropolitan Sacramento |
| Yellow Warbler<br>*Dendroica petechia brewsteri* (nesting) | CSSC | Dense riparian vegetation. | **Moderate.** Rare breeder on the Sacram<br>suitable riparian breeding habitat occurs |
| Yellow-breasted Chat<br>*Icteria virens* (nesting) | CSSC | Dense riparian vegetation. | **Present.** A few breeding season record<br>watershed; rare breeder on the Sacrame<br>suitable riparian breeding habitat occurs |
| Grasshopper Sparrow<br>*Ammodramus savannarum* | CSSC | Annual and native perennial grasslands. | **Present.** A few recent breeding and wi<br>fallow fields and annual grasslands in th<br>areas west of Highway 5 in the watersh |
| Yellow-headed Blackbird<br>*Xanthocephalus xanthocephalus* | CSSC | Breeds in freshwater marshes, but will also forage and winter in agricultural grain fields and grasslands. | **Present.** A few breeding colonies occu<br>Basin Watershed, and smaller numbers<br>flocks with large numbers of other blac |

**Table 3. Biology. Special-Status Wildlife Species, Their Status, and Potential Occurrence in the Colusa B**

| NAME | *STATUS | HABITAT | POTENTIAL FOR OCCURR |
|---|---|---|---|
| Tricolored Blackbird<br>*Agelaius tricolor* (nesting colony) | FSC/CSSC | Blackberry brambles, riparian thickets, freshwater emergent wetland, thistle, agriculture, annual grassland. | **Present.** Within species' documented b<br>suitable foraging and nesting habitat oc |
| Pallid bat<br>*Antrozous pallidus* | CSC | Roosts in rock crevices, caves, mine shafts, under bridges, in buildings and tree hollows. Forages in open lowland areas. | **Moderate.** Within species' range; suita<br>the watershed. |
| **State Protected Species** | | | |
| White-tailed Kite<br>*Elanus leucurus* (nesting) | Fully protected | Oak savanna, annual grasslands, agricultural landscapes, urban development near agriculture or grasslands. | **Present.** Uncommon breeder and year-<br>watershed. |
| Ringtail<br>*Bassiriscus astutus* | Fully protected | Oak savanna, oak woodland, chaparral, riparian woodland. | **Low.** Locally-distributed in northern C<br>species' range, but known to be extirpa<br>the Sacramento Valley floor; suitable ha<br>watershed. |

**Key to Special-status Species**

FE=Federally Endangered
FT=Federally Threatened
SE=State Endangered
SR=State Rare
ST=State Threatened
CSSC=California Species of Special Concern
FSC=Federal Species of Special Concern

**Table 4. Biology. Special-status Wildlife Species in Each WHR Landcover Type in the Colusa Basin Wat**

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Develo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| **Invertebrates** | | | | | | | | | | | | | | | |
| Vernal Pool Tadpole Shrimp | | | | B | | | | | | | | | | | |
| Conservancy Fairy Shrimp | | | | B | | | | | | | | | | | |
| Vernal Pool Fairy Shrimp | | | | B | | | | | | | | | | | |
| Valley Longhorn Elderberry Beetle (where ever elderberry shrubs occur) | | | | | | B | B | B | B | B | B | | B | | |
| **Amphibians** | | | | | | | | | | | | | | | |
| California Tiger Salamander | | | | B | V | | | | | | | | | | |
| Western Spadefoot Toad | | | | B | V | | | | | | | | | | |
| **Reptiles** | | | | | | | | | | | | | | | |
| Northwestern Pond Turtle | V | V | B | B | | | | B | B | B | B | | B | | |
| California Horned Lizard | | | | | | | | | | | | B | B | | |
| Giant Garter Snake | | | B | B | | | | | | | | | | | |
| **Birds** | | | | | | | | | | | | | | | |
| American White Pelican | V | | | | | | | | | | | | | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Develo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lacustrine (Unvegetated Ponds) | Riverine | Freshwater Emergent Wetland | Seasonal Wetland/Vernal Pool | Annual Grassland | Tamarisk | Blackberry Scrub | Great Valley Riparian Scrub | Great Valley Mixed Riparian Forest | Great Valley Cottonwood Riparian Forest | Mixed Willow species | Blue Oak Savanna | Valley Oak Woodland | Irrigated Row and Field Crops | Irrigated Hay (Alfalfa) |
| Redhead | V | | B | | | | | | | | | | | | |
| White-tailed Kite | | | | V | V | V | V | V | B | B | B | V | B | V | V |
| Bald Eagle | | V | V | V | | | | | V | | | | | | |
| Northern Harrier | | | B | V | B | | | | | | | V | | V | V |
| Swainson's Hawk | | | | | V | | | V | B | B | B | | B | V | V |
| Golden Eagle | | | | | V | | | | V | | | V | | | |
| Peregrine Falcon | | | V | V | V | | | | | | | | | | |
| Prairie Falcon | | | | | V | | | | | | | V | | | |
| Greater Sandhill Crane | | | V | V | | | | | | | | | | V | V |
| Mountain Plover | | | | | V | | | | | | | | | V | V |
| Black Tern | V | | B | B | | | | | | | | | | | |
| Yellow-billed Cuckoo | | | | | | | V | V | B | B | B | | V | | |
| Burrowing Owl | | | | | B | | | | | | | | | V | V |
| Long-eared Owl | | | | | V | | | | B | | | | | | |
| Short-eared Owl | | | V | | V | | | | | | | | | | V |
| Vaux's Swift | V | | V | | | | | | V | | | | | | |

| Species Name | Aquatic Habitats | | | | | Shrubland | | Riparian Habitats | | | | Woodlands | | Develo | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Lacustrine (Unvegetated Ponds)** | **Riverine** | **Freshwater Emergent Wetland** | **Seasonal Wetland/Vernal Pool** | **Annual Grassland** | **Tamarisk** | **Blackberry Scrub** | **Great Valley Riparian Scrub** | **Great Valley Mixed Riparian Forest** | **Great Valley Cottonwood Riparian Forest** | **Mixed Willow species** | **Blue Oak Savanna** | **Valley Oak Woodland** | **Irrigated Row and Field Crops** | **Irrigated Hay (Alfalfa)** |
| Olive-sided Flycatcher | | | | | | | | V | V | V | V | V | V | | |
| Willow Flycatcher | | | | | | V | V | V | V | V | V | | | | |
| Loggerhead Shrike | | | V | V | B | V | V | B | | | B | B | | B | B |
| Bank Swallow | V | B | V | V | V | | | V | | | | | | | |
| Yellow Warbler | | | | | | | V | V | B | B | B | V | V | | |
| Yellow-breasted Chat | | | | | | | B | B | B | B | B | V | | | |
| Grasshopper Sparrow | | | | | B | | | | | | | | | | |
| Tricolored Blackbird | | | B | B | V | | B | B | B | B | B | | V | V | V |
| **Mammals** | | | | | | | | | | | | | | | |
| Townsend's Big-eared Bat | | | V | V | | V | V | V | V | B | V | | V | | |
| Pallid Bat | V | V | V | V | | V | V | V | B | B | V | | B | | |
| Ringtail | | B | | | | | | | B | B | | B | | | |
| American Badger | | | | | B | | | | | | | B | B | | |

B = Breeding in Habitat
V = Non-Breeding Visitor in Habitat

In addition, applications of pesticides in these agricultural systems pose concerns for potential negative effects on wildlife and on water quality, and on the ability of managers to meet water quality standards. Fortunately, there are many alternative techniques to pesticides being implemented or tested for invasive weed management on various scales and applications. Among these are late spring burning, persistent flooding, intensive sheep or goat grazing, mechanical removal and introduction of exotic herbivorous insects. Although these techniques will ultimately benefit special-status and other wildlife species by improving the quality of grassland, riparian, and wetland habitats, they often lead to temporary loss of vegetative cover and temporary disturbance to these species if they are present on-site during weed removal and/or herbicide spraying. Therefore, these species will vacate the affected area until native vegetation regenerates to provide habitat values of cover and food. The time for species to colonize will vary considerably based upon their habitat requirements. For yellow-billed cuckoos, yellow-breasted chats and yellow warblers that require riparian woodland, this time lag can depend upon the proximity of existing habitat occupied by these species, the growth rates of woody plants (soil depth and quality, water table depth etc), and the existing native plant cover and their condition/structure within the affected weed management area. For grassland species such as Golden eagle, prairie falcon, long-billed curlew and burrowing owl, the availability of food (insects for some, rodents for others) will play a larger role in maintaining their occupancy of weed management areas.

Management of water conveyance structures such as irrigation canals can impact a few wetland species such as the giant garter snake, western pond turtle, least bittern, California black rail, burrowing owl, and yellow-headed and tricolored blackbirds. Regular maintenance activities such as dredging, vegetation removal, ground squirrel control (resulting in eventual loss of burrows for burrowing owls), and grading of levees can result in the temporary loss of habitat and temporary disturbance to these species if they are present on-site during these activities. With the exception of weed control, such activities generally do not result in the increased quality of habitat for affected species and, therefore, are not ultimately beneficial.

Geomorphic-Bioengineering design approaches to erosion control along canals, levees, and tributary streams not only help stabilize stream banks to reduce soil erosion, they also provide and enhance riparian habitat. A geomorphic-bioengineering design approach can create more sustainable and environmentally beneficial bank stabilization structures and treatments than the traditional engineering design approach. First, by taking reach-scale geomorphic processes and factors into account, a geomorphic-bioengineered design is less likely to cause increased bank erosion at a downstream site. A geomorphic-bioengineered design also incorporates native vegetation to the extent feasible and seeks to create not just hard surfaces but habitat along the water's edge.

Urban development of rangeland and agricultural lands will lead to loss of habitat for all species, but may ultimately increase nesting habitat for the Swainson's hawk and white-tailed kite, provided that mature trees develop within the urban area and that these are in fairly close proximity to suitable foraging habitat during the breeding season which is primarily alfalfa fields and to a-lesser-extent, wet pastures and low growing row crops.

An important aspect of land management within the Colusa Basin Watershed is the presence of wildlife refuges that are heavily managed for wildlife and the large acreage of rice fields. The refuges support many wetland-dependant species during the summer months, but are also vital to the huge wintering waterfowl population. Rice fields outside of the refuge system provide substantial habitat values to waterfowl, gulls, cranes, shorebirds, and other wetland species (Sterling and Buttner 2005). Therefore, management of water, upland edges (hedgerows, etc), and pesticides in rice fields can greatly influence these habitat values. Alternative methods to traditional rice farming have been implemented to great success for wildlife, pesticide reduction, and water quality enhancement in a few organic rice farms and the Vic Fazio State Wildlife Area within the Sacramento Valley. For example, flooding rice fields to decompose rice-stubble during the winter results in 275,000 ac of surrogate wetlands in the Sacramento River Valley. Without this practice, there would only be about 80,000 acres of seasonal wetlands in the Valley (Cline 2005). Flooded rice fields vastly increase the amount of seasonal wetlands, which provide key wintertime waterfowl habitat along the Pacific Flyway.

### *Special-status Plants*

The special-status plant species (those species listed under the State or Federal Endangered Species Acts or on CNPS List 1A, 1B, 2, or 3) with potential to occur within the Colusa Basin Watershed are summarized in **Table 5-Biology**. Based on the literature review, 72 special-status plant species were originally identified as potentially occurring in the Colusa Basin Watershed vicinity. Based on habitat requirements, 15 of these species are considered to be unlikely to occur within the watershed. Of the 57 remaining species, 24 are present and 33 have the potential to occur within the Colusa Basin Watershed boundary. Many (28) of these species are associated with vernal pool habitats. Seven of these species are listed as state and/or federally threatened or endangered and 6 of these threatened or endangered species are associated with vernal pool habitats. The spatial distribution of vernal pool habitats is shown in **Figures 4-Biology** and **5-Biology**, CNDDB records.

### Invasive Plants

Non-native, invasive plant species present a management concern within native habitats, rangelands, and agricultural fields. Invasive species may be detrimental or destructive to native plant species, ecosystem structure and function, rangeland and agronomic crops. They are often difficult to control or eradicate. They compete with native or crop plant species for nutrients, sunlight, and water; they provide poor habitat for wildlife (relative to native habitats and species), use large quantities of water, and can increase flooding and erosion along waterways. The following section provides an overview of the invasive plant species of particular concern in the Colusa Basin Watershed due to potential impacts to native habitats and rangelands.

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| **Federal or State Endangered Species** | | | | |
| Palmate-bracted bird's-beak *Cordylanthus palmatus* | FE, SE, CNPS 1B | May - October | Chenopod scrub and alkaline soils in valley and foothill grassland. Known elevation range: 16-508 ft (5-155 m). | **Present.** Occurs within the v |
| Butte County meadowfoam *Limnanthes floccosa* ssp. *californica* | FE, SE, CNPS 1B | March - May | Vernal pool complexes and mesic valley and foothill grassland. Known elevation range: 164-3051 ft (50-930 m). | **Low.** Potential habitat is pre watershed boundary, but the occurrences within Californi County. |
| Hairy orcutt grass *Orcuttia pilosa* | FE, SE, CNPS 1B | May - September | Vernal pools. Known elevation range: 180-656 ft (55-200 m). | **Present.** Occurs within the v |
| Greene's Tuctoria *Tuctoria greenei* | FE, SR, CNPS 1B | May - September | Vernal pools. Known elevation range: 98-3510 ft (30-1070 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |
| **Federal or State Threatened Species** | | | | |
| Colusa grass *Neostapfia colusana* | FT, CE, CNPS 1B | May - August | Adobe soils in vernal pools. Known elevation range: 16-656 ft (5-200 m). | **Present.** Occurs within the v |
| Hoover's spurge *Chamaesyce hooveri* | FT, CNPS 1B | July - August | Vernal pools on volcanic mudflow or clay substrate. Known elevation range: 82-820 ft (25-250 m). | **Present.** Occurs within the v |
| Slender orcutt grass *Orcuttia tenuis* | FT, SE, CNPS 1B | May - October | Vernal pools. Known elevation range: 115-5774 ft (35-1760 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |
| **CNPS Listed Species** | | | | |
| Bent-flowered fiddleneck *Amsinckia lunaris* | CNPS 1B | March - June | Coastal bluff scrub, cismontane woodland, valley and foothill grassland. Known elevation range: 10-1640 ft (3-500 m). | **Present.** Occurs within the v |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Konocti manzanita *Arctostaphylos manzanita* ssp. *elegans* | CNPS 1B | March - May | Volcanic substrate in chaparral, cismontane woodland, and lower montane coniferous forest. Known elevation range: 1295-5299 ft (395-1615 m). | **Low.** It is unlikely there is p the watershed boundary and t occurrences within the waters |
| Jepson's milk-vetch *Astragalus rattanii* var. *jepsonianus* | CNPS 1B | April - June | Often in serpentinite substrate in chaparral, cismontane woodland, and valley and foothill grassland. Known elevation range: 1050-2297 ft (320-700 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Ferris's milk-vetch *Astragalus tener* var. *ferrisiae* | CNPS 1B | April - May | Vernally mesic meadows and seeps, subalkaline flats in valley and foothill grassland. Known elevation range: 16-246 ft (5-75 m). | **Present.** Occurs within the v |
| Alkali milk-vetch *Astragalus tener* var. *tener* | CNPS 1B | March - June | Alkaline soils in playas, adobe clay soils in valley and foothill grassland, and vernal pools. Known elevation range: 3-525 ft (1-60 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |
| Heartscale *Atriplex cordulata* | CNPS 1B | April - October | Saline and alkaline soils in chenopod scrub, meadows and seeps, and sandy soils in valley and foothill grassland. Known elevation range: 3-1230 ft (1-375 m). | **Present.** Occurs within the v |
| Brittlescale *Atriplex depressa* | CNPS 1B | May - October | Alkaline and clay soils in chenopod scrub, meadows and seeps, playas, valley and foothill grassland, and vernal pools. Known elevation range: 3-1050 ft (1-320 m). | **Present.** Occurs within the v |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| San Joaquin spearscale *Atriplex joaquiniana* | CNPS 1B | April - October | Alkaline soils in chenopod scrub, meadows and seeps, playas, and valley and foothill grassland. Known elevation range: 3-1050 ft (1-320 m). | **Present.** Occurs within the w |
| Lesser saltscale *Atriplex minuscula* | CNPS 1B | May - October | Alkaline sandy soils in chenopod scrub, playas, and valley and foothill grassland. Known elevation range: 49-656 ft (15-200 m). | **Low.** Potential habitat withi boundary, but no known occu watershed. This species is o approximately five extant oc |
| Vernal pool smallscale *Atriplex persistens* | CNPS 1B | July - October | Alkaline vernal pools. Known elevation range: 33-377 ft (10-115 m). | **Present.** Occurs within the w |
| Subtle orache *Atriplex subtilis* | CNPS 1B | June - August | Valley and foothill grassland. Known elevation range: 131-328 ft (40-100 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th Known from fewer than 20 o |
| Big-scale balsamroot *Balsamorhiza macrolepis* var. *macrolepis* | CNPS 1B | March - June | Chaparral, cismontane woodland, valley and foothill grassland, sometimes on serpentine substrate. Known elevation range: 295-4593 ft (90-1400 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Indian Valley Brodiaea *Brodiaea coronaria* ssp. *rosea* | CNPS 1B | May - June | Serpentine substrate in closed-cone coniferous forest, chaparral, cismontane woodland, and valley and foothill grassland. Known elevation range: 1099-4757 ft (335-1450 m). | **Low.** Potential suitable habi the watershed boundary. |
| Coast range bindweed *Calystegia collina* ssp. *tridactylosa* | CNPS 1B | April - June | Serpentine, rocky, gravelly, openings in chaparral and cismontane woodland. Known elevation range: 0-1969 ft (0-600 m). | **Low.** Potential suitable habi the watershed boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Pink creamsacs<br>*Castilleja rubicundula* ssp. *rubicundula* | CNPS 1B | April - June | Serpentine soils in chaparral openings, cismontane woodland, meadows and seeps, and valley and foothill grassland. Known elevation range: 65-2953 (20-900 m). | **Low.** Potential suitable habi the watershed boundary. |
| Pappose tarplant<br>*Centromadia parryi* ssp. *parryi* | CNPS 1B | May - November | Coastal prairie, meadows and seeps, coastal salt marsh, and vernally mesic valley and foothill grassland, often on alkaline substrate. Known elevation range: 0-328 ft (0-100 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Stony Creek spurge<br>*Chamaesyce ocellata* ssp. *rattanii* | CNPS 1B | May - October | Chaparral and valley and foothill grassland. Known elevation range: 279-2625 ft (85-800 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Dwarf soaproot<br>*Chlorogalum pomeridianum* var. *minus* | CNPS 1B | May - August | Serpentine soils in chaparral. Known elevation range: 1000-3280 ft (305-1000 m). | **Low.** Potential suitable habi the watershed boundary. |
| Hospital canyon larkspur<br>*Delphinium californicum* ssp. *interius* | CNPS 1B | April - June | Openings in chaparral and mesic substrates in cismontane woodland. Known elevation range: 754-3593 ft (230-1095 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th |
| Recruved larkspur<br>*Delphinium recurvatum* | CNPS 1B | March - June | Alkaline substrate in cismontane woodland and valley and foothill grassland. Known elevation range: 9-2461 ft (3-750 m). | **Present.** Occurs within the v |
| Brandegee's eriastrum<br>*Eriastrum brandegeeae* | CNPS 1B | April - August | Volcanic and sandy substrate in chaparral and cismontane woodland. Known elevation range: 1000-3379 ft (305-1030 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Tracy's eriastrum *Eriastrum tracyi* | CNPS 1B | June - July | Chaparral and cismontane woodland. Known elevation range: 1033-3199 ft (315-975 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Snow Mountain buckwheat *Eriogonum nervulosum* | CNPS 1B | June - September | Serpentine soils in chaparral. Known elevation range: 984-6906 ft (300-2105 m). | **Low.** Potential suitable habi the watershed boundary. |
| Diamond-petaled California poppy *Eschscholzia rhombipetala* | CNPS 1B | March - April | On alkaline or clay soils in valley and foothill grassland. Known elevation range: 0-3199 ft (0-975 m). | **Present.** Occurs within the v |
| Adobe-lily *Fritillaria pluriflora* | CNPS 1B | February - April | Chaparral, cismontane woodland, valley and foothill grassland, often on adobe soils. Known elevation range: 197-2313 ft (60-705 m). | **Present.** Occurs within the v |
| Boggs Lake hedge-hyssop *Gratiola heterosepala* | CNPS 1B | April - August | In clay soils along lake margins in marshes and swamps, and vernal pools. Known elevation range: 32-7792 ft (10-2375 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |
| Hall's harmonia *Harmonia hallii* | CNPS 1B | April - June | Serpentine soils in chaparral. Known elevation range: 65-2723 ft (20-830 m). | **Low.** Potential suitable habi the watershed boundary. |
| Two-carpellate western flax *Hesperolinon bicarpellatum* | CNPS 1B | May - July | On serpentine substrate in chaparral. Known elevation range: 196-3297 ft (60-1005 m). | **Low.** Potential suitable habi the watershed boundary. |
| Brewer's western flax *Hesperolinon breweri* | CNPS 1B | May - July | Chaparral, cismontane woodland, valley and foothill grassland, usually on serpentine soil. Known elevation range: 98-2953 ft (30-900 m). | **Low.** Potential suitable habi the watershed boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Drymaria-like western flax *Hesperolinon drymarioides* | CNPS 1B | May - August | Serpentine soils in closed-cone coniferous forest, chaparral, cismontane woodland, and valley and foothill grassland. Known elevation range: (100-1130 m). | **Low.** Potential suitable habi the watershed boundary. |
| Napa western flax *Hesperolinon serpentinum* | CNPS 1B | May - July | Serpentine soils in chaparral. Known elevation range: 164-2625 ft (50-800 m). | **Low.** Potential suitable habi the watershed boundary. |
| Tehama County western flax *Hesperolinon tehamense* | CNPS 1B | May - July | Serpentine substrate in chaparral and cismontane woodland. Known elevation range: 328-3281 ft (100-1000 m). | **Low.** Potential suitable habi the watershed boundary. |
| Bolander's horkelia *Horkelia bolanderi* | CNPS 1B | June - August | On edges and vernally mesic areas in chaparral, lower montane coniferous forest, meadows and seeps, and valley and foothill grassland. Known elevation range: 1476-3609 ft (450-1100 m). | **Present.** Occurs within the v |
| Red Bluff dwarf rush *Juncus leiospermus* var. *leiospermus* | CNPS 1B | March - May | Vernally mesic chaparral, cismontane woodland, meadows, valley and foothill grassland, and vernal pools. Known elevation range: 115-3346 ft (35-1020 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |
| Coulter's goldfields *Lasthenia glabrata* ssp. *coulteri* | CNPS 1B | February - June | Coastal salt marshes and swamps, playas, and vernal pools. Known elevation range: 3-4003 ft (1-1220 m). | **Present.** Occurs within the v |
| Colusa layia *Layia septentrionalis* | CNPS 1B | April - May | Sandy and serpentine soils in chaparral, cismontane woodland, and valley and foothill grassland. Known elevation range: 328-3593 ft (100-1095 m). | **Present.** Occurs within the v |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Legenere *Legenere limosa* | CNPS 1B | April - June | Vernal pools. Known elevation range: 3-2887 ft (1-880 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |
| Heckard's pepper-grass *Lepidium latipes* var. *heckardii* | CNPS 1B | March - May | Alkaline flats in valley and foothill grassland. Known elevation range: 33-656 ft (10-200 m). | **Present.** Occurs within the v |
| Red-flowered lotus *Lotus rubriflorus* | CNPS 1B | April - June | Cismontane woodland and valley and foothill grassland. Known elevation range: 656-1394 ft (200-425 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Milo Baker's lupine *Lupinus milo-bakeri* | CNPS 1B | June - September | Cismontane woodland, often along roadsides, and valley and foothill grassland. Known elevation range: 1295-1411 ft (395-430 m). | **Present.** Occurs within the v |
| Cobb Mountain lupine *Lupinus sericatus* | CNPS 1B | March - June | Broadleaved upland forest, chaparral, cismontane woodland, and lower montane coniferous forest. Known elevation range: 902-5003 ft (275-1525 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Indian Valley bush mallow *Malacothamnus aboriginum* | CNPS 1B | April - October | Rocky substrate, often in burned areas, in chaparral and cismontane woodland. Known elevation range: 492-5577 ft (150-1700 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th |
| Veiny monardella *Monardella douglasii* ssp. *venosa* | CNPS 1B | May - July | Heavy clay soils in cismontane woodland, valley and foothill grassland. Known elevation range: 197-1345 ft (60-410 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Baker's navarretia *Navarretia leucocephala* ssp. *bakeri* | CNPS 1B | May - July | Mesic soils in cismontane woodland, lower montane coniferous forest, meadows and seeps, valley and foothill grassland, and vernal pools. Known elevation range: 49-5709 ft (15-1740 m). | **Present.** Occurs within the v |
| Ahart's paronychia *Paronychia ahartii* | CNPS 1B | March - June | Cismontane woodland, valley and foothill grassland, and vernal pools. Known elevation range: 98-1673 ft (30-510 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Butte County checkerbloom *Sidalcea robusta* | CNPS 1B | April - June | Chaparral and cismontane woodland. Known elevation range: 295-5249 ft (90-1600 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th Known from approximately 2 Butte County, California. |
| San Francisco campion *Silene verecunda* ssp. *verecunda* | CNPS 1B | March - June | Sandy soils in coastal bluff scrub, chaparral, coastal prairie, coastal scrub, and valley and foothill grassland. Known elevation range: (30-645 m). | **Moderate to Low.** Potential within the watershed, but the occurrences within 5 mi of th Known from fewer than 20 o |
| Freed's jewel-flower *Streptanthus brachiatus* ssp. *hoffmanii* | CNPS 1B | May - July | Serpentine soils in chaparral and cismontane woodland. Known elevation range: 1607-4003 ft (490-1220 m). | **Low.** Potential suitable habi the watershed boundary. |
| Green jewel-flower *Streptanthus breweri* var. *hesperidis* | CNPS 1B | May - July | Serpentine and rocky substrate in chaparral and cismontane woodland. Known elevation range: 426-2493 ft (130-760 m). | **Low.** Potential suitable habi the watershed boundary. |
| Morrison's jewel-flower *Streptanthus morrisonii* subspecies | CNPS 1B | April - September | Serpentine soils in chaparral and cismontane woodland. Known elevation range: 2 95-3396 ft (90-1035 m). | **Low.** Potential suitable habi the watershed boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Caper-fruited tropidocarpum *Tropidocarpum capparideum* | CNPS 1B | March - April | Alkaline hills in valley and foothill grassland. Known elevation range: 3-1493 ft (1-455 m). | **Present.** Occurs within the v |
| Fox sedge *Carex vulpinoidea* | CNPS 2 | May - June | Freshwater marshes and swamps, riparian woodland. Known elevation range: 98-3937 ft (30-1200 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Morris' beard-moss *Didymodon norrisii* | CNPS 2 | N/A | Cismontane woodland and on intermittently mesic rock in lower montane coniferous forest. Known elevation range: 1968-5577 ft (600-1700 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Dwarf downingia *Downingia pusilla* | CNPS 2 | March-May | Valley and foothill grassland in mesic soils and vernal pools. Known elevation range: 3-1460 ft (1-445 m). | **Moderate.** Potential habitat known occurrences within 5 boundary. |
| Snow Mountain willowherb *Epilobium nivium* | CNPS 2 | July - October | Rocky soils in chaparral and upper montane coniferous forest. Known elevation range: 2608-8202 ft (795-2500 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |
| Round-leaved filaree *Erodium macrophyllum* | CNPS 2 | March - May | Clay soils in cismontane woodland, and valley and foothill grassland. Known elevation range: 49-3937 ft (15-1200 m). | **Present.** Occurs within the v |
| Rose-mallow *Hibiscus lasiocarpus* | CNPS 2 | June - September | Freshwater marshes and swamps. Known elevation range: 0-394 ft (0-120 m). | **Present.** Occurs within the v |
| Eel-grass pondweed *Potamogeton zosteriformis* | CNPS 2 | June - July | Assorted freshwater marshes and swamps. Known elevation range: 0-6102 ft (0-1860 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Wright's trichocoronis *Trichocoronis wrightii* var. *wrightii* | CNPS 2 | May - September | Alkaline substrate in meadows and seeps, marshes and swamps, riparian forests, and vernal pools. Known elevation range: 16-1427 ft (5-435 m). | **Present.** Occurs within the v |
| Columbian watermeal *Wolffia brasiliensis* | CNPS 2 | April - December | Assorted shallow freshwater marshes and swamps. Known elevation range: 98-328 ft (30-100 m). | **Present.** Occurs within the v |
| Henderson's bent grass *Agrostis hendersonii* | CNPS 3 | April - May | Mesic substrate in valley and foothill grassland and vernal pools. Known elevation range: 229-1000 ft (70-305 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |
| Butte County fritillary *Fritillaria eastwoodiae* | CNPS 3 | March - June | Chaparral, cismontane woodland, and openings in lower montane coniferous forest, sometimes on serpentine soils. Known elevation range: 164-4921 ft (50-1500 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |
| Woolly-headed Lessingia *Lessingia hololeuca* | CNPS 3 | June - October | Clay and serpentine substrates in broadleaved upland forest, coastal scrub, lower montane coniferous forest, and valley and foothill grassland. Known elevation range: 49-1001 ft (15-305 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |
| Mt. Diablo cottonweed *Micropus amphibolus* | CNPS 3 | March - May | Rocky substrate in broadleaved upland forest, chaparral, cismontane woodland, and valley and foothill grassland. Known elevation range: 147-2707 ft (45-825 m). | **Moderate.** Potential habitat no known occurrences withir boundary. |

**Table 5. Biology. Special-status Plant Species, Their Status, and Potential Occurrence in the Colusa Basi**

| NAME | *STATUS | BLOOM | HABITAT | POTENTIAL FOR OC SITE |
|---|---|---|---|---|
| Little mousetail<br>*Myosurus minimus* ssp. *apus* | CNPS 3 | March - June | Valley and foothill grassland and alkaline substrate in vernal pools. Known elevation range: 65-2100 ft (20-640 m). | **Moderate.** Potential habitat no known occurrences withi boundary. |

Key to Special-status Species Rarity Ratings

FE=Federally Endangered
FT=Federally Threatened
SE=State Endangered
SR=State Rare
ST=State Threatened
CSSC=California Species of Special Concern
FSC=Federal Species of Special Concern
CNPS List 1A=Plants presumed to be extinct in California
CNPS List 1B= Plants rare and endangered in California and elsewhere
CNPS List 2= Plants rare and endangered in California, more common elsewhere
CNPS List 3= Plants about which more information is needed, review list
CNPS List 4= Plants of limited distribution, watch list

Although there is no centralized repository of spatial data of invasive plant species extents or rates of spread for the state or counties, each County Agriculture Commissioner's office provides leadership and guidance for invasive species in their respective county. Their work is further supported through cooperative Weed Management Areas that incorporate federal, state, and local agencies along with local residents. The Colusa Basin Watershed encompasses 2 Weed Management Areas: Glenn-Tehama-Colusa and Yolo. The California Invasive Plant Species Council [CA-IPC] provides generalized maps of individual invasive species that contain information about the extent and rate of spread within each county based on information collected from section-surveys or collected from a variety of local sources such as local land managers or Weed Management Areas coordinators (**Figures 9-Biology** through **Figure 14-Biology**). This assessment relies on these sources of existing information to characterize the status and extent of invasive plant species within the Colusa Basin Watershed.

In the Colusa Basin Watershed there are numerous invasive species; however, 8 are of particular concern due to their extent, rate of spread, or ecosystem impacts (**Table 6-Biology**; Miller, pers. comm.). These plant species are organized below based upon the habitat they affect (upland, wetland, riparian) and have not yet been ranked according to their priority for control in the Colusa Basin Watershed. The relative length of information given for each species below is a reflection of the amount of readily available information published on each species, rather than an indication of priority for control. While many watershed plans focus on management of riparian weeds, the future management planning should identify the prioritization and control-plan for species within the Colusa Basin Watershed.

**Table 6. Biology. Invasive Plant Species of Particular Management Concern in Colusa Basin Watershed.**

| Common Name | Species | Affected Habitats |
|---|---|---|
| Giant reed | *Arundo donax* | Riparian |
| Salt cedar | *Tamarix parviflora* | Riparian |
| Perennial pepperweed | *Lepidium latifolium* | Upland & Wetland |
| Yellow starthistle | *Centaurea solstitialis* | Upland |
| Purple starthistle | *Centaurea calcitrapa* | Upland |
| Medusahead | *Taeniantherum caput-medusae* | Upland |
| Barbed goatgrass | *Aegilops triuncialis* | Upland |
| Creeping water primrose | *Ludwigia* spp. (*uruguayensis*) | wetland |

**Yellow Starthistle.** Yellow starthistle is a winter annual (sometime biennial) forb species that occurs in open hills, grasslands, roadsides, and rangelands. It is considered one of the most serious rangeland weeds in California (CA-IPC 2007). It is estimated that yellow starthistle has invaded 14 million ac in California; the most of any invasive species (CA-IPC 2007). The spatial extent and spread of yellow starthistle within Colusa Basin Watershed mirrors these statewide trends, as it is probably the most abundant invasive species in the northern Colusa Basin Watershed (Miller 2007). Impacts of yellow starthistle include significant increased groundwater consumption, lower forage quality of rangelands, lower plant diversity, and fragmentation of sensitive plant and animal habitats (DiTomaso et al. 2006). These impacts represent a high economic and ecological cost to agriculture (crops and grazing) and sensitive native habitats such as native grasslands and blue oak woodlands. However, it is regarded as an important late-season food source for honey bees (DiTomaso et al. 2006). Numerous methods are employed to control yellow starthistle including mechanical, chemical, and biological; however, complete eradication is currently unlikely among large size infestations. The specific elements of an integrated management strategy to control yellow star thistle depend on the ultimate land use objectives for a given area (DiTomaso et al. 2006).

Control of invasive plant species populations in areas adjacent to the Colusa Basin Watershed contribute to control within the Watershed by eliminating propagule sources that can invade the Watershed and provide opportunities for information exchange that could assist control efforts within the Watetrshed. Yolo County Weed Management Area partnered with Yolo County Public Works and Yolo County Department of Agriculture to reduce noxious weeds along roadsides in the county. A total of 1600 ac were treated using broadleaf herbicide treatments with the goal of converting the land to native grasses. Much of this area was invaded by yellow star thistle. They followed control treatments with native grass plantings to help establish native grassland habitats in these formerly invaded areas (Sacramento River Watershed Program 2007).

**Purple Starthistle.** Purple starthistle is a biennial (sometimes annual) forb species that presents similar concerns as yellow starthistle such as reducing forage quality and invading areas of native habitat. However, purple starthistle is not known to form monotypic stands to the same extent as yellow starthistle and its water usage has not been documented as clearly (CA-IPC 2007).

The Glenn-Tehama-Colusa Weed Management Area has recently facilitated a project near the town of Sites where 300 ac of rangeland have been chemically treated to control purple starthistle (Sacramento River Watershed Program 2007).

**Medusahead.** Medusahead is an annual grass that invades disturbed grassland, chaparral, and oak woodland habitats. It is abundant in the foothill rangeland of the northwestern portion of the Colusa Basin Watershed where it occurs with barbed goatgrass (Miller 2007). Medusahead often occurs on clay soils where there is late season moisture, whereas well-drained soils are less likely to host this species (Maurer et al. 1988). The thatch layer of medusahead enhances its own germination, while preventing germination of native grasses and forb species. Livestock do not usually find it palatable, except in early spring or under forced grazing management scenarios (Maurer et al. 1988). Control has been achieved using springtime controlled burning or heavy sheep grazing. Chemical treatment can be effective, but also negatively impacts native grasses. Maintaining diverse, intact native perennial grassland habitat seems to exclude medusahead, though restoration of this habitat following disturbance (such as overgrazing) requires initial eradication of medusahead followed by seeding with an appropriate native grass seed mix and 3-5 yrs of follow-up invasive species control to be successful (Maurer et al. 1988).

**Barb Goatgrass.** Barb goatgrass is an annual grass that invades grassland, rangeland, and oak woodland habitats found in the western foothills. Once it is mature, it is essentially unpalatable to livestock. The Glenn County Weed Management Area has a project aimed at early detection and eradication of barbed goatgrass in Tehama, Glenn, and Colusa counties (Sacramento River Watershed Program 2007). Research in Mendocino County concluded that 2 consecutive years of late spring prescribed burning nearly eliminated barbed goatgrass (DiTomaso et al. 2001).

**Perennial Pepperweed.** Perennial pepperweed is an herbaceous perennial plant from southeast Europe that can invade a wide variety of habitat types including riparian areas, marshes, and floodplains as well as hay fields, roadsides, and rangelands. Pepperweed can form large monospecific stands that exclude regeneration of native plant species, thereby decreasing plant species diversity and structural complexity (CA-IPC 2007). Its root system is extensive, at times reaching 9 ft deep. Such root architecture is thought to be a factor in its competitive advantage over native plant species and contributes to the difficulty of eradication via mechanical methods (Renz 2000). Pepperweed can also transport salts from lower soil horizons and deposit them at the soil surface, which can further shift plant composition to favor halophytes (Renz 2000). Control treatments include continual flooding or chemical methods. Glenn-Tehama-Colusa Weed Management Area has been working to control and eradicate perennial pepperweed in Glenn County. Yolo Weed Management Area has been engaged in trying to control perennial pepperweed in Grasslands Park south of the Colusa Basin Watershed (Sacramento River Watershed Program 2007).

**Giant Reed.** Giant reed is a perennial, reed-like grass that can grow extremely quickly (up to 2 inches a day) and can reach a height of 30 ft tall (Hoshovsky 1987). The species is believed to be native to eastern Asia and was intentionally introduced to southern California in the 1820s for use as erosion control in drainage canals and thatching for roofs (Bell 2002). It is also used for reeds in musical instruments and in ornamental landscaping (CSU Sacramento and Sonoma Ecology Center 2005). Giant reed is an invasive plant that can be found throughout California, usually below 1000 ft elevation (Dudley 2006). The stalks of giant reed, called “culms,” resemble those of bamboo can reach diameters of 1.5 inches (Hoshovsky 1987). Giant reed has fleshy rhizomes from which tough fibrous roots grow and penetrate deeply into the soil. Giant reed’s primary mode of reproduction is vegetative and occurs through the rooting of stem fragments or the colonial extension of underground rhizomes (EIP Associates 2002). Seed produced by giant reed are seldom, if ever, fertile (Bell 2002). However, a recent study showed that sampled seed from Ventura County in Southern California had a 7% germination rate in “ideal” laboratory conditions (NRCS 2005).

Giant reed can tolerate a wide range of abiotic conditions. It grows best in well-drained soils with an abundance of available moisture. In California, the largest colonies occur in riparian areas and floodplains, often along streams that have been physically disturbed and dammed upstream (Dudley 2006). However, giant reed is also quite drought-tolerant, and populations occur well beyond the margins of riparian vegetation (Dudley 2006). Giant reed is shade tolerant and can grow beneath existing riparian vegetation. The growth of giant reed can be impeded by lack of moisture during the first year, but plants 2-3 yrs old can survive drought without a problem. The ability of giant reed to survive drought is due to its coarse, drought resistant rhizomes and roots that can grow deeply into the soil. Giant reed plants can also survive periods of excessive moisture (Hoshovsky 1987). Overall, giant reed is well adapted to disturbance dynamics of riparian systems. For example, when flood events break up clumps of giant reed and spread the pieces downstream, fragmented stem nodes and rhizomes can take root and establish as new plant clones. The rapid growth rate and strong competitive ability enables giant reed to invade recently disturbed areas quickly and out-compete native vegetation (Hoshovsky 1987). Giant reed tends to form large, continuous, clonal root masses that can cover several acres, often at the expense of native riparian vegetation that cannot compete. Root masses can become more than 3 ft thick and are capable of stabilizing stream banks and terraces, altering flow regimes. In addition giant reed can reduce groundwater availability within aquifers by using large amounts of water to supply its relatively high growth rate (Bell 2002). Giant reed is highly flammable even when green and can carry fire into a creek corridor. The dense growth habit of giant reed can more than double the available fuel for wildfires compared to native vegetation (Dudley 2006). After a fire disturbance, giant reed grows back rapidly from its roots without competition from other plants, often thicker than before the fire (CSU Sacramento and Sonoma Ecology Center 2005).

The Glenn-Tehama-Colusa Weed Management Area has been facilitating a project with its partner organizations (BLM, Colusa County Resource Conservation District, CALFED Bay-Delta Program, and UC Davis) to remove giant reed and salt cedar from the Bear Creek drainage, adjacent to the southwest perimeter of the Colusa Basin Watershed. One-half mile of land along Bear Creek in Colusa County has been chemically treated for giant reed and salt cedar to protect the riparian area. Plant material was removed after the chemical treatments. GCRCD has worked with landowners to chemically treat 20 ac of giant reed and salt cedar along Lower Stony Creek, just north of the Colusa Basin Watershed as a pilot project. The GCRCD is currently preparing a Management Plan for Lower Stony Creek that will include giant reed and salt cedar control projects. Cache Creek Conservancy and UC Davis are testing biological control options for giant reed in the adjacent Cache Creek Watershed and have documented the efficiency of control methods (SERCAL 2007).

**Salt Cedar.** Salt cedar is a deciduous, loosely branched shrub or small tree. It derives its name from its cedar-like foliage and its ability to grow in saline or alkaline soils (Carpenter 1998). Salt cedar is a non-native, invasive plant species indigenous to Western Europe and the Mediterranean, North Africa, northeastern China, India, and Japan. Although it is uncertain how salt cedar was introduced to North America, it was first identified in the western U.S. in the 1800s and was available at California nurseries as early as 1856 (Zouhar 2003). Salt cedar is thought to have been introduced in the U.S. to be used in wind breaks, to control erosion, and as an ornamental plant (DiTomaso 1998). From the 1920s to the 1960s, salt cedar rapidly spread, particularly in the southwestern U.S. The rapid increase is primarily due to the regulation of streamflows following the construction of large dams and water diversion projects. Once salt cedar establishes along major drainages, it easily spreads to outlying streams, wetlands, and springs via windblown seeds (Zouhar 2003). Salt cedar has numerous, large basal branches that can grow to approximately 20 ft tall (Carpenter 1998). The leaves are scale-like and the foliage deciduous. Salt cedar flowers produce numerous tiny, tufted seeds, and the seed can be dispersed by wind or water (DiTomaso 1998). The root system is much deeper than giant reed, extending to the water table, and is also capable of extracting water from unsaturated soil layers (Zouhar 2003). Salt cedar is a facultative phreatophyte, meaning that it can draw water from underground sources but once established it can survive without access to ground water. Unlike giant reed, salt cedar can propagate from seed easily as well as from buried or submerged stems (Carpenter 1998). Even after the aboveground portion of the plant is removed, mature salt cedar plants can reproduce from adventitious roots (root sprouting, Zouhar 2003). Salt cedar is tolerant of highly saline habitats, and it concentrates assimilated salt in its leaves. Over time, as leaf litter accumulates under the plants, the surface soil can become highly saline and impede future colonization by many native plant species (Carpenter 1998). The accumulation of salt in surface soils can occur particularly along dammed rivers that are no longer subjected to annual flooding and scouring (Zouhar 2003). Similar to giant reed, salt cedar is an aggressive, invasive species that can tolerate a wide range of environmental conditions once established. It can replace or displace native woody species, such as cottonwood and willow, which occupy similar habitats. Other undesirable ecological attributes of salt cedar include providing generally lower wildlife habitat value than native vegetation, drying up springs, wetlands, riparian areas, and small streams by lowering the surface water table, and obstructing stream channels by forming dense stands within the channel. Unlike giant reed, salt cedar seedlings usually grow more slowly than native riparian plant species and mature plants are highly susceptible to shade (Carpenter 1998). The Glenn-Tehama-Colusa Weed Management Area has worked to control salt cedar along Bear Creek as described above in the section on giant reed. Cache Creek Conservancy and UC Davis are testing biological control options for salt cedar in the adjacent Cache Creek Watershed and have documented the efficiency of control methods (SERCAL 2007)

**Creeping Water Primrose.** Creeping water primrose is an aquatic weed species that forms dense mats above and below the water surface in shallow, stagnant, nutrient-rich pools, and in areas with hydrological distrurbance, such as flood control channels, irrigation ditches and irrigation ponds (Verdone 2004). It can also persist in drier transition zones as well. Once established, it can spread very rapidly via asexual reproduction (stem fragments). Seed from populations in Sonoma County were not found to be viable (Verdone 2004). The plant escaped from ornamental/domestic use and continues to spread via animals, boats, flooding, and flowing water (Verdone 2004). Heavily invaded waterways can potentially experience altered water-flow, increased sedimentation, and decreased water quality (Verdone 2004). Creeping water primrose can outcompete native aquatic and wetland plant species, thereby reducing species diversity. Areas that were once open water habitat become closed mats of creeping water primrose, which degrades waterfowl habitat (Verdone 2004). Some public agencies in other states have used mechanical and chemical methods to control it including aquatic-approved form of glyphosate (Rodeo®) or covering with opaque materials (WA DOE 2008).

### Regulated Habitats and Permitting Overview

The purpose of this section is to provide a broad overview of the federal and state environmental regulations and agencies potentially involved in regulating the sensitive biological resources of the Colusa Basin Watershed. **Figures 5-Biology** through **Figure 8-Biology** in this report show the approximate location of some sensitive species and habitats that may be protected under the jurisdiction of the USFWS, DFG, United States Army Corps of Engineers [USACE] and/or RWQCB. However, the level of detail provided within this Watershed Assessment is not sufficient as a baseline for the environmental review of specific projects. The below environmental regulations require site-specific impact assessments by a qualified biologist and communications with the appropriate regulatory agencies during the environmental review process for specific projects.

**Federal Endangered Species Act.** FESA protects listed wildlife species from harm or "take" which is broadly defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, collect, or attempt to engage in any such conduct. Take can also include habitat modification or degradation that directly results in death or injury to a listed wildlife species. An activity can be defined as "take" even if it is unintentional or accidental. Listed plant species are provided less protection than listed wildlife species. Listed plant species are legally protected from take under FESA if they occur on federal lands or if the project requires a federal action, such as a Section 404 fill permit.

The USFWS and the National Marine Fisheries Service [NMFS] have jurisdiction over federally listed threatened and endangered species under the FESA. The USFWS also maintains lists of proposed and candidate species. Species on these lists are not legally protected under the FESA, but may become listed in the near future and are often included in their review of a project.

**California Endangered Species Act.** CESA (Fish and Game Code of California, Chapter 1.5, Sections 2050-2116) prohibits the take of any plant or animal listed or proposed for listing by the State as rare (plants only), threatened, or endangered. In accordance with the CESA, the DFG has jurisdiction over state-listed species (California Fish and Game Code 2070). DFG regulates activities that may result in "take" of individuals (i.e., "hunt, pursue, catch, capture, or kill, or attempt to hunt, pursue, catch, capture, or kill"). Habitat degradation or modification is not expressly included in the definition of "take" under the California Fish and Game Code. The DFG, however, has interpreted "take" to include the "killing of a member of a species which is the proximate result of habitat modification ..."

**California Environmental Quality Act.** CEQA requires lead agencies on projects to prepare an Initial Study and in some cases an EIR for projects that are not considered exempt from CEQA. The purpose of CEQA is to inform the general public and obtain public input regarding the potential environmental impacts of proposed projects. The CEQA process, when functioning as intended, facilitates the avoidance, minimization, and mitigation of potentially significant environmental impacts during the design and implementation of projects.

With respect to rare species, Section 15380(b) of the CEQA Guidelines provides that a species not listed on the federal or state lists of protected species may be considered rare if the species can be shown to meet certain specified criteria. These criteria have been modeled after the definitions in FESA and CESA and the section of the California Fish and Game Code dealing with rare or endangered plants or animals. This section was included in the guidelines primarily to deal with situations in which a public agency is reviewing a project that may have a significant effect on a species that has not yet been listed by either the USFWS or DFG or species that are locally or regionally rare.

The CDFG has produced 3 lists (amphibians and reptiles, birds, and mammals) of "species of special concern" that serve as "watch lists." Species on these lists either are of limited distribution or the extent of their habitats has been reduced substantially, such that threat to their populations may be imminent. Thus, their populations should be monitored. They may receive special attention during environmental review as potential rare species, but do not have specific statutory protection.

CNPS, a non-governmental conservation organization, has developed lists of plant species of concern in California. Vascular plants included on these lists are defined as follows:

| | |
|---|---|
| List 1A | Plants considered extinct |
| List 1B | Plants rare, threatened, or endangered in California and elsewhere |
| List 2 | Plants rare, threatened, or endangered in California but more common elsewhere |
| List 3 | Plants about which more information is needed - review list |
| List 4 | Plants of limited distribution-watch list |

These CNPS listings are further described by the following threat code extensions:

.1—seriously endangered in California
.2—fairly endangered in California
.3—not very endangered in California

Although the CNPS is not a regulatory agency and plants on these lists have no formal regulatory protection, plants appearing on List 1B or List 2 are, in general, considered to meet CEQA's Section 15380 criteria and adverse effects to these species may be considered significant.

**Federal Migratory Bird Treaty Act (16 U.S.C. Sec. 703).** The federal MBTA (16 U.S.C., §703, Supp. I, 1989) prohibits killing, possessing, or trading in migratory birds except in accordance with regulations prescribed by the Secretary of the Interior. The trustee agency that addresses issues related to the MBTA is the USFWS. Migratory birds protected under this law include almost all native birds, with the exception of the wrentit (*Chamaea fasciata*), which is the sole member of its family in the new world (probably inadvertently skipped), and certain game birds (e.g., turkeys and pheasants; Federal Register 70(2):372-377). This act encompasses whole birds, parts of birds, and bird nests and eggs.

Construction disturbance during the breeding season could result in the incidental loss of fertile eggs or nestlings, or otherwise lead to nest abandonment, a violation of the MBTA. The MBTA protects active nests from destruction and all nests of species protected by the MBTA, whether active or not, cannot be possessed. An active nest under the MBTA as described by the Department of the Interior in their Migratory Bird Permit Memorandum dated 15 April 2003 is one having eggs or young. Nest starts, prior to egg laying, are not protected from destruction.

**California State Fish and Game Code.** The DFG exerts jurisdiction over the bed and banks of rivers, lakes, and streams according to provisions of 1601 to 1603 of the Fish and Game Code. The Fish and Game Code requires a Streambed Alteration Agreement for the fill or removal of material within the bed and banks of a watercourse or waterbody and for the removal of riparian vegetation.

Migratory birds are also protected in and by the state of California. The State Fish and Game Code §3513 specifically emulates the MBTA and other sections and subsections of §3500-3516 provide additional protections for birds. Specifically, §3503 protects birds' nests and eggs from all forms of needless take. All native birds are protected (including the wrentit), although game birds may be taken with a hunting license. Disturbance that causes nest abandonment and/or loss of reproductive effort is considered "take" by the CDFG. In addition, § 3511 lists species that are "fully protected" and cannot be taken or possessed at any time.

In addition, raptors (eagles, hawks, and owls) and their nests are specifically protected in California under Fish and Game Code Section 3503.5. Section 3503.5 states that it is "unlawful to take, possess, or destroy any birds in the order Falconiformes or Strigiformes (birds of prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto." For all of these regulations, resource agencies typically consider "nests" to be active nests (nests with eggs or chicks). Destruction of inactive nests is generally not considered "take."

Additionally, the California Fish and Game Code contains lists of vertebrate species designated as "fully protected" (Code § 3511 [birds], §4700 [mammals], §5050 [reptiles and amphibians], §5515 [fish]). Such species may not be taken or possessed.

**Clean Water Act.** Under Section 404 of the CWA, the USACE is responsible for regulating the discharge of fill material into waters of the U.S. Waters of the U.S. and their lateral limits are defined in 33 CFR Part 328.3 (a) and include streams that are tributary to navigable waters and their adjacent wetlands. Wetlands that are not adjacent to waters of the U.S. are termed "isolated wetlands" and, depending on the circumstances, may also be subject to USACE jurisdiction.

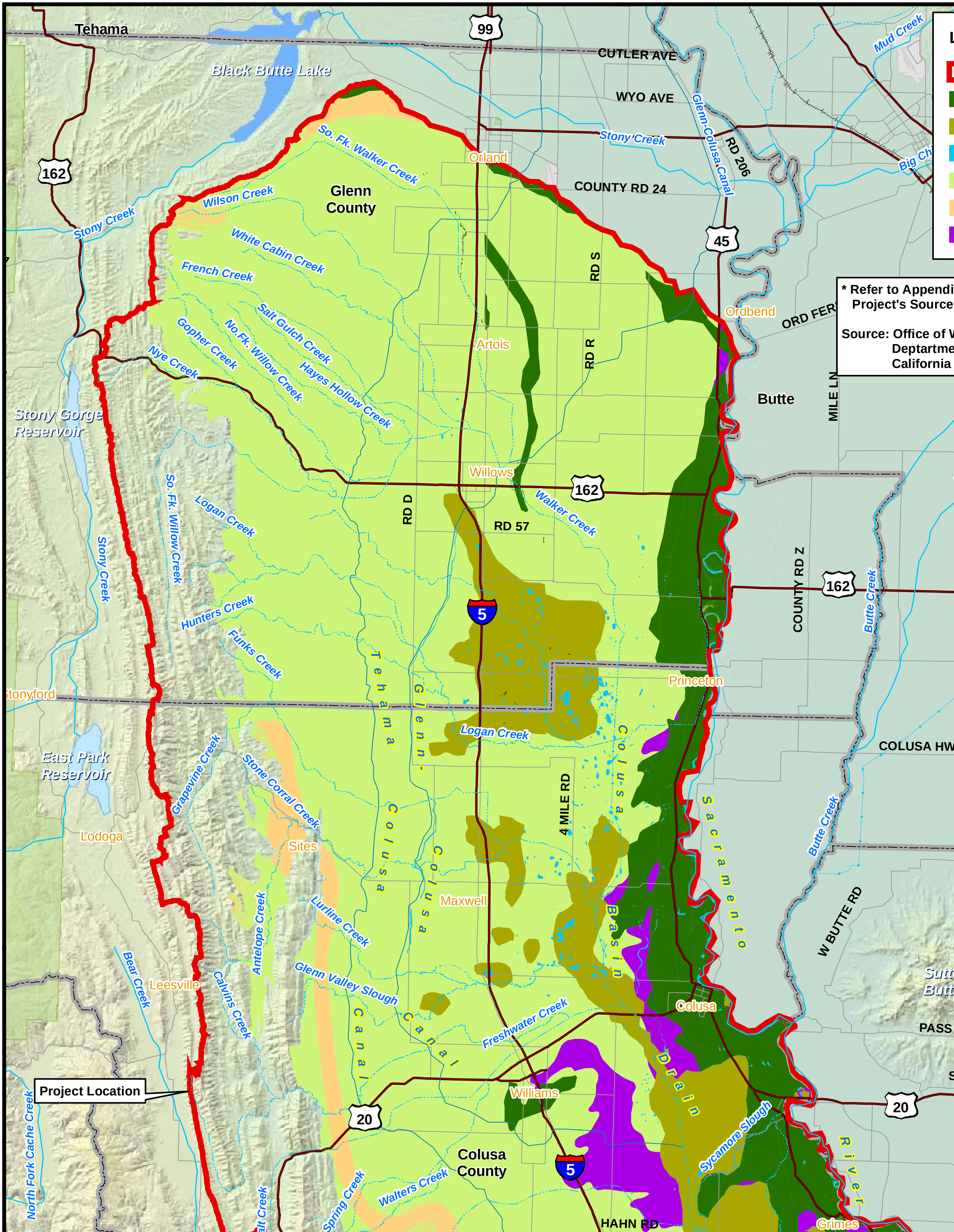
**Rivers and Harbors Act.** Under Section 10 of the Rivers and Harbors Act (1899) 33 U.S.C. 403, the building of any wharfs, piers, jetties, and other structures within navigable waters is prohibited without Congressional approval, and excavation or fill within navigable waters requires the approval of the Chief of Engineers. Service concerns include contaminated sediments associated with dredge or fill projects in navigable waters.

Authority of the USACE to issue permits for the discharge of refuse matter into or affecting navigable waters under section 13 of the 1899 Act (33 U.S.C. 407; 30 Stat. 1152) was modified by title IV of P.L. 92-500, October 18, 1972, the Federal Water Pollution Control Act Amendments of 1972 (33 U.S.C. 1341-1345; 86 Stat. 877), as amended, which established the NPDES Permits.

The Fish and Wildlife Coordination Act (16 U.S.C. 661-667e; 48 Stat. 401), as amended, provides authority for the USFWS to review and comment on the effects on fish and wildlife of activities proposed to be undertaken or permitted by the USACE.

**California Water Quality and Waterbody Regulatory Programs.** Under the Porter-Cologne Water Quality Control Act (Porter-Cologne), the SWRCB has the ultimate authority over State water rights and water quality policy. However, Porter-Cologne also establishes nine RWQCBs to oversee water quality on a day-to-day basis at the local/regional level.

Pursuant to Section 401 of the Federal CWA, projects that are regulated by the USACE must obtain water quality certification from the RWQCB. This certification ensures that the Project will uphold state water quality standards. The RWQCB may impose mitigation requirements even if the USACE does not.


Tehama
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East Park Reservoir
Grapevine Creek
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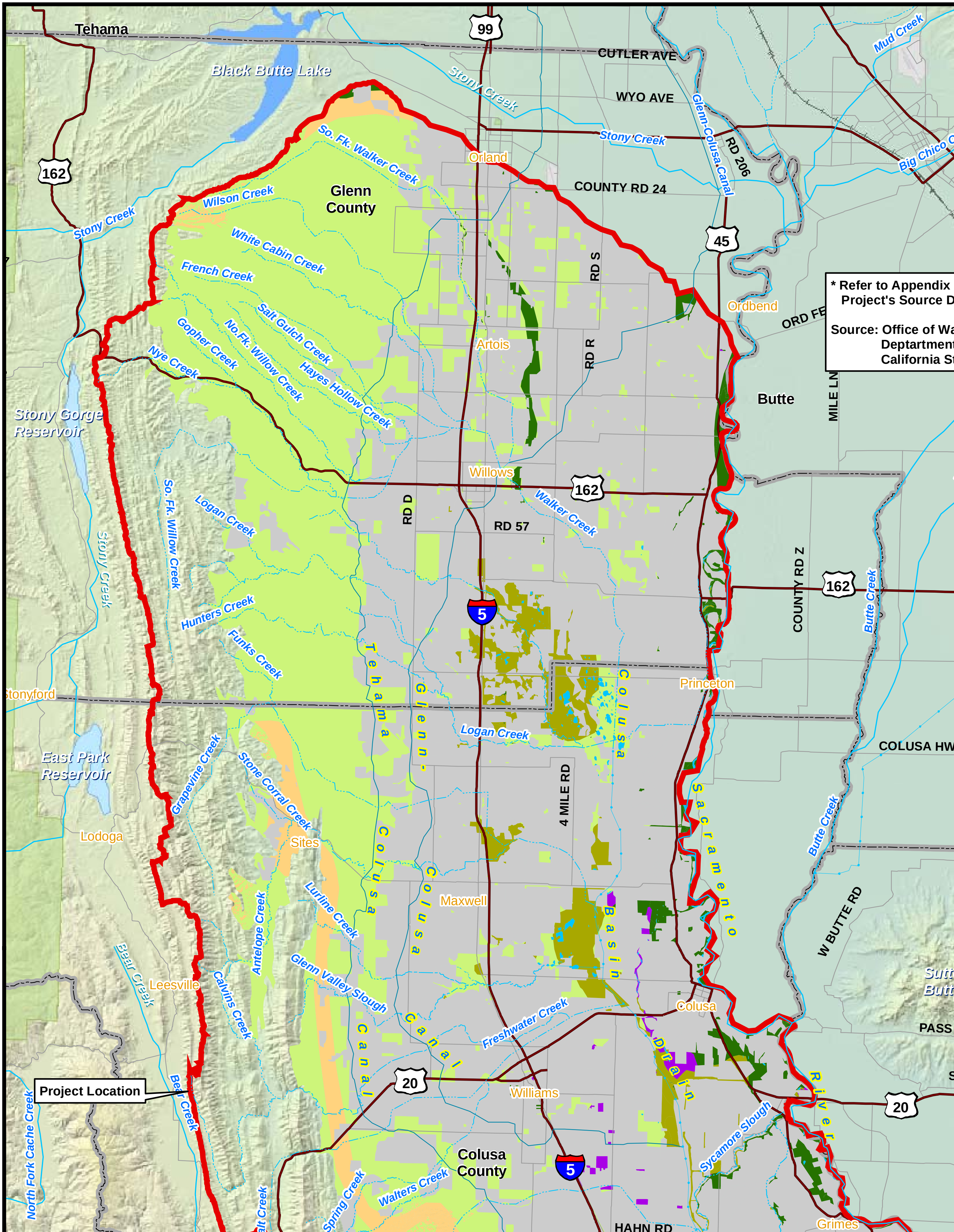

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Hunters Creek
Funks Creek
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Stonyford
Logan Creek
COLUSA HW
East Park Reservoir
Grapevine Creek
Stone Corral Creek
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Lurline Creek
Antelope Creek
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Calvins Creek
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Freshwater Creek
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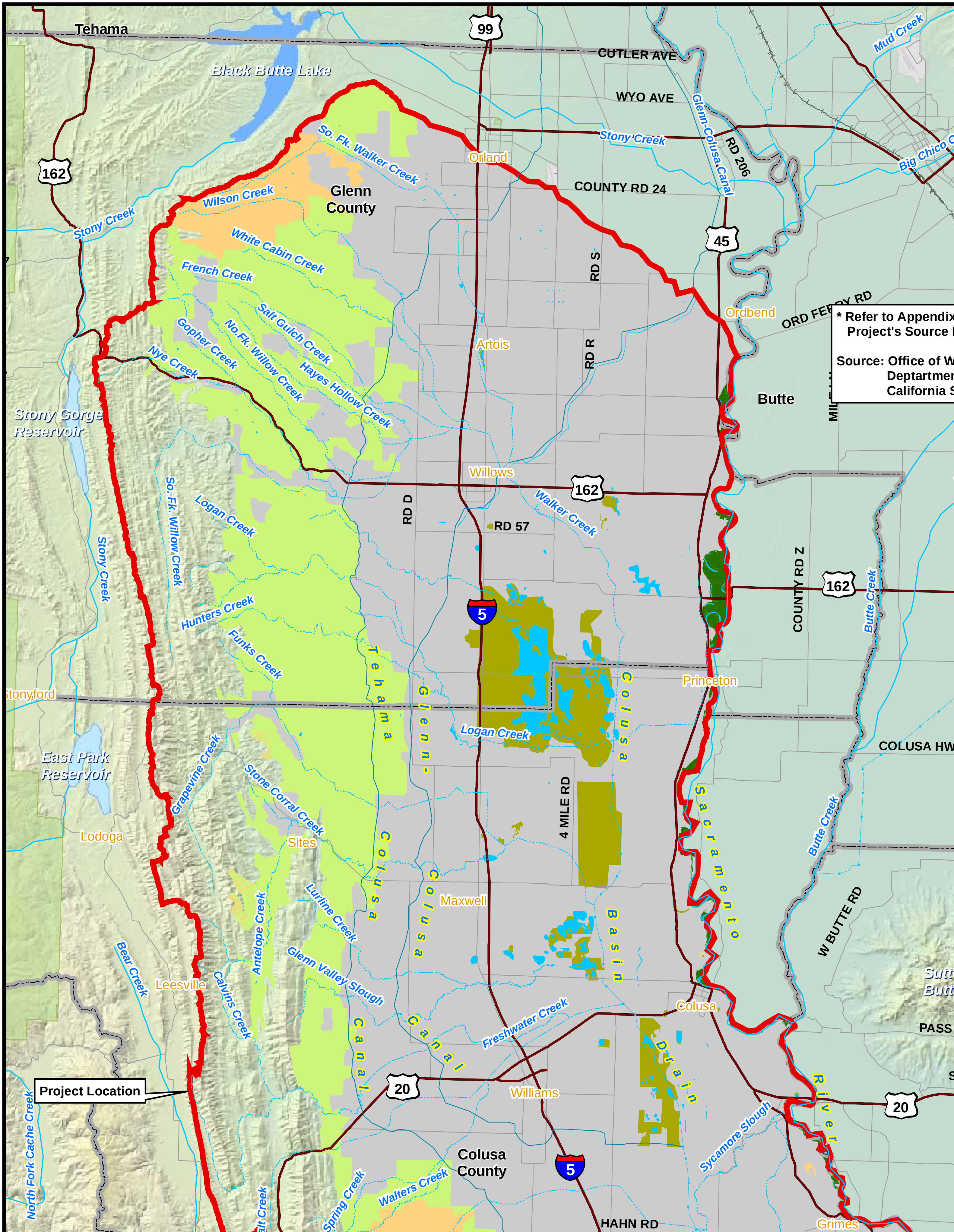
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Princeton
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Logan Creek
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Grapevine Creek
Stone Corral Creek
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Lurline Creek
Basin
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Bear Creek
Glenn Valley Slough
Leesville
Calvins Creek
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Colusa
Freshwater Creek
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Walters Creek
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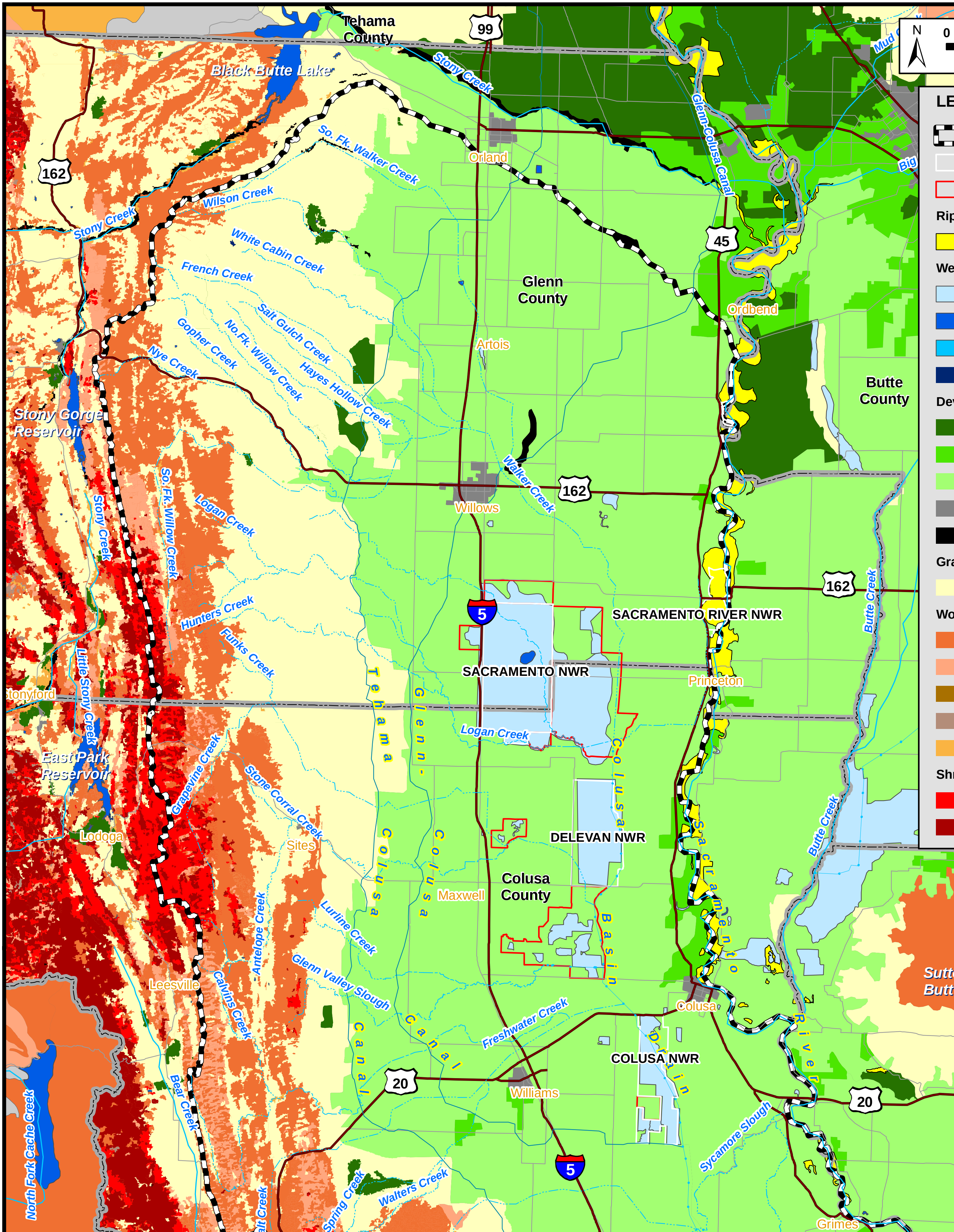
Grimes



Tehama County
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Orland
Glenn-Colusa Canal
162
Wilson Creek
Stony Creek
White Cabin Creek
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French Creek
Glenn County
Salt Gulch Creek
Gopher Creek
No.Fk. Willow Creek
Ordbend
Artois
Nye Creek
Hayes Hollow Creek
Butte County
Stony Gorge Reservoir
Walker Creek
162
Willows
So. Fk. Willow Creek
Stony Creek
Logan Creek
162
5
SACRAMENTO RIVER NWR
Butte Creek
Hunters Creek
Funks Creek
SACRAMENTO NWR
Princeton
Little Stony Creek
Tehama
Glenn-
Logan Creek
Colusa
East Park Reservoir
Grapevine Creek
Stone Corral Creek
Lodoga
Sites
DELEVAN NWR
Sacramento
Butte Creek
Colusa
Colusa
Maxwell
Colusa County
Antelope Creek
Lurline Creek
Basin
Glenn Valley Slough
Leesville
Calvins Creek
Colusa
Freshwater Creek
Canal
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River
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Bear Creek
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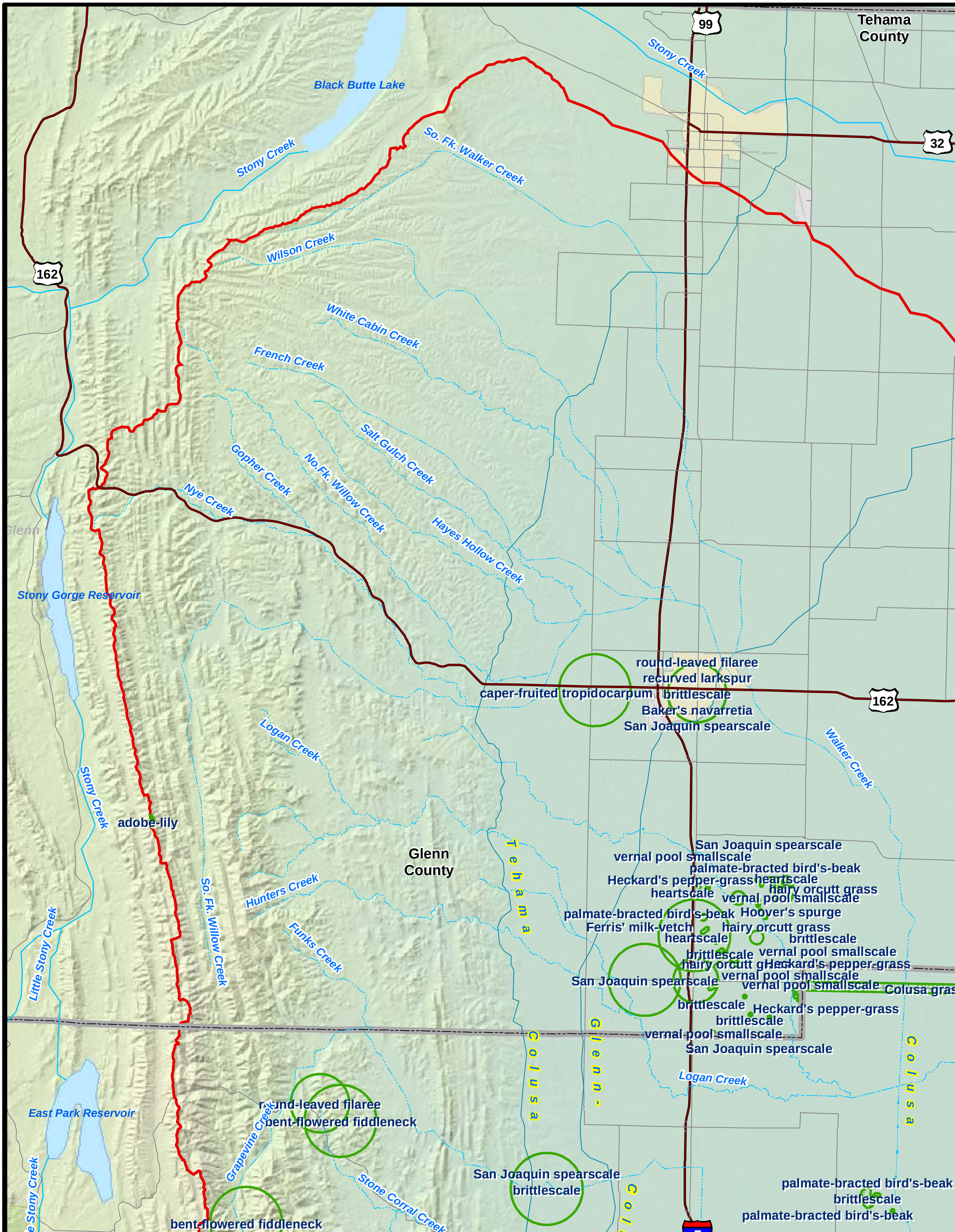
Walters Creek
Spring Creek
Grimes


Tehama County
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Black Butte Lake
32
So. Fk. Walker Creek
Stony Creek
Wilson Creek
162
White Cabin Creek
French Creek
Salt Gulch Creek
Gopher Creek
No.Fk. Willow Creek
Nye Creek
Hayes Hollow Creek
Glenn
Stony Gorge Reservoir
round-leaved filaree
recurved larkspur
caper-fruited tropidocarpum
brittlescale
162
Baker's navarretia
San Joaquin spearscale
Logan Creek
Walker Creek
Stony Creek
adobe-lily
Glenn County
T e h a m a
San Joaquin spearscale
vernal pool smallscale
palmate-bracted bird's-beak
Heckard's pepper-grass
heartscale
hairy orcutt grass
vernal pool smallscale
Hunters Creek
So. Fk. Willow Creek
palmate-bracted bird's-beak
Ferris' milk-vetch
Hoover's spurge
hairy orcutt grass
Funks Creek
brittlescale
vernal pool smallscale
Heckard's pepper-grass
Little Stony Creek
San Joaquin spearscale
vernal pool smallscale
Colusa gras
Heckard's pepper-grass
brittlescale
vernal pool smallscale
San Joaquin spearscale
C o l u s a
G l e n n -
C o l u s a
Logan Creek
East Park Reservoir
round-leaved filaree
bent-flowered fiddleneck
Grapevine Creek
San Joaquin spearscale
brittlescale
Stone Corral Creek
palmate-bracted bird's-beak
brittlescale
palmate-bracted bird's-beak
bent-flowered fiddleneck
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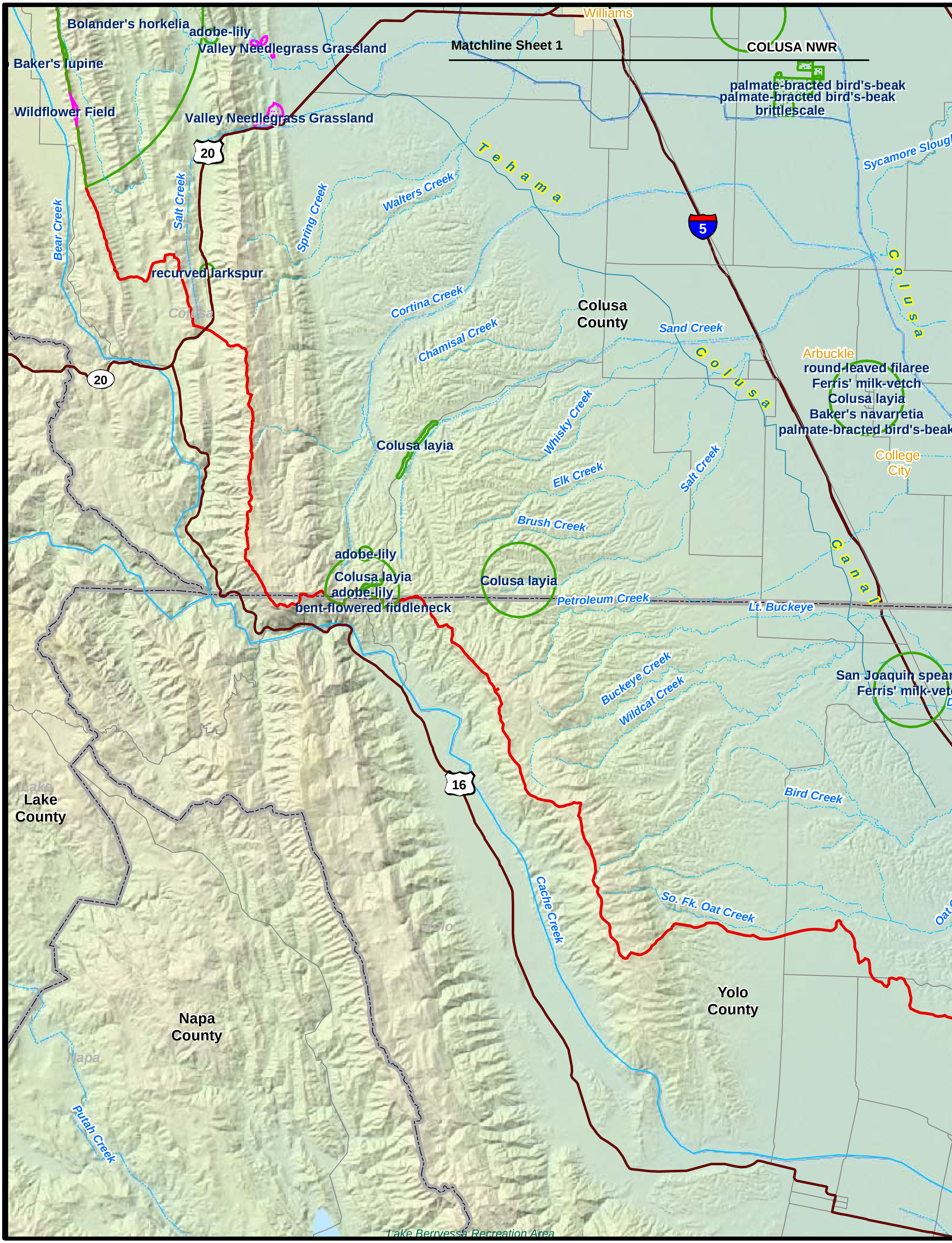
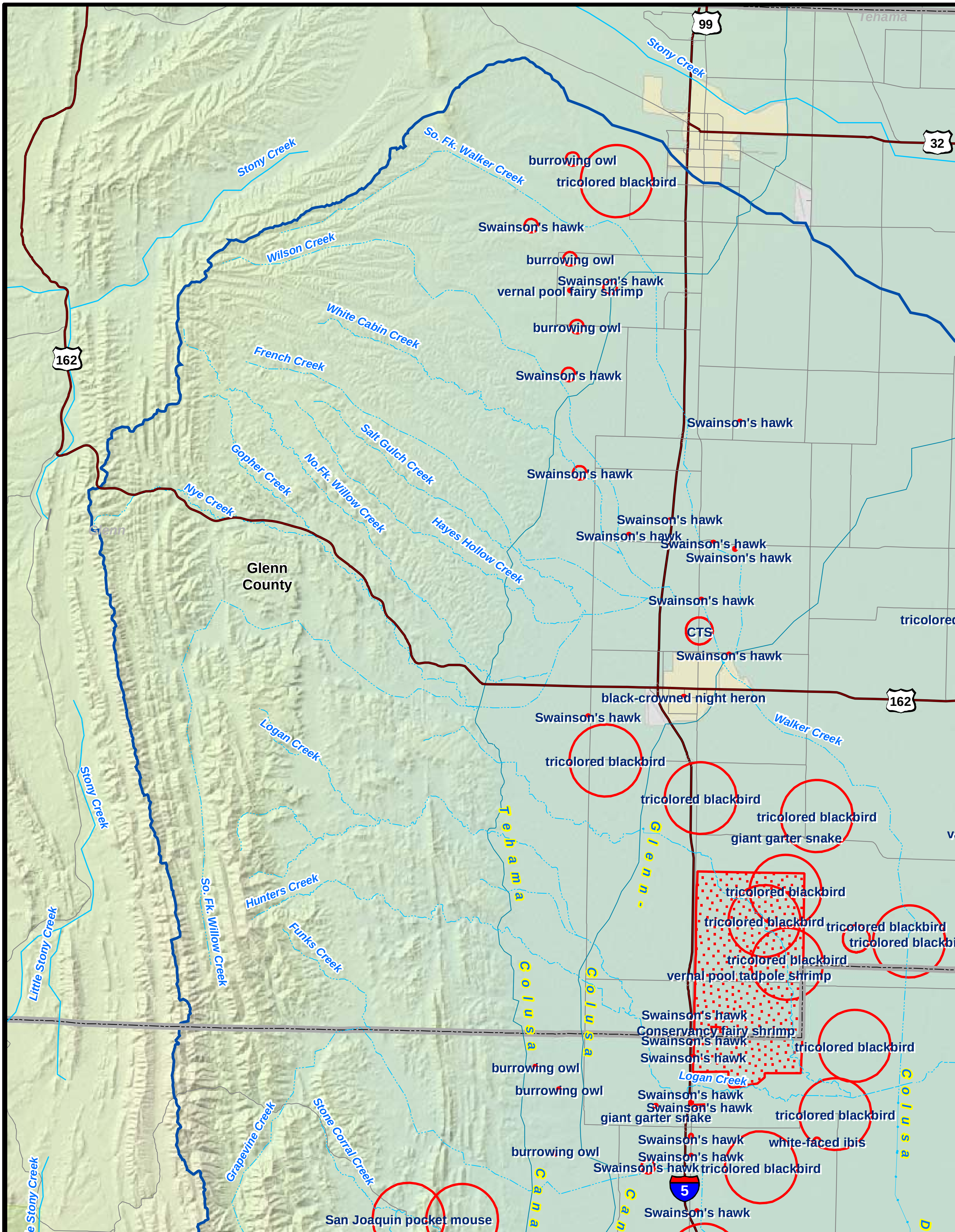
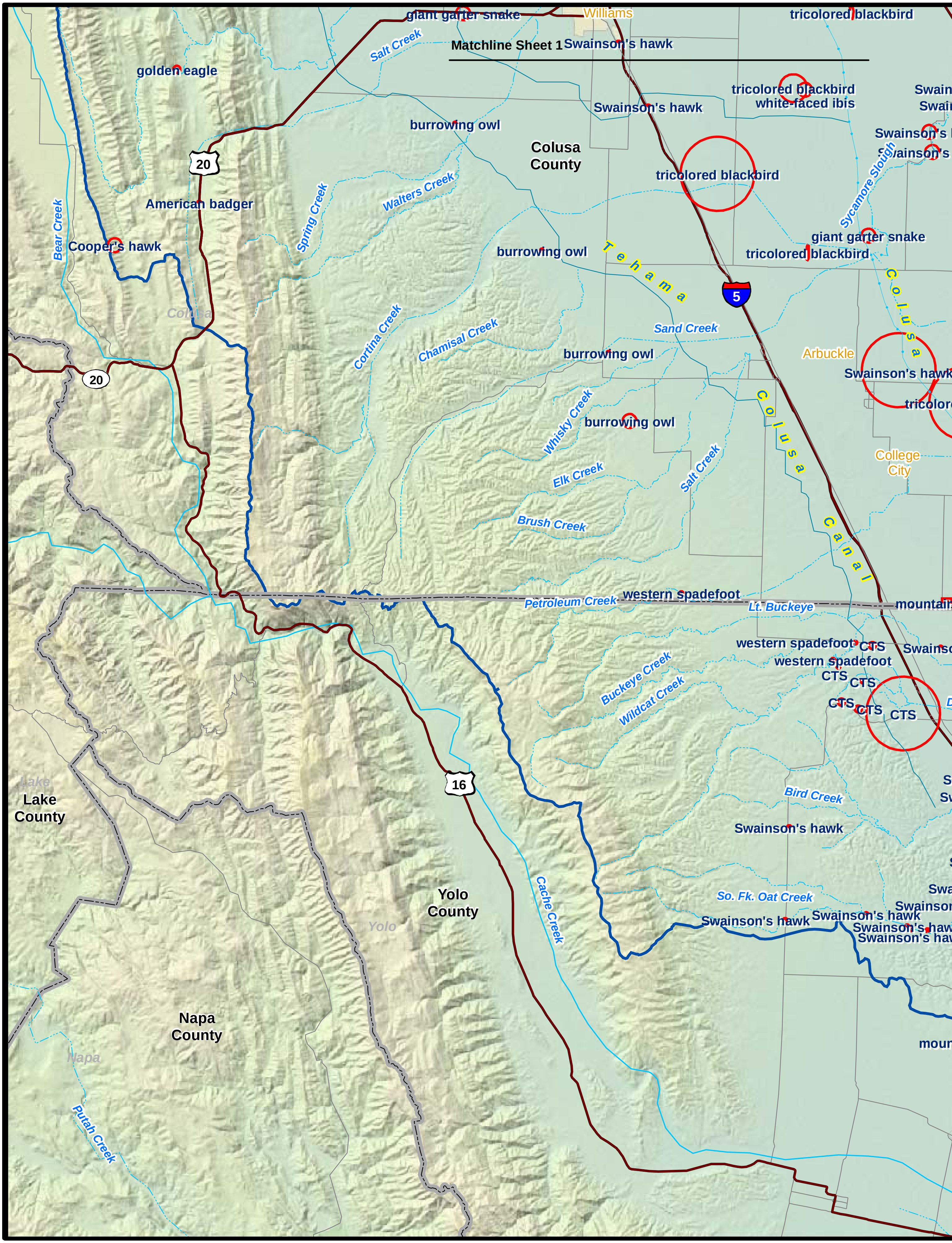


Matchline Sheet 1
Williams
COLUSA NWR
Bolander's horkelia
adobe-lily
Valley Needlegrass Grassland
Baker's lupine
Wildflower Field
Valley Needlegrass Grassland
palmate-bracted bird's-beak
palmate-bracted bird's-beak
brittlescale
Sycamore Slough
20
Salt Creek
Bear Creek
Spring Creek
Walters Creek
Tehama
5
recurved larkspur
Colusa
Cortina Creek
Colusa County
Sand Creek
Chamisal Creek
Colusa
20
Arbuckle
round-leaved filaree
Ferris' milk-vetch
Colusa layia
Baker's navarretia
palmate-bracted bird's-beak
Whisky Creek
Colusa layia
Elk Creek
Salt Creek
College City
Brush Creek
adobe-lily
Colusa layia
adobe-lily
Colusa layia
bent-flowered fiddleneck
Petroleum Creek
Lt. Buckeye
Canal
Buckeye Creek
Wildcat Creek
16
Bird Creek
Lake County
Cache Creek
So. Fk. Oat Creek
Yolo
Yolo County
Napa County
Napa
Putah Creek
Lake Berryessa Recreation Area



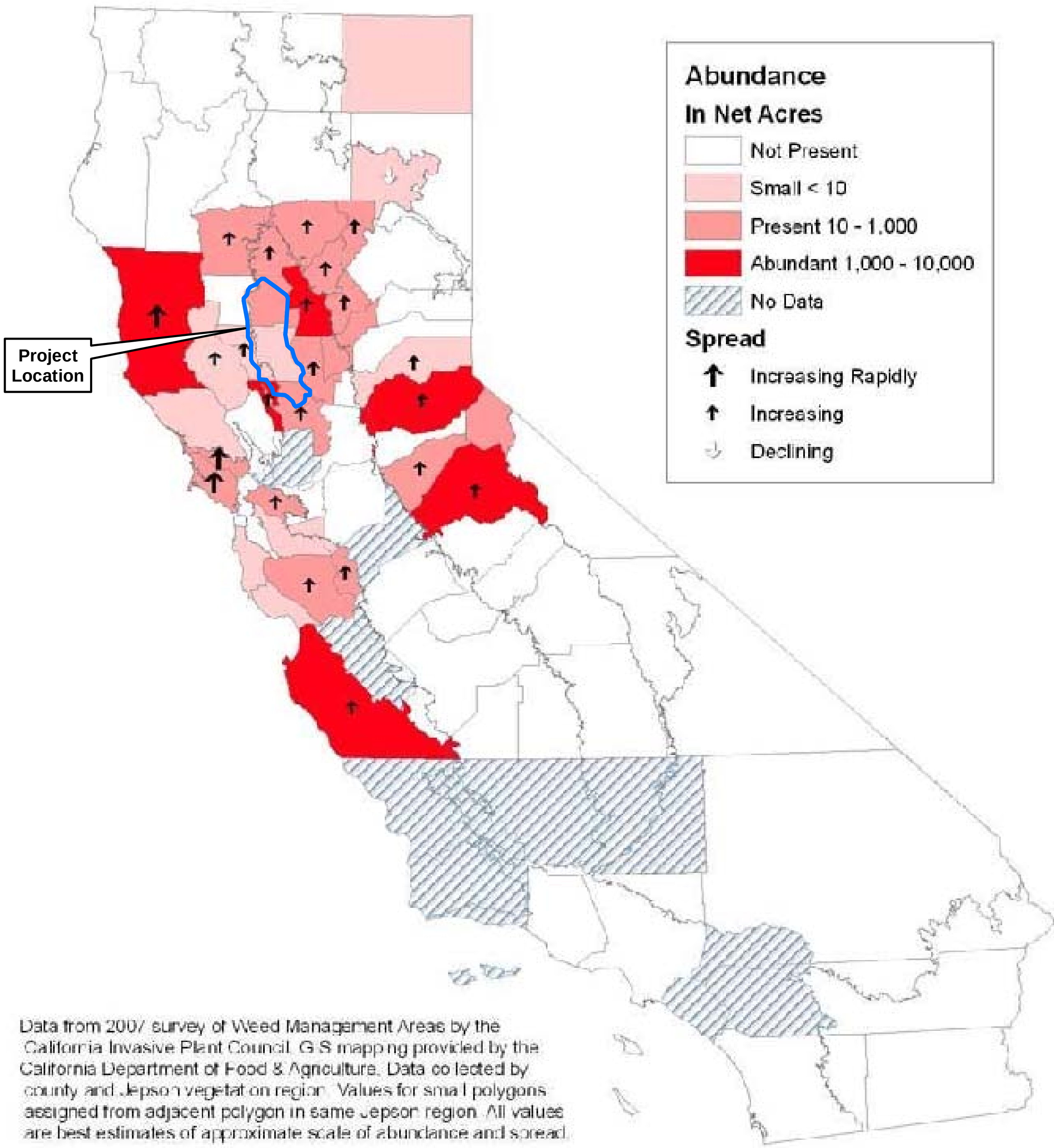
Tehama
99
Stony Creek
32
Stony Creek
So. Fk. Walker Creek
burrowing owl
tricolored blackbird
Swainson's hawk
Wilson Creek
burrowing owl
Swainson's hawk
vernal pool fairy shrimp
White Cabin Creek
burrowing owl
162
French Creek
Swainson's hawk
Swainson's hawk
Salt Gulch Creek
Gopher Creek
No.Fk. Willow Creek
Swainson's hawk
Nye Creek
Glenn
Swainson's hawk
Hayes Hollow Creek
Swainson's hawk
Swainson's hawk
Swainson's hawk
Glenn County
Swainson's hawk
tricolored
CTS
Swainson's hawk
162
black-crowned night heron
Swainson's hawk
Walker Creek
Logan Creek
tricolored blackbird
Stony Creek
tricolored blackbird
tricolored blackbird
Tehama
Glenn -
giant garter snake
Hunters Creek
tricolored blackbird
So. Fk. Willow Creek
tricolored blackbird
tricolored blackbird
Little Stony Creek
Funks Creek
tricolored blackbird
Colusa
Colusa
tricolored blackbird
vernal pool tadpole shrimp
Swainson's hawk
Conservancy fairy shrimp
Swainson's hawk
tricolored blackbird
Swainson's hawk
burrowing owl
Logan Creek
Colusa
burrowing owl
Swainson's hawk
Swainson's hawk
giant garter snake
tricolored blackbird
Grapevine Creek
Stone Corral Creek
Swainson's hawk
white-faced ibis
burrowing owl
Swainson's hawk
Swainson's hawk
tricolored blackbird
Stony Creek
5
Canal
Can
Swainson's hawk
San Joaquin pocket mouse



Matchline Sheet 1
giant garter snake
Williams
tricolored blackbird
Swainson's hawk
Salt Creek
golden eagle
tricolored blackbird
white-faced ibis
Swainson's hawk
burrowing owl
Colusa County
20
American badger
Spring Creek
Walters Creek
tricolored blackbird
Sycamore Slough
Bear Creek
Cooper's hawk
burrowing owl
Tehama
giant garter snake
tricolored blackbird
5
Colusa
Cortina Creek
Chamisal Creek
Sand Creek
burrowing owl
Arbuckle
Swainson's hawk
20
Whisky Creek
burrowing owl
Colusa
College City
Elk Creek
Salt Creek
Brush Creek
Canal
Petroleum Creek
western spadefoot
Lt. Buckeye
western spadefoot
CTS
western spadefoot
CTS
CTS
CTS
CTS
CTS
Buckeye Creek
Wildcat Creek
Lake
Lake County
16
Bird Creek
Swainson's hawk
Yolo County
Yolo
Cache Creek
So. Fk. Oat Creek
Swainson's hawk
Swainson's hawk
Napa County
Napa
Putah Creek

# *Aegilops triuncialis*

## barb goatgrass




**H. T. HARVEY & ASSOCIATES**
*ECOLOGICAL CONSULTANTS*

**Colusa Basin Watershed Assessment: Barbed Goatgrass**

| | | |
|---|---|---|
| Proj No. **2850-01** | Date **Dec. 2008** | Figure **9 - Biology** |

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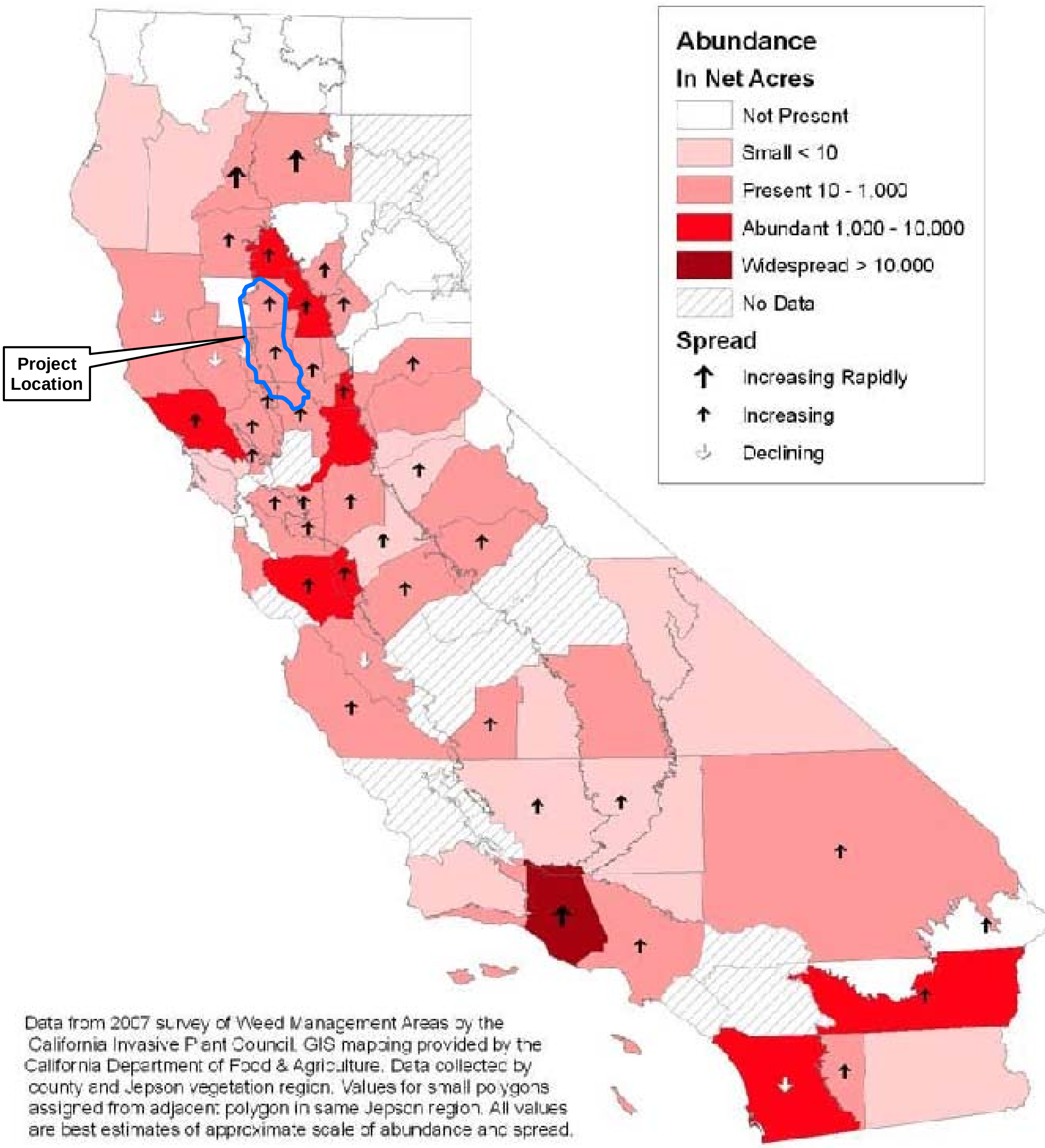
# *Arundo donax*
## giant reed




Data from 2007 survey of Weed Management Areas by the California Invasive Plant Council. GIS mapping provided by the California Department of Food & Agriculture. Data collected by county and Jepson vegetation region. Values for small polygons assigned from adjacent polygon in same Jepson region. All values are best estimates of approximate scale of abundance and spread.

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

**Colusa Basin Watershed Assessment: Giant Reed**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 10 - Biology |
|---|---|---|
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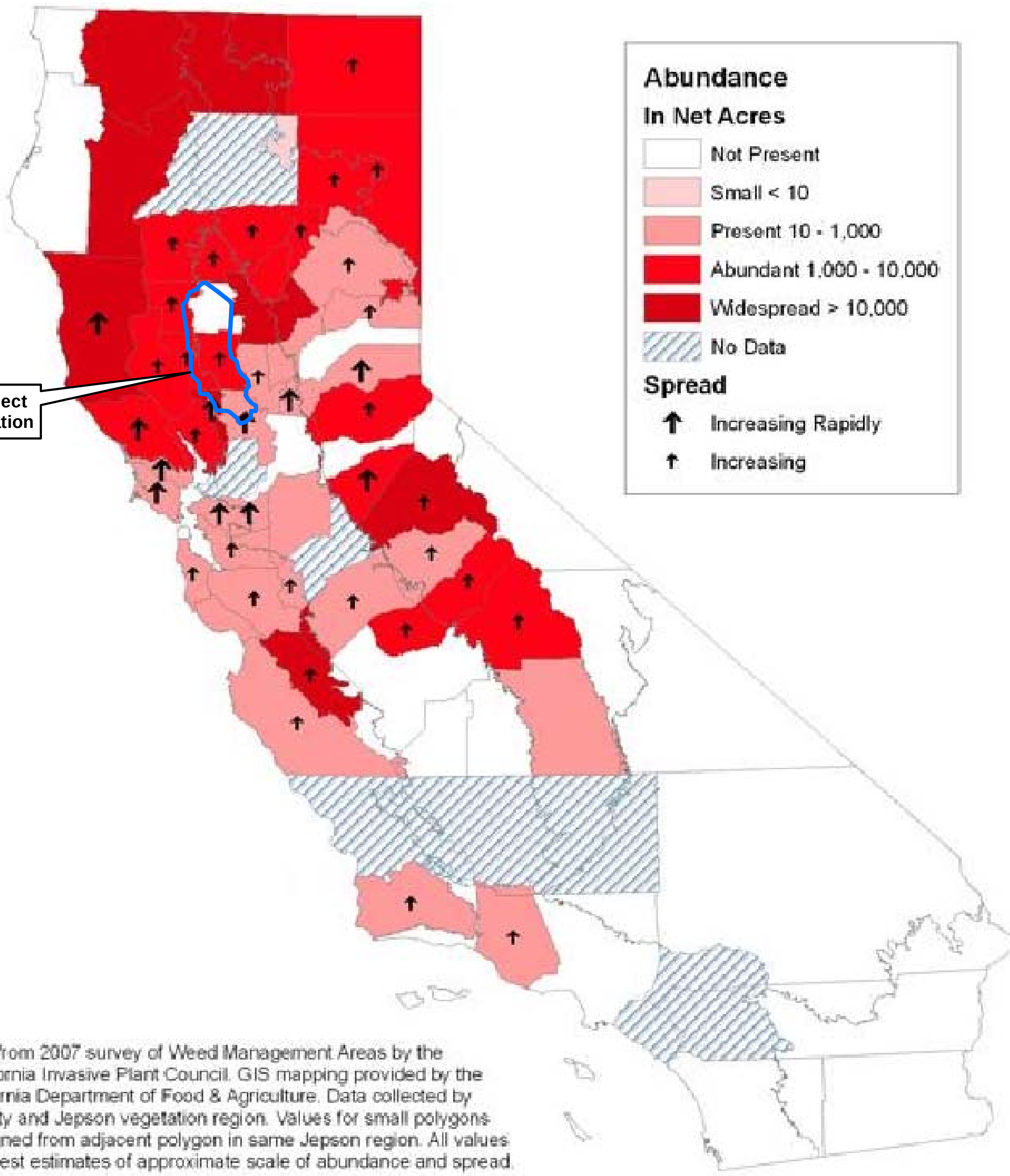
# *Taeniatherum caput-medusae*

medusahead




Data from 2007 survey of Weed Management Areas by the California Invasive Plant Council. GIS mapping provided by the California Department of Food & Agriculture. Data collected by county and Jepson vegetation region. Values for small polygons assigned from adjacent polygon in same Jepson region. All values are best estimates of approximate scale of abundance and spread.

H. T. HARVEY & ASSOCIATES
ECOLOGICAL CONSULTANTS

**Colusa Basin Watershed Assessment: Medusahead**

| Proj No. 2850-01 | Date Dec. 2008 | Figure 11 - Biology |
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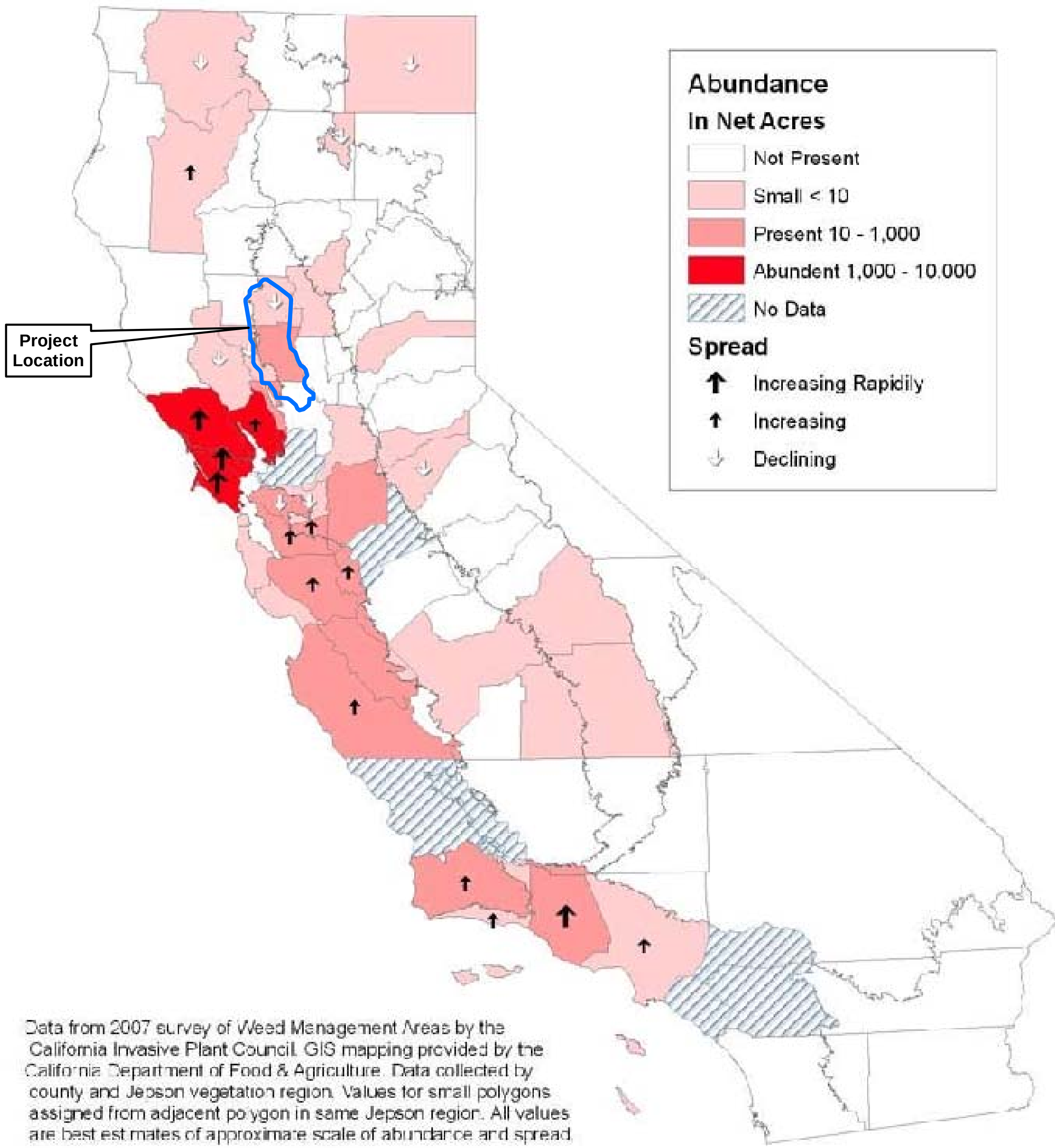
# *Centaurea calcitrapa*

## purple starthistle

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*ECOLOGICAL CONSULTANTS*

**Colusa Basin Watershed Assessment: Purple Starthistle**

| Proj No. **2850-01** | Date **Dec. 2008** | Figure **12 - Biology** |
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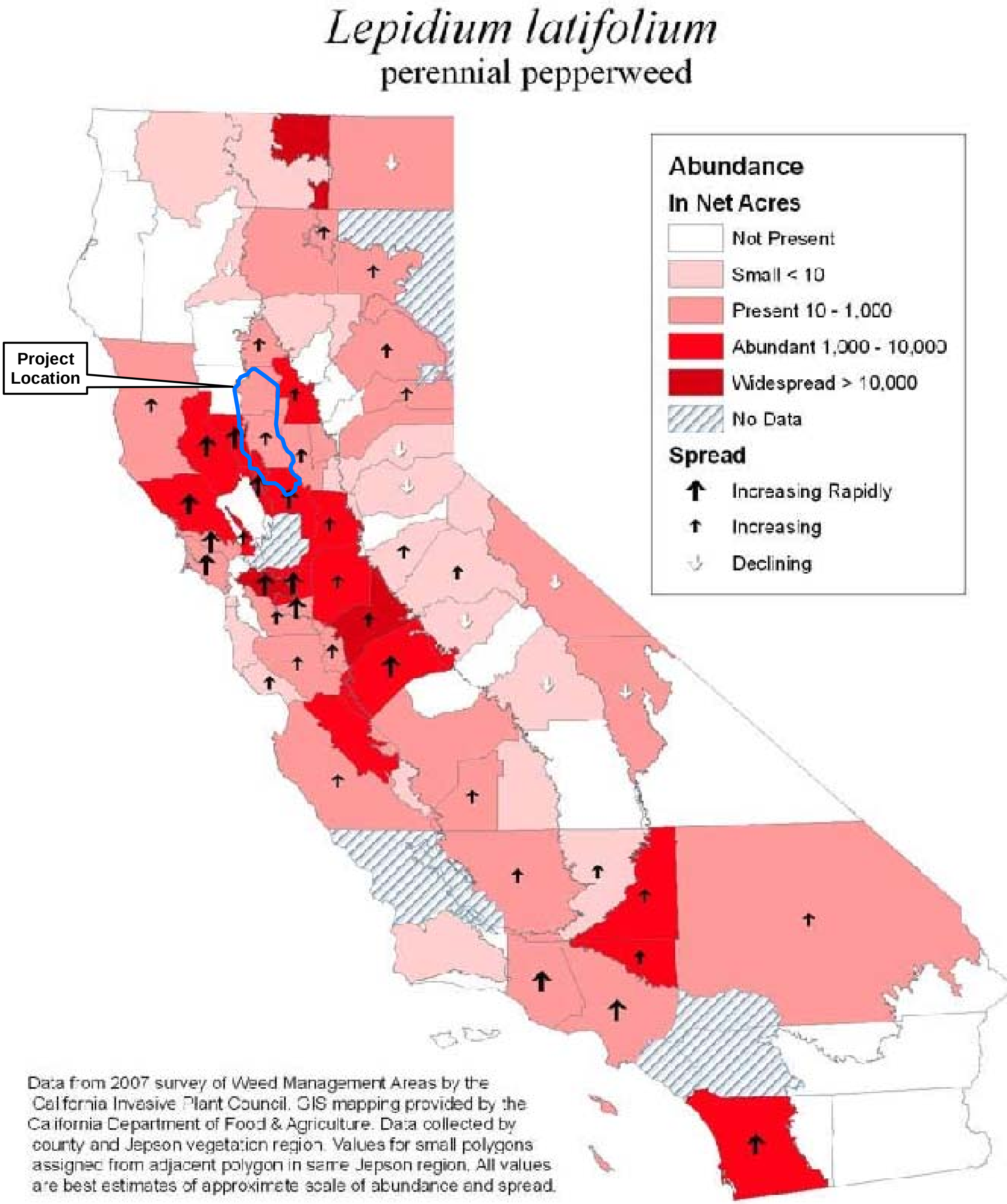


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**Colusa Basin Watershed Assessment: Perennial Pepperweed**

| | | |
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| Proj No. **2850-01** | Date **Dec. 2008** | Figure **13 - Biology** |

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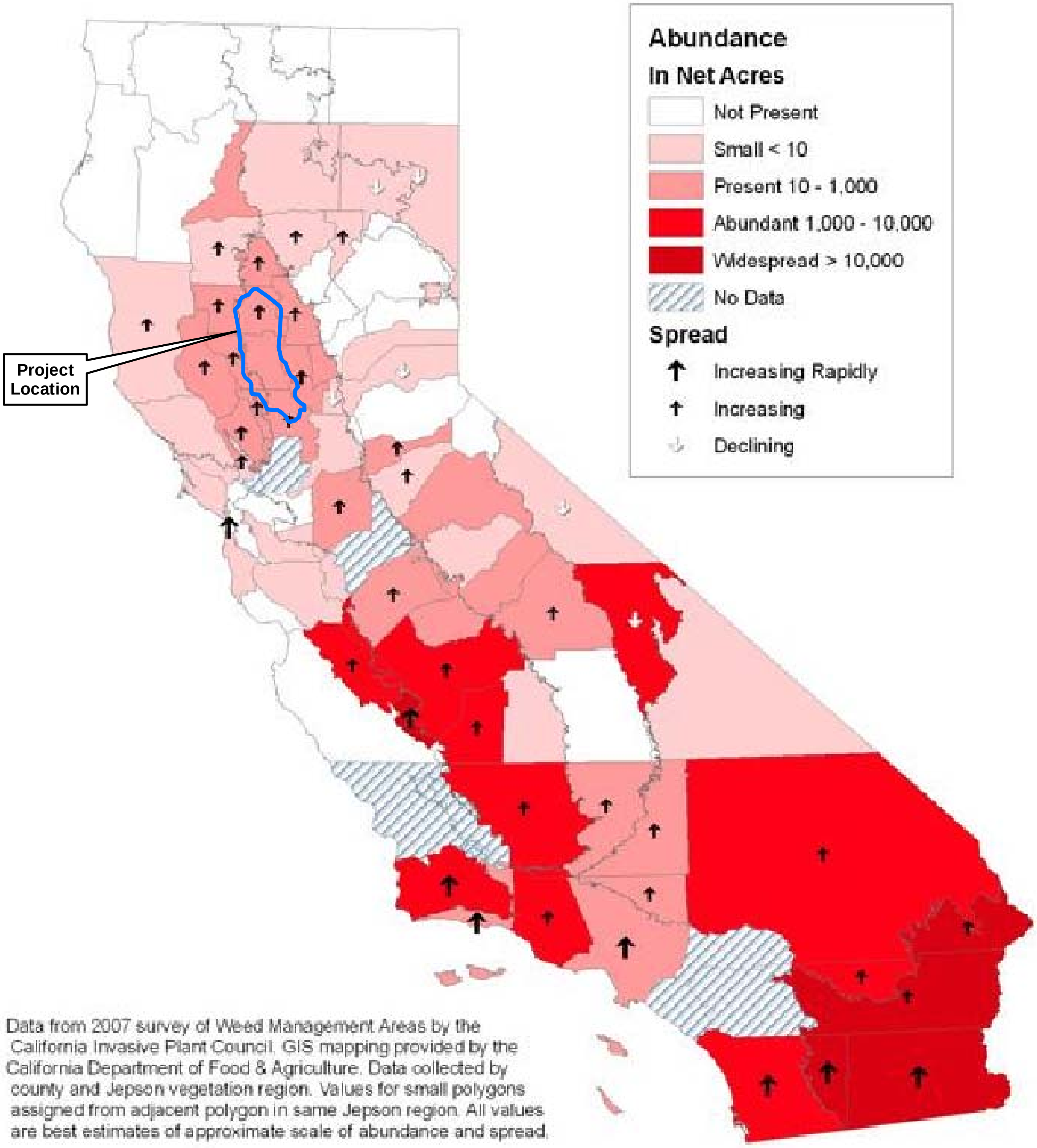
# *Tamarix ramosissima*

saltcedar, tamarisk




Data from 2007 survey of Weed Management Areas by the California Invasive Plant Council. GIS mapping provided by the California Department of Food & Agriculture. Data collected by county and Jepson vegetation region. Values for small polygons assigned from adjacent polygon in same Jepson region. All values are best estimates of approximate scale of abundance and spread.

**H. T. HARVEY & ASSOCIATES**
*ECOLOGICAL CONSULTANTS*

**Colusa Basin Watershed Assessment: Saltcedar**

| | | |
|---|---|---|
| Proj No. **2850-01** | Date **Dec. 2008** | Figure **14 - Biology** |

**SM** **N:/Projects/2850-01/Figures/April 2008**

# DATA GAPS

The following section identifies data gaps. We have selected the data and information gaps that would be the most useful to fill to inform the next phase of integrated watershed management planning.

## LAND-USE

### Updated General Plans for each County in the Watershed

Updated general plans for each county in the watershed will provide updated population growth projections and will present the preferred alternatives for growth and development. As a result of the plans and policies presented in the next generation of county general plans, portions of the Colusa Basin Watershed will experience some land conversion, which will both affect and be affected by issues related to stormwater management, groundwater use, flood control, habitat protection, and agricultural protection. Many of these issues are also central stakeholder concerns for this Watershed Assessment and presumably for future watershed planning. Therefore, there will be opportunities to integrate future watershed management planning with each county's comprehensive land-use planning actions.

This data gap should be filled by the proposed work of the counties within the watershed, provided they each update and adopt their renewed general plans according to schedule. The current Yolo County general plan dates to 1983, with a revised version due out in 2008 (Yolo County Community Development Agency 1983). The Colusa County general plan was adopted in 1989 with a horizon of 20 yrs (to 2010), but its housing element was updated in 2003. The remainder of this plan will be due for a revision to cover the 2010-2030 time period. The latest version of the Glenn County general plan was completed in 1993 and it was conceived as a 20 yr plan to be renewed in 2012 (QUAD Consultants 1993). It is also currently under revision.

## GEOMORPHOLOGY

### Fluvial Geomorphology for Stream Restoration and Bank Stabilization Design

**Digital High-resolution Color Ortho Photos and Digital Topographic Contour Elevation Map (Air Photo DEM).** The most useful database to acquire for fluvial geomorphic assessment and inventory work along the foothill streams and the Colusa Basin Drain would be a set of digital color orthophotos overlain by 1-ft interval topographic contours. These have multiple potential uses from hydraulic modeling and floodplain mapping for flood control alternatives, to riparian corridor mapping, restoration, management, and monitoring (discussed below). These would also document a baseline condition of the geomorphology of watershed lands. With its generally sparse tree cover, the Colusa Basin Watershed is well suited to digital topographic mapping using high-resolution aerial photos. For example, accurate stream cross-section and longitudinal bed profiles could be extracted directly from the DEM using Auto-Cad or ArcViewGIS. The DEM could be overlain with property boundary data so that site topographic maps could be quickly viewed and extracted for conceptual project design purposes, facilitating the preparation of grant applications to obtain funding for project design and construction.

# DATA GAPS

The following section identifies data gaps. We have selected the data and information gaps that would be the most useful to fill to inform the next phase of integrated watershed management planning.

## LAND-USE

### Updated General Plans for each County in the Watershed

Updated general plans for each county in the watershed will provide updated population growth projections and will present the preferred alternatives for growth and development. As a result of the plans and policies presented in the next generation of county general plans, portions of the Colusa Basin Watershed will experience some land conversion, which will both affect and be affected by issues related to stormwater management, groundwater use, flood control, habitat protection, and agricultural protection. Many of these issues are also central stakeholder concerns for this Watershed Assessment and presumably for future watershed planning. Therefore, there will be opportunities to integrate future watershed management planning with each county's comprehensive land-use planning actions.

This data gap should be filled by the proposed work of the counties within the watershed, provided they each update and adopt their renewed general plans according to schedule. The current Yolo County general plan dates to 1983, with a revised version due out in 2008 (Yolo County Community Development Agency 1983). The Colusa County general plan was adopted in 1989 with a horizon of 20 yrs (to 2010), but its housing element was updated in 2003. The remainder of this plan will be due for a revision to cover the 2010-2030 time period. The latest version of the Glenn County general plan was completed in 1993 and it was conceived as a 20 yr plan to be renewed in 2012 (QUAD Consultants 1993). It is also currently under revision.

## GEOMORPHOLOGY

### Fluvial Geomorphology for Stream Restoration and Bank Stabilization Design

**Digital High-resolution Color Ortho Photos and Digital Topographic Contour Elevation Map (Air Photo DEM).** The most useful database to acquire for fluvial geomorphic assessment and inventory work along the foothill streams and the Colusa Basin Drain would be a set of digital color orthophotos overlain by 1-ft interval topographic contours. These have multiple potential uses from hydraulic modeling and floodplain mapping for flood control alternatives, to riparian corridor mapping, restoration, management, and monitoring (discussed below). These would also document a baseline condition of the geomorphology of watershed lands. With its generally sparse tree cover, the Colusa Basin Watershed is well suited to digital topographic mapping using high-resolution aerial photos. For example, accurate stream cross-section and longitudinal bed profiles could be extracted directly from the DEM using Auto-Cad or ArcViewGIS. The DEM could be overlain with property boundary data so that site topographic maps could be quickly viewed and extracted for conceptual project design purposes, facilitating the preparation of grant applications to obtain funding for project design and construction.

**Stream Bank Condition Inventory and Restoration Project Prioritization.** No inventories have been made of the channelized, armored, and still intact sections of the foothill streams. Inspection of the 1:24,000 scale 1993-1999 air photos underlying the Colusa Basin Soil Survey maps reveal numerous locations where the riparian corridor appears relatively intact and the active channel and streambanks are presumably in a relatively natural condition. These features would be more accurately identified and screened using the Air Photo DEM described above. Using such an Air photo DEM as a field base map, these features could be mapped and evaluated using RTK GPS field inventory survey of the foothill stream corridors. Such a detailed survey overlay could be designed to have multiple objectives and resource management benefits. Topographic data collected under the stream canopy and along the toes of steep banks could be input into the surface model comprising the DEM so that topographic contours could be refined as necessary along the stream corridors. Mapped intact stream sections could be used as analogs for future stream restoration project design. Flood high water marks and debris lines could be mapped as input data for hydraulic models and proxy design discharge data for stream restoration projects. Bank erosion could be inventoried and correlated with the exposure of variously consolidated alluvial deposits (geologic units) exposed in the stream banks, and the effects of channelization and revetments.

Priority stream bank stabilization and stream and floodplain restoration projects could be identified and catalogued by the survey for future refinement and prioritization. Vegetation features could be mapped in detail and these polygons and point data could be viewed in their geomorphic context.

Landowner willingness to allow such a survey might be encouraged by landowner site interviews during the process of the survey work; there is much value in the cumulative landowner experience with channel modifications and maintenance work. Landowner experience should be considered as part of any future efforts to restore sections of the foothill streams.

**Historical Geomorphic Analysis**. The best repository of historical stream condition are the early air photos of the basin combined with field observations of geomorphic processes. Examining the earliest high quality set of 9” x 9” orthopair black and white air photos is recommended first to determine what information is available about the fluvial geomorphology of the foothill streams prior to much of the channelization and other riparian corridor modification that have taken place after 1850. For example, such an analysis combined with follow up field assessments could provide the best available information for documenting the timing and rate of channel bed incision. 1927 photos covering the watershed lands might be held at the Shields Library at UC Davis.

## HYDROLOGY

### Mean Daily Flow Data

Compared to other regions and large watersheds in California, the Colusa Basin watershed has very few historical streamflow data. Beginning now to collect mean daily flow data for some of the foothill streams would prove helpful anywhere stream restoration and riparian vegetation establishment work will occur in the future. It may make most sense to collect these data nearer the downstream ends of the foothill streams where riparian corridor restoration efforts generally might be more successful both because the groundwater table is naturally nearer to the streambed elevation and seepage from applied irrigation water may be helping to sustain baseflows or wet conditions through the summer. Such data would represent baseline stream-groundwater conditions for evaluating success of any future groundwater recharge projects. It would be sensible to locate pressure-transducer type stage gages on bridge abutments at existing road crossings because stream banks are generally subject to frequent erosion and modification by landowners.

In the absence of new stream gage data, hydrologic conditions affecting stream bank and riparian corridor restoration project design and success can be indirectly assessed using groundwater monitoring wells to the extent that stream-groundwater interactions are understood (discussed below).

**Peak Flow Data**

The watershed also has very few historical annual peak flow data. Presently peak flow data are collected at only one gage: South Fork Willow Creek near Fruto under operations resumed by DWR after the 1998 flood. New peak flow data on foothill streams would be very helpful for stream restoration design, but landowner accounts might substitute for this purpose. New data may be more useful for refining the evaluations of potential flood management projects for mitigating crop damage incurred by summer and winter flooding along the Colusa Basin Drain. DWR (1990) recommended a list of first priority and second priority new gaging stations that is a good starting point for discussion.

**Water Budget**

The most recently compiled irrigation season water budget may be that of DWR (1990). A more recent water budget would be helpful for water supply planning purposes. It may not be feasible to prepare a reliable winter season or total annual water budget because there is presently only one gage collecting peak flow data.

DWR published semi-annual groundwater monitoring well data for about 98 wells in the Colusa Basin Watershed. These data are available for analysis. It may be helpful to prepare current Spring and Fall groundwater contour elevation maps for comparison to the 1975 and 1988 maps in DWR (1990) to understand groundwater elevation trends for planning groundwater management actions. This work is presumably being accomplished by the groundwater management plan efforts in each of the counties.

**Flood Management**

DWR (1962, 1964, 1990), CBDD, and USBR (Navigant Consulting, Inc. 2000; CH2MHill 2003), and many other miscellaneous engineering reports have compiled a lot of information over time in preparing and evaluating various combinations of potential flood protection measures in the watershed. Not all of the available information was obtained and reviewed in preparing this assessment.

Future flood management efforts would undoubtedly benefit greatly from generating the Air Photo DEM data described above. These data could be used to update the topography of historically inundated areas along the Colusa Basin Drain. The Air Photo DEM would probably also reveal the presence and configuration of new levees and other features affecting drainage. Bathymetry of the Colusa Basin Drain could be acquired using traditional surveying methods or possibly more efficiently using a boat-mounted depth sounding device and a boat-mounted RTK-GPS transceiver, and these data could be input into the surface model of the Air Photo DEM to improve its accuracy for the purposes of monitoring the need for and effects of channel dredging, and refining hydraulic models of the channel capacity.

The Air Photo DEM would also provide baseline channel condition data, located upstream and downstream from proposed or constructed foothill stormwater detention reservoirs. These data would facilitate monitoring and evaluation of potential geomorphic effects downstream from the dams.

The DEM data could be used as direct input data into hydraulic models of the foothill streams and could be used to measure channel conveyance capacity along their lengths and map floodplain surfaces. These channel capacities could be compared to calculated conveyance capacity at road and railroad crossings to identify and prioritize crossings needing enlargement.Water Quality

- Obtain more extensive groundwater quality data throughout the Colusa Basin to gain a better understand of where areas of lower quality water are located.
- Continue monitoring groundwater for nitrate.
- Monitor effectiveness of TMDLs as limits are implemented.
- Track pesticide use in the Colusa Basin to see if there are correlations or relationships with detections in water. Also look for relationships with changes in Best Management Practices.
- Increase water quality monitoring of Sacramento River tributaries in the watershed. Existing data is limited.

## BIOLOGY

### Vegetation

- Survey and map the extent of the following invasive plant species within riparian habitats and drainage canals: salt cedar, giant reed, and Ludwigia to provide further information for Weed Management Area coordinators.
- Identify locations of sensitive habitats (e.g., wetlands, riparian, sycamore alluvial woodland, oak woodland) that are currently not protected within NWR System or other conservation lands. Conduct a rapid assessment to characterize the functions and values of these sensitive habitat areas.

  Such survey work could be utilized not only to inform management planning, but also to identify reference sites for habitat restoration projects; sites which have been less impacted by human activities and could potentially serve as models for restoration project design. Characterization of such reference sites could help to determine target ecosystem goals for ecological restoration projects (e.g., target topography, soils, hydrology, and plant community composition). For example, during this assessment we observed potential riparian habitat reference sites for foothill streams along Brush Creek (upstream of Boles Road), along the North Fork of Elk Creek, and along Elk Creek (upstream of the Hillgate Road crossing).

- Conduct a study to determine where riparian corridor improvements would be most efficiently supported by targeted groundwater recharge. The net effect of groundwater pumping and irrigation imports has likely been to raise the natural groundwater table nearer to or above the bed elevation of the foothill streams in the lower elevation reaches, near the valley flat. This effect could benefit riparian corridor restoration projects by providing shallow groundwater conditions conducive to the establishment of obligate, riparian vegetation. Future groundwater recharge projects could be designed to help restore riparian habitat by targeting recharge in foothill stream reaches lying immediately upstream from sufficiently wetted reaches.

**Wildlife**

Knowing the exact location of special-status wildlife species would enable proper assessments of potential project impacts. These assessments could be used for planning project locations, schedules and mitigation measures that would reduce these potential project impacts. It would also provide reference sites for future habitat restoration designs and enable coordinated planning to help maximize conservation benefits to special-status species.

**Analyze and Summarize Existing Special-status Species Data for the Watershed.** Much information and location data for many special-status species, excluding data in the California Natural Diversity Database, are not readily available and have not been summarized for the Colusa Basin Watershed and as such, signify a data gap. Many of these data exist as subsets of larger data sets and have not been summarized by the data-gathering institutions/agencies for the Colusa Basin Watershed. Other data have not yet been made available to the public. The task of identifying, collating and summarizing all of the potential data is a daunting task that may take many weeks to accomplish, provided that these data were readily available to the watershed assessment team.

The following are examples of existing data that could be collated and summarized for the watershed. There are data on the relative abundance of bird species in the national wildlife refuges in the Colusa Basin. Waterfowl counts are conducted each year along with nongame and upland gamebird surveys. Biologists from the Sacramento National Wildlife Refuge system have conducted a limited amount of surveys for Yellow-billed Cuckoos. There is also a dataset from point counts of birds from Point Reyes Bird Observatory that may include a few riparian locations within the Colusa Basin Watershed. Data from a recent Black Tern survey by PRBO should be incorporated. Additionally, recent statewide surveys for nesting Swainson's Hawks, Burrowing Owls and Tricolored Blackbirds and wintering Long-billed Curlews have been conducted and data for the watershed should be available once these survey reports are published. However, these surveys were not comprehensive and may have missed many areas within the watershed. There may be additional data on giant garter snakes occurrences in the watershed that have not been uploaded into the CNDDB yet, and these would need to be included.

**Collect New Data on Special-status Wildlife Species Habitat and Population Distributions.** There does not appear to be much recent data on the relative abundance of special-status wildlife in the watershed outside of the national wildlife refuges and the Dunnigan Hills area and the following are representative of the types of basic locational data gaps thus far:

- locations of California Tiger Salamanders and their potential habitat outside of the Dunnigan area;
- locations of other vernal pool species such as vernal pool fairy shrimp, vernal pool tadpole shrimp, and western spadefoot toad;
- locations of areas with large stands of elderberry shrubs that provide important habitat for the valley elderberry longhorn beetle.
- locations where western pond turtles are successfully reproducing;
- locations and sizes of current Bank Swallow breeding colonies;
- nesting locations of special-status raptors outside of the national wildlife refuges;
- important Greater and Lesser Sandhill Crane wintering areas outside of the national wildlife refuges;
- locations and relative abundance of Grasshopper Sparrow;
- locations of riparian habitat patches that are occupied by or suitable for Yellow-billed Cuckoo, Purple Martin, Yellow-breasted Chat and California Yellow Warbler.

# WATERSHED ACTION ITEMS

## NEXT STEPS TOWARD DEVELOPMENT OF A WATERSHED MANAGEMENT PLAN

As noted in the Introduction section, the CCRCD has a successful history of assisting landowners with land stewardship projects throughout the Colusa Basin Watershed; however, these projects were not necessarily linked to a comprehensive conservation and management strategy for the Colusa Basin Watershed. Therefore, the CCRCD intends to develop a management plan for the Colusa Basin Watershed to identify and prioritize projects that are "best for the watershed" and locally driven. This Watershed Assessment is the first step in this process and has compiled and interpreted existing information for the watershed in a single document.

The following section provides general recommendations for initiation of the future management planning process and summarizes stakeholder concerns as a basis for developing the planning goals.

### Preparation of an Integrated Watershed Management Plan

We recommend the preparation of an Integrated Watershed Management Plan (IWMP) for the Colusa Basin Watershed. Adopting the watershed as the planning area facilitates the successful management of water-related resources and issues because the management unit (i.e., the watershed) is the natural boundary of water flow as opposed to more arbitrary property and governmental boundaries. An "integrated watershed management" approach facilitates productive dialogue among local stakeholders within the watershed (e.g., landowners, water districts, non-profit groups, cities and counties, state and federal regulatory agencies) to establish a clear set of management goals and develop collaborative, innovative solutions/projects to achieve those goals. The solutions of an IWMP strive to balance environmental, economic, and social concerns (i.e., triple bottom line). An "integrated" approach involves developing interdisciplinary solutions that serve multiple objectives and are based upon a sound, scientifically-based understanding of physical and ecosystem processes. For example, projects that reconnect floodplains to creek channels (at appropriate landscape locations) can reduce flooding, reduce downstream channel/bank erosion, increase groundwater recharge, and improve riparian habitat quality and quantity.

California's Watersheds, Clean Beaches, and Water Quality Act of 2002 (AB 2534) established the states' Integrated Watershed Management Program to improve water quality, habitat, fisheries, water supply reliability, flood management, river corridor recreation, forest and fuels management, hydropower management, and for controlling erosion and sedimentation. The California Resources Agency and California Environmental Protection Agency established the California Watershed Council in 2003 to implement this program. The Integrated Watershed Management Program provides grant programs for the development of IWMPs and for the implementation of projects based on IWMPs. The reader is directed to the California Watershed Portal for more information on this program (http://cwp.resources.ca.gov/cwc_about.html).

An Integrated Watershed Management Planning process for the Colusa Basin Watershed should involve the following basic elements:

- Establish a workgroup of key stakeholders to guide the preparation of the management plan. The workgroup should include representatives of local land owners and land users from all three counties and statewide groups such as: County RCDs, CA Rice Commission, County Extension Advisors, County Planning Departments, Drainage Districts, and Agricultural Commissioners. In addition, it will be essential for the workgroup to also include those government agencies that will have regulatory authority over future projects and/or have resource management responsibilities that overlap with the planning goals. Such agencies include the various water/irrigation districts, DWR, RWQCB, CDFG, USFWS, and USACE.
- Create a Memorandum of Understanding, signed by the workgroup members, to ensure their commitment to participation and collaboration.
- Facilitate the workgroups' establishment of a focused, well-defined, and achievable set of watershed management goals and measurable objectives. The goals should address the workgroups top land management concerns, while preserving and restoring natural watershed resources and processes. This is a critical step in the process.
- As part of the goals development process, the workgroup should determine how the IWMP process will interface with the existing major planning processes in the Colusa Basin Watershed including County and City General Plan Updates, the Colusa Basin Drainage District's Integrated Resource Management Program for Flood Control, and the Yolo, Colusa, and Glenn County Groundwater Management Planning process. In other words, will this IWMP serve as a vehicle for integrating all or a subset of the above planning processes with broader watershed-scale goals that reach beyond strictly flood control, groundwater management and development planning? Or will the IWMP serve to fill "holes" in the above, existing planning processes?
- Fill those data gaps necessary to conceptualize and prioritize projects to achieve the workgroups goals and objectives.
- Formulate a suite of proposed projects (at a broad, conceptual level) that achieve the workgroup's goals and objectives. For each project, identify a project leader from the workgroup, partnering agencies and landowners, environmental review/permitting requirements, estimate the duration, and provide planning-level cost estimates. Group certain projects into programs, if appropriate.
- Prioritize the proposed project/program list. This process will then serve as a basis for the acquisition of funds to implement the management plan. Consider pilot projects where there is considerable uncertainty in the science to predict results and to get actions started on the ground.
- Include consideration of the potential future effects of global warming, population increases, and development on the watershed

**Initial Identification of Stakeholder Resource Issues and Goals**

As noted in the Watershed Action Items section, establishing focused, achievable goals among workgroup members will be an initial and critical step in developing a successful IWMP. As a preliminary step in this process, stakeholder concerns were identified both via public meetings and stakeholder interviews during this assessment. **Appendix 3-Introduction** provides summaries of the individual stakeholder interviews. **Table 1-Watershed Action Items** summarizes the stakeholder resource concerns and related goals/objectives that have been identified (these concerns have not yet been prioritized). These resource issues and preliminary goals can serve as a starting place for the future workgroups' development of the management plan goals and objectives.

**Table 1. Watershed Action Items. Preliminary Identification of Stakeholder Resource Issues and Goals.**

| Resource Issue | Preliminary Goals and Objectives |
|---|---|
| Water Quality and Soil Erosion | • Improve water quality<br>• Identify water quality issues and recommend water quality control measures for urban and rural areas<br>• Educate landowners to help control non-point source pollution<br>• Recommend and implement best management practices for agricultural and rangeland areas to reduce soil erosion and associated sediment loading into drainages |
| Flood Control | • Reduce flooding along the Colusa Basin Drain and other floodprone areas<br>• Assess the status and functionality of degrading flood control infrastructure (e.g., drainage canals, ditches, canal banks, levees)<br>• Find ways to allow floodwaters onto floodplains without damaging crops, homes, and infrastructure.<br>• Determine the cumulative effects of existing wetland and riparian restoration projects on flooding<br>• Protect banks/levees of ephemeral streams: reducing localized flooding<br>• Improve infiltration ability of flood-prone areas and natural drainages<br>• Identify (geographically) where natural channels have been removed (through land leveling, etc.) and identify its effect upon storm runoff and localized flooding<br>• Compensate farmers whose rice land is used for off stream storage<br>• Develop and implement measures to control runoff in foothills, orchards, rice fields, rangelands and on all other agricultural lands |
| Agricultural Land Preservation | • Preserve as much prime Agricultural land as is reasonably possible<br>• Minimize development on floodplains and highly productive agricultural lands<br>• Limit 10 ac splits<br>• Restrict development to the surrounding incorporated areas and sphere of influence of existing towns<br>• Have development fees pay the true costs of new services |

| Resource Issue | Preliminary Goals and Objectives |
|---|---|
| Weed Control | • Control invasive plant species that compete with beneficial species that provide better erosion protection and habitat<br>• Map the distribution of invasive plants species and develop a strategy for control (e.g., salt cedar, arundo, purple star thistle, medusa head, silver leaf nightshade, etc.)<br>• Educate landowners regarding the ecology of invasive weeds and how to manage them |
| Regulatory Agency Interface on Projects | • Improve cooperation between regulatory agencies to resolve conflicting input on projects<br>• Strike an effective balance between environmental and economic interests to maintain the economic viability for farmers and counties<br>• Work with the economic goals established at the county level<br>• Sustainably manage oak woodland habitats |
| Rice Straw | • Develop effective straw removal techniques<br>• Develop effect straw storage techniques<br>• Develop programs to assist growers with straw related operations<br>• Develop and support uses for large amounts of rice straw<br>• Establish a cellulose/ethanol Technical Advisory Committee to brainstorm ideas. |
| Air Quality | • Improve air quality<br>• Plant more permanent crops to provide soil protection thereby greatly reducing the amount of dust and smoke in the air |

## EXAMPLE PROJECT IDEAS

During the course of this assessment, we began to identify potential projects that could address some of the stakeholder concerns. Since the watershed planning goals will not be formalized until the management plan is underway, the following merely provides examples of a few potential projects. The purpose of this list is simply to provide preliminary examples of projects that could come out of an integrated planning process.

### Foothill Streams — Creek Bank Stabilization and Riparian Habitat Restoration Projects

1. Brush Creek at Boles Road: Creek bank erosion and a lack of riparian vegetation cover were noted at this location. The following steps could be taken at various locations along this reach:
    - Establish small setback from creek bank (15-30 ft) which would not require removal of orchard to facilitate live oak woodland revegetation along the top of bank to minimize future bank erosion and improve habitat conditions.
    - Widen active channel to a sustainable width and revegetate graded slopes
    - Layback creek bank and apply bioengineering solutions
2. Elk Creek at Hillgate Road Crossing: Creek bank erosion was observed downstream of the road crossing. The creek banks could be graded to a gentler slope and revegetated with native riparian species.

**Oak Woodland Habitat Management**

- The CCRCD has recently developed an Oak Woodland Management Plan. Elements of this plan could be integrated into the future Colusa Basin Watershed Management Plan.
- Explore the potential to purchase conservation easements to protect intact stands of oak woodland habitat.

**Wetland and Riparian Management and Restoration Projects**

- Assess opportunities to expand the NRCS Wetland Reserve Program within the watershed by identifying appropriate sites and willing landowners.
- Anticipate mitigation requirements for proposed flood control detention basins and initiate restoration site search, site selection criteria, and overall strategy on a watershed basis. The USACE and EPA recently issued a final rule setting forth new guidelines for compensatory mitigation for aquatic resource impacts that emphasize watershed-based approaches to mitigation (USACE/EPA 2008)
- Work with residents of the watershed that are experiencing flooding problems who may be interested in exploring the feasibility of voluntary ecological restoration opportunities on their land that could minimize soil loss, loss of arable land, and provide flood control relief.
- Survey and inquire with local stakeholders about the status of remnant historic slough channels that may be supporting riparian habitat and provide strategies for management and enhancement of these riparian habitats (e.g., Sycamore Slough contains remnant stands of Sycamore Alluvial Woodland Habitat).

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**PERSONAL COMMUNICATIONS**


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Alderson, J. 2008. Agricultural Engineer, Colusa County Natural Resources Conservation Service. Personal communication regarding native plant species occurring in the chaparral community. Communication via comments on draft Colusa Basin Watershed Assessment-Existing Conditions Section.

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**Appendix 1. Introduction.**
**List of Acronyms and Abbreviations**

**Acronyms and Abbreviations.**

| | |
|---|---|
| AB | Assembly Bill |
| af | Acre-feet |
| ARP | Archeological Research Program |
| ASAR | Adjusted Sodium Absorption Rate |
| BDAT | Bay Delta and Tributaries |
| BDCM | bromodichloromethane |
| BLM | Bureau of Land Management |
| BMP | Best Management Practices |
| CAL FIRE | California Department of Forestry and Fire Protection |
| CA-GAP | California Gap Analysis Project |
| CA-IPC | California Invasive Plant Species Council |
| CaSIL | California Spatial Information Library |
| CBDD | Colusa Basin Drainage District |
| CCP | Comprehensive Conservation Planning |
| CCRCD | Colusa County Resource Conservation District |
| CEQA | California Environmental Quality Act |
| CESA | California Endangered Species Act |
| cfs | Cubic feet per second |
| CNDDB | California Natural Diversity Data Base |
| CNPS | California Native Plant Society |
| Coalition | Sacramento Valley Water Quality Coalition |
| CPA | Community Planning Areas |
| CRC | California Rice Commission |
| CSU | California State University |
| CWAM | California Watershed Assessment Manual |
| CWA | Clean Water Act |
| DBCM | Dibromochloromethane |
| DFG | California Department of Fish and Game |
| DO | Dissolved oxygen |
| DOF | California Department of Finance |
| DPR | California Department of Pesticide Regulation |
| DWR | California Department of Water Resources |
| EC | Electrical conductivity |
| EIR | Environmental Impact Report |
| EIS | Environmental Impact Statement |
| EO | Element occurrence |
| EPA | Environmental Protection Agency |
| FESA | Federal Endangered Species Act |
| FMMP | Farmland Mapping and Monitoring Program |
| FRAP | Fire and Resources Assessment Program |
| GGRCD | Glenn County Resource Conservation District |
| IRMP | Integrated Resource Management Plan |
| IWMP | Integrated Watershed Management Plan |
| MBTA | Migratory Bird Treaty Act |

| | |
|---|---|
| MCL | maximum contaminant level |
| MRPP | Monitoring and Reporting Program Plan |
| NAS | National Academy of Sciences |
| NAWQA | National Water Quality Assessment Program |
| NCWA | Northen California Water Association |
| NMFS | National Marine Fisheries Service |
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | National Resource Conservation Service |
| NTU | Nephelometric Turbidity Units |
| NWR | National Wildlife Refuge |
| OEHHA | California Office of Environmental Health Hazard Assessment |
| OP | Organophosphate |
| ppb | Parts per billion |
| PUD | Public Utilites District |
| RD | Reclamation District |
| RUSLE | Revised Universal Soil Loss Equation |
| RWQCB | California Regional Water Quality Control Board |
| SERCAL | Society for |
| SC | Specific conductance |
| SDSU | San Diego State University |
| SS | Suspended soils |
| SWRCB | State Water Resources Control Board |
| TAC | Technical Advisory Committee |
| taf | thousand acre-feet |
| TCA | Trichloromethane |
| TDS | Total dissolved solids |
| THM | Trihalomethane |
| TIE | Toxicity Identification Evaluation |
| TMDL | Total Maximum Daily Load |
| UC | University of California |
| ULL | Urban Limit Line |
| USACE | U.S. Army Corps of Engineers |
| USBR | U.S. Bureau of Reclamation |
| USDA | U.S. Department of Agriculture |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geologic Survey |
| USLE | Universal Soil Loss Equation |
| VOC | volatile organic chemical |
| WA DOE | Washington State Department of Ecology |
| WDL | Water Data Library |
| WHR | Wildlife Habitat Relations System |
| WMA | Wildlife Management Area |
| ybp | Years before present |

**Appendix 2. Introduction.**
**Technical Advisory Committee Members**

**Technical Advisory Committee Members**

| | |
|---|---|
| **Alderson, Jack**<br>Agricultural Engineer<br>Natural Resources Conservation Service<br>Colusa Field Office<br>100 Sunrise Boulevard, Suite B<br>Colusa, CA 95932<br>Jack.Alderson@ca.usda.gov<br>Ph: (530) 458-2931 x118 | **Casey, Andrea**<br>District Conservationist<br>Natural Resources Conservation Service<br>Colusa Field Office<br>100 Sunrise Boulevard, Suite B<br>Colusa, CA 95932<br>Andrea.Casey@ca.usda.gov<br>Ph: (530) 458-2931 x112 |
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**Appendix 3. Introduction.**
**Stakeholder Interview Summaries**

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Jack Alderson, Agricultural Engineer, Colusa County NRCS

**Interviewer:** Matt Smeltzer, Engineer/Geomorphologist with Geomorph

**Date:** 11 October 2007

*This interview was made as a half-day in person discussion focused on geomorphology and historical changes of Basin streams, including review of historical maps and air photos for selected sites, and a follow-up half-day*

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- This question was not specifically asked, but he highlighted several issues focused on his areas of expertise (hydrology, soil-plant community relationships, stream restoration, bank erosion, etc.), with the primary focus probably being on management of stream corridors within agricultural lands to promote greater bank stability and native riparian vegetation establishment, and addressing ongoing bank erosion problems where streams have been realigned and ditched along the road grid.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- This question was not specifically asked, but for example, he said that tree crops have become more prevalent along the western edge of the Basin where dryland crops were previously dominant.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- This question was not specifically, asked, but he offered that the Arbuckle area in the southern part of the Basin didn't have row crops and rice growing, so the streams weren't used for irrigation diversion and tailwater, resulting in more natural sediment transport continuity and more ephemeral hydrology.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- He said that chamise and blue oak woodland came farther down into the Basin valley flat lands in the southern part of the Basin, probably because of the different soils. For example, the Cooper Monograph of shrubs in California mentions Arbuckle.
- He highlighted that there are very few remnants of the pre-development stream corridors and representative vegetation left in the Basin.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- This question was not asked.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- This question was not asked.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- He said that the foothill streams on the southern part of the Basin are more ephemeral than the foothill streams to the north, and this difference has been exaggerated to some extent by the greater prevalence of irrigated row crops to the north.
- He said that most of the Basin valley flat lands were a permanent and seasonal wetland under pre-development conditions, with streams like Sycamore Slough being the primary surface drainage for those wetlands.
- He said that the Back Levee and Drain causes “back flooding” (stormwater ponding) upstream (to the west).
- He said that recent prohibition of burning rice straw has led to more winter time flooding of rice straw and reduction in flood storage available on rice lands for attenuating floods, exacerbating flooding elsewhere.
- He said that Maxwell and Williams have flooding problems, and Colusa does also, mostly along the fringes.
- He said that there is more flooding on the downstream end of the foothill streams both because of the back-flooding effect of the Drain/Back Levee and the shallow depositional nature of the streams, as has been exacerbated possibly by the extent to which the upstream channels have been narrowly confined, causing more coarse-grained sediment to transport farther downstream than under pre-development conditions.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- He provided numerous examples of sites where there has been ongoing or recent bank erosion, typically resulting from channelization, confinement between artificial banks and levees, channel realignment and ditching along the rectilinear road grid, and in some cases resulting from streams having been "farmed over" in releveling the land.
- He said that there is a 10-ft high headcut on Sand Creek at Sand Creek Road crossing and some of the recent downcutting may have been due to sand and gravel extraction from the Creek several miles downstream near Cortina School Road.
- He said that there are ongoing erosion problems along the south side of Hahn Road caused by the streams being realigned and confined in a narrow ditch along the road.
- Etc.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- This question was not asked.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- This question was not specifically asked, but he said in general:
  - Improved techniques for native plant establishment at stream restoration sites
  - Stream conveyance capacity vs. peak floods for foothill streams
  - Representative pre-development plant community and stream-floodplain form concepts for use as restoration endpoint.

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Bob Alvernaz, Current CCRCD Director (1970-2008), long-time farmer/rancher

**Interviewer:** Max Busnardo and Matthew Ramsay, with H. T. Harvey & Associates

**Date:** 27 November 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- See below for the issues. In particular

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- Conversion of foothill lands (dryland farming) to Almond Orchards is a big change due to economics (e.g., increases in the cost of living). Almonds earn far more than dryland farming. Drainage within these orchards causes erosion.
- These lands had been dry for years/dryland farmed until the Tehama-Colusa Canal was constructed which now provides a water source to support irrigated orchards. This change in the water regime has led to substantial soil erosion- see soil erosion question below for more information.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- Rice- they used to run a lot of water through the rice fields (short retention time). Now due to water quality concerns the RWQCB requires longer holding times to allow for natural decomposition of the pesticides.
- Years ago all the rice straw was burned which prevented disease problems in rice (e.g., stem rot). So, now they need to apply fungicides. Now the Rice Research Board is developing new varieties of rice that are resistant to these diseases.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- Wetlands- he feels wetlands are adequately protected by the Clean Water Act.
- Riparian – Ranchers in the hills are undertaking projects to protect and restore riparian habitat (e.g., NRCS promotes riparian habitat protection and restoration
- *Oak woodlands- over ~ 60% has not been cut since he's been in the Basin. However, in the last 10 years oak woodlands have been getting clear cut due to economics (e.g., along Hwy 20); good money in oak firewood especially when cattle prices went down. He feels that this is a problem and there has been some backlash from the community- so he thinks that the clear cutting may be slowing down.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- *Giant reed and salt cedar are abundant in Colusa County and need to be controlled. CCRCD had an area meeting a few years ago- It is abundant from Hwy 99 east (e.g., Freshwater Creek, Spring Creek). Most abundant along a canal the Maxwell-Colusa Rd (which goes to Sites and Stonyford).
- Salt Cedar- being actively controlled along Cache Creek lead by Greg Thompson (UC Davis).
- Johnson grass- Is a big problem for rice farmers. Has started to colonize along Glenn-Colusa Canal, then expanding onto adjacent rice levees. Now Glenn-Colusa irrigation district has controlled it on the Canal banks, however it is difficult to control in rice.
- Yellow-flowering aquatic weed is a problem in rice fields. It likely was accidentally transferred from the Glenn-Colusa Canal to the adjacent rice fields via Glenn-Colusa irrigation district maintenance activities.
- Monocorum?- is a problem in rice.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- He's not a hunter and his ranch is outside of the Pacific Flyway
- Deer are not very abundant at his ranch west of Sites- they appear to have declined in the foothills. They are more abundant where there is more water- Almond orchards, rice fields, up by East Park Reservoir.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- *Flooding appears to have increased in the last few decades west of I5 (Freshwater Creek, Cortina Creek); He thinks that Hwy 99, and east of that the Railroad tracks (probably worst) and then I5 (which has better drainage that the former two); Production farming due to Tehama Colusa Canal has increased the soil moisture in the dry season (above the former dryland farming condition) which has increased runoff.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- Almond orchards probably more cause erosion than expected likely due to higher soil moisture at start of rainy season due to irrigation. More erosion RCD has a grant with CAFF to assess almond orchard erosion- 11 growers are participating (which likely includes older orchards). They plan to start utilizing cover crops. Older orchards (10-15 years old) in the Arbucle area may have greater erosion issues since these orchards.
- Croplands that are flood irrigated which led to erosion (e.g., tomatoes and wheat). Now they have a sediment trap. He would like to try utilizing polymers to help control erosion by increasing suspended sediment deposition.
- *In the rangeland hills near Sites, along Grapevine Creek he has observed high water and channel erosion.
- *He bought ranch in ~1971. He has observed substantial incision (~4ft) on an ephemeral drainage that has a small 40-60 ac watershed. This incision happened over approximately from 1970-2000. However, this phenomenon occurs throughout the foothills of the Basin.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- RWQCB and Cal Rice Commission is doing a good job of protecting the water quality downstream on Sacramento River.
- He had heard from someone that there was a mercury mine in the area of Sites.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

He wants the consultants to cover this.

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Roberta Firoved, Industry Affairs Manager with California Rice Commission

**Interviewer:** Max Busnardo, Project Manager with H. T. Harvey & Associates

**Date:** 9 November 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- Water availability and supply. Population in CA is growing and the need to share resources continues to grow. Rice is produced on ~500,000 acres in Sac Valley (among 9 continuous counties).
- Rice growers are concerned that future development will increase the competition for water.
- Set asides required of developers, but not well maintained could cause an influx of weeds not common in rice. This is a concern to growers.
- Low and high Dissolved Oxygen (DO) and low pH have been detected in all agricultural drains at low percentages. However, the cause of this potential problem has been difficult to identify. The California Rice Commission historical monitoring results show that DO and pH were dependent on temperature and flow, which were factors beyond the control of rice farmers.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- Rice grows on heavy clay soils which doesn't support other crops. If it's in rice it stays in rice.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- Rice growing started in Butte County ~100 years ago.
- It used to be common practice to burn stubble (since stubble breaks down slow due to the high silica content and fiber, and low humidity) but, due to air quality regulations, rice farmers cannot burn more than 25% of the farmed area. So now they employ the decomposition flooding method to get rid of the rice stubble. This method involves using

equipment stomp or chop the stubble followed by shallow flooding of the field to promote microbial decomposition.

- The remaining rice stubble and organic matter gets incorporated into the soil the next year when fields are prepped for planting. With rice straw being incorporated this will likely improve soil texture. Growers are reporting that they are using less N fertilizer than before the implementation of decomposition flooding. UC Davis researchers are currently conducting studies to determine why less N fertilizer is required.
- Water seeding = flying soaked seed over a prepped and flooded field. Growers still use granular herbicides via aerial application onto flooded fields. The newer herbicides are contact herbicides, which require water to be drawn down in field prior to application. This complicates water level management and sometimes increases water use. Therefore, rice farmers prefer granular herbicides

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- She didn't know.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- Watergrass has always been a persistent problem. "In Cal we grow good rice and good weeds!"
- They don't have a long list of herbicides and the herbicides used have a similar mode of action. As such, there is concern that resistant strains will evolve. The California Rice Commission is working with UC Davis to explore the potential benefits of alternating cultural practices on weed invasion (e.g., drill seeding alternated with water seeding).
- Weedy red rice found in Glenn County. There currently is not enough information to determine the significance of this problem to rice.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- Duck hunters are complaining that rice provides too much habitat and dilutes duck abundance! They flood ~300,000 out of the ~500,000 acres of rice in Sac Valley. In addition, the Sac Valley has been designated Shorebird Habitat of International Significance by the Manomet Center for Conservancy. .

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- She is not aware of any large changes over the last 20 years.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- She has not witnessed any erosion issues in the rice growing region of the basin. However, the California Rice Commission water sampling is located in the flatlands where erosion is not evident.
- Rice field drainage water is clear because the water is slowly discharged off of the field.
- Colusa Basin Drain has been murky from Carp that stir up the bottom.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- The California Rice Commission has 20 years of water quality data collected as part of the Rice-Pesticides Program. In ~1991, this program became part of the Regional Water Quality Control Board's Basin Plan. The Rice Commission manages the Irrigated lands Program (Ag Waiver) for the rice industry. The agricultural community wasn't historically regulated for water quality prior to Dec 2002. After that, the Regional Water Quality Control Board set forth a conditional waiver from discharge permit for irrigated lands. Otherwise individual farms would require permits. So the Rice-Pesticides Program was used as the basis for the structure of a commodity specific coalition to manage the Irrigated Lands Program.
- The California Rice Commision submits reports to the Regional Water Quality Control Board annually. The Rice Commission could provide copies of their annual reports to the Colusa County RCD, if requested.
- The Sacramento Valley Water Quality Coalition also prepares annual water quality monitoring reports in compliance with the Ag Waiver program for non-rice areas; these can be downloaded from the Northern California Water Association (NCWA) website; NCWA is the best source of valley-wide water quality information, excluding rice farms.
- The California Rice Commission believes that the rice industry has reduced pesticide loading to the Sacramento River by 99% over the last 20 years. In recent years, pesticides have been below detection limits in water samples. This has been

accomplished via management practices of Rice-Pesticides Program-1. developed water holding requirements in rice fields following pesticide application, as the number one factor responsible for reduced pesticide export from rice fields; 2. pesticides are being used less due to the concern that pests will evolve resistance over time; 3. reduced-risk pesticides are continually being developed and utilized; 4. monitoring program; 6. communications with membership; 7. close working relationships with growers, Regional Board, UC Davis researchers, and the pesticide industry.

- Rice growers no longer use organophosphate pesticides. Also, the majority of herbicides, and all fungicides are designated reduced-risk products by the EPA.
- The California Rice Commission funded some mercury monitoring in rice and did not find Hg problems. They are no longer monitoring for mercury. USGS has a mercury monitoring program in the Valley.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- She doesn't know of any data gaps other than those described above.

**Other Notes**

California is the second largest rice producing state in the Nation next to Arkansas which has 2mill acres. Cal rice is used for sushi, paella, risotto, beer, cereals, etc. in U.S. Japan is the largest export market for California rice. Cost of regulation doubles the cost of production in California.

## Colusa Basin Watershed Assessment Stakeholder Interview

**Stakeholder Interviewed:** John Garner, Current Colusa Basin Drainage District Director-District 2, longtime farmer in the basin 40+ years

**Interviewer:** Jennifer Masters, Colusa Basin Watershed Coordinator with Colusa County RCD

**Date:** 30 November 2007

**Question 1:** How do you think cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response 1:**

- Rice is main crop in the northeastern part of the basin. That hasn't changed much, and he doesn't anticipate it changing much because the price of rice at level it is at has good return.
- For the basin as a whole, however, there are more permanent crops going in and less row crops: cotton, tomatoes, beans, etc. There are still row crops just not as many and there has been a switch over to walnuts, almonds, and pistachios. The cause of this change is due to economics. Row crops take more water than permanent crops which makes profitability for permanent crops better. Drip and sprinkler vs. flood.
- On a side note: Alfalfa has become more evident due to increase in price.

**Question 2:** In your opinion, how have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response 2:**

- All management practices have changed. Mostly due to economics – water quantity. The west side is short on water through contractual agreements with the state and the top tier of water costs more, so farmers are trying to find crops that use less water or get better return on crop to pay for water, and different crops come with different management practices.
- The state prohibits the use of many chemicals for weed control. Plants become resistant to the chemicals used, so new chemicals are created that are more expensive. In farming rice; to apply chemicals they have to drain the field, spray the chemical on, and flood field again. This process uses more water which leads to increased expenses.
- Also, rice species have changed from past species. Rice used to be 6' tall, it grew very fast and because of the height, it controlled the weeds on its own by shading them out. However, yields in the tall species were not as high as the shorter species that were being developed because so much of the growth energy went to stalk and leaves. So, new higher yielding, shorter crops were created. These shorter varieties were slower to grow

so water grass became a problem. Therefore chemicals were needed to control the weeds.

- Burning is permitted for disease control: 25% of fields max. The actual that gets burned is usually 12-13% due to allowable burn days and/or rain. Rice straw management practices such as stomping, disking, and flooding are all a result of regulations on burning.
- Climate is another factor that comes into play for the planting and harvesting of crops: Rains later in spring and later in fall thus the need for more equipment and more people to get all work done in shorter amount of time creates more dust and uses more diesel because of the need to get the crop in or harvested in the small window that is there.

**Question 3:** Do you think that the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)? If so, how has it changed?

**Response 3:**

- Biggest change is from row crop to permanent crops… permanent crops are managed more closely. Less and less strips of natural habitat from weed suppression because of wanting to maximize yields… habitat has changed, it has been worse. There needs to be meandering corridors not just a patch. There used to be ditches where pheasants and such could hide but they are managed so closely that there isn't the habitat left behind for wildlife.

**Question 4:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response 4:**

- Weeds have become problematic. Because of restrictions on sterilant type chemicals and other chemicals, Star Thistle, Johnson Grass, and other weeds are becoming a problem. Round up is expensive and plants are becoming resistant to it. There are fewer tools to use and more cost incurred because of it.
- Irrigation Districts are having a problem with aquatic weeds; esp. black tail moss. Irrigation districts have to get permits, training, and do extensive reporting in order to be allowed to chemically remove these types of weeds, or they have to use mechanical labor to remove them. A new weed, Parrot Feather, has been a problem in the Delta and it has been introduced. It will quickly become a problem.
- There can be success in weed control however it is going to cost a lot.

**Question 5:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response 5:**

- On the upland type birds, such as pheasant, quail, etc. there has been a decrease. It is thought that because there is less trapping, hunting, and poisons used there has been an increase in coyote, skunk, and other predator species which has aided in the decrease of upland birds.
- Water fowl have truly dispersed and spread out over the basin rather than mainly staying in the refuges. In the past, the wildlife refuges and duck clubs were the only wetlands, so the concentrations of water fowl made it appear that there were large amounts of birds. But now with the flooding of rice fields to decompose the rice stubble and hold the water before release, there are more "lakes" out there for the birds to nest.
- The flocks have spread out through the flooded rice fields, the refuges, and Duck Clubs which make the numbers seem fewer. Duck clubs will complain that there are less game birds, however he doesn't think so; they are just more spread out.
- Refuges were created because of the old variety of rice being tall harvest didn't start until nov-dec. Waterfowl would come in and feed in the rice fields before harvest and cause problems for the farmers. The Government came and created refuges to keep the birds in the refuges and out of the fields.
- For other types of wildlife, there is still a good amount of wildlife along the river.

**Question 6:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response 6:**

- This has been very changed. In the past when there was a heavy rain, it used to take 6-7 days to run out of the west onto the flatlands in the basin. When it got there, it would run through many checks that would slow it down. There used to be 20 checks in a 100 acre field when the tall rice was farmed and the water had a lesser impact on the basin when it came in large amounts.
- Now, everything is flat. In rice fields there are now only 2 checks per 100 acres. Everything is flat and it floods in 2 – 3 hours after running out of the west. The water flows right out of the hills through the valley. There are less wetlands and meandering creeks because they have been removed and the lay of the land in the basin has such a flat gradient that the water backs up and floods. The Sacramento Flood Control Agency holds more water in Yolo Bypass which slows down the water and causes more water to be pushed back into the basin.

**Question 7:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response 7:**

- The basin is such a rice producing area and most is heavy clay. He states we don't have a lot of erosion and a lot of silt. Erosion happens more on the west side because of the soils there on Sand Creek and Salt Creek: the farmers on that side have taken measures to prevent it. Historically, erosion hasn't gotten better or worse. Gully washers will happen and they will transport sediment, but that is historical. On his property that he's farmed for 50 years he hasn't seen an erosion problem.

**Question 8:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change?

**Response 8:**

- 30 years ago there was always a lot of water and a lot of water was used in the fields. The water in the basin comes from the Sacramento River. University studied water in sac for ec levels and it came back at a .1 which is good. In the more recent history there has been a push to conserve water and hold water for quality purposes. The natural salts that occur in the water, in a clay soil like that of the basin, will leech if water is conserved through the fields too much resulting in reduced yields in last few checks of a rice field. Because there was enough water in the past to flow through the fields, salt wasn't a problem.
- There were water quality problems in the 60's and 70's as the farmers didn't realize the chemicals were using were so mobile. When this was realized, there were measures taken to eventually to reduce the half life of the chemicals. Now that we are more scientifically aware of water quality and through science and BMP's, all crops are being pushed hard to implement BMP's to increase water quality.
- Water Quality in the basin is chemically better than it used to be due to the knowledge we have gained. The Water Quality out of the river hasn't changed and is about the same as it has always been.
- NOTE **RD108 has good historical data for water quality.

**Question 9:** How has the Ag waiver program affected water quality in the basin?

**Response 9:**

- The Ag commissioner has been really pro active on the MO's. when it was first passed, that Ag was not going to be allowed an automatic waiver,
- NCWA had a meeting to come up with a waiver for growers to be informed of BMP's. Then the chemicals would be able to be traced back to who purchased it, who applied it, etc. It has worked pretty well… every once in a while there is a problem. Sometimes non toxic levels of ec, do, e-coli and DDT will show up. Wildlife and septic systems were found to be the main sources of e-coli: mostly wildlife. Ec and do are being found because of water conservation and reduced flows. DDT is still being found in the soil because of past practices.
- The waiver doesn't seem to have changed the water quality at all… it has just made farmers more aware.
- ec directly related to salt… water districts and Bureau of Reclamation push water conservation. There is a fee structure on water to reduce waste, to keep chemicals in the

fields to reduce the half life, and to conserve water. This, however, ultimately lowers the amount of water in the drain and increases the ec's and reduces the oxygen in the water.

**Question 10:** How has the Regional Water Quality Control Board rice herbicide program (started in the mid 80's) affected water quality in the basin?

**Response 10:**

- Long term yes… short term no… see above. Over time the water quality has been changed.

**Question 11:** Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response 11:**

- There are Mercury mines west of the basin and there is some runoff. Also, Mercury is air born from coal burning in China… it comes over in the jet stream and ends up in the rice fields where it settles and it shows up in the monitoring.

**Question 12:** Have you ever had an incident where you needed information about the Colusa Basin Watershed that was not currently available, that you think would be useful for future management?

**Response 12:**

- No not really… he's lived here his whole life. He's kept himself aware and involved since the late 60's. RD 108 has a pretty good archive of water development and water issues. He was involved with the Colusa Mutual Water Company.
- History about why the drain was built - RD108 has a book by George Bacey about this. Glenn Colusa upper districts would drain water and the water had no place to go so it formed a lake in the Colusa Grimes area: there were lawsuits… so the drain was created. Originally the landowners were granted water rights to the water that flowed through their property in the drain… later the Government came in and said they didn't have any rights to the water.

**Question 13:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin?

**Response 13:**

- A concern he has is Groundwater vs. Surface water rights with the Government, but this isn't something that he thinks the Assessment will address.
- He does think that there is a gap between flood control on the west side and the things we can do on the east side where it floods… Disconnect between the watershed, the natural

resources, the water districts, and the community… the interconnection is important, but not necessarily there.

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Bob Johnson, Operations Superintendent, Glenn County Department of Public Works.

**Interviewer:** Matt Smeltzer, Engineer/Geomorphologist with Geomorph

**Date:** 14 November 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- He is concerned with resolving flood management and bank erosion problems, particularly related to transportation infrastructure and agricultural land management.
- He is concerned with effects of changed rangeland management practices in the upper watershed areas.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- This question was not asked.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- He said as an example that during the early 1970s the farmers grazed sheep and planted barley every fourth year, but now they graze year round and overgrazing is happening in places as a result. Shallow-rooted star thistle and other weeds have replaced the deep-rooted native grasses, reducing soil stability.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- See above.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- See above.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- As one example, he has seen wildlife reoccupy the riparian corridor on the agricultural land he owns and operates, after setting back from the creek and allowing the stream to occupy a wider area.
- He has seen problems with beavers building debris jams that float downstream during floods and block bridge openings.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- This question wasn't specifically asked, but he reports that flooding generally begins to be a problem in Glenn County when the peak flow exceeds about a 5-year flood. One of the greatest contributors to flooding is blockage of bridge and railroad openings by woody debris.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- He has noticed that chronic bank erosion is common where the stream corridor has been made narrow, the streams have been farmed over, or realigned and channelized. As examples, he mentioned the realigned section of French Creek near the T-C Canal. He also mentioned there was frequent levee erosion and overtopping in a straightened section of Willow Creek where the landowner annually removed debris and sediment from the channel.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- This question was not asked.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- This question was not specifically asked, but he said in general:
  - that debris basins may need to be looked at as a way to prevent debris blockage of bridges during floods.
  - He said that changes to rangeland practices in the upper watershed areas are not well documented or understood.
  - He said the manageability of streams could be increased by giving the streams more room and not trying to keep them so straight and narrow, but that there are few examples of this being done for demonstrating how this can work.

## Colusa Basin Watershed Assessment Stakeholder Interview

**Stakeholder Interviewed:** Greg Mensik, Sacramento Wildlife Refuge, U.S. Fish and Wildlife Service

**Interviewer:** John Sterling, Wildlife Ecologist with H. T. Harvey & Associates

**Date:** 28 November 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- One of his main concerns was the tightening of flow-through water from agricultural systems that can be used by wildlife as well as the future of water sales that would further reduce the available water to wildlife.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- He reported the conversion of rice to cotton or olive orchards as well as pastures and upland grasslands to orchards (made easier due to new drip irrigation technology/systems). This leads to loss of waterfowl habitat, and loss of raptor and other grassland wildlife habitat due to conversion to orchards.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- The rice burn legislation has resulted in more flooded waste grain and foraging habitat for waterbirds due to increased flooding of rice fields in summer/fall for rice straw decomposition.
- There had been an increase from 60,000 to 250,000 flooded rice acres in the Sacramento Valley.
- Post-harvest treatment of rice fields have changed and can dramatically decrease the amount of waste grain that wintering waterfowl depend upon for food. For example, the combination of baling, then double disking results in the nearly complete loss of waste grain available to foraging waterfowl. Other treatments vary in their impact to waste grain availability.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- The Central Valley Joint Venture, the North American Waterfowl Management Plan, the Wetland Reserve Program and other initiatives/programs have rejuvenated the managed wetlands (both public and private) throughout the basin by greatly increasing their quality and quantity.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- In wetlands and irrigation ditches, primrose is a new problem that U.C. Davis researchers are studying control methods.
- In uplands and some seasonal wetlands, star thistle, perennial pepperweed and cocklebur are significant problems for the refuges. Control is only conducted in relatively small scales due to time and money constraints.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- In the 1970s and 1980s, approximately 80% of waterfowl in the region were surveyed on six state and federal closed zones (wildlife areas and refuges). Because of new refuges and wildlife areas and because of the tremendous increase in flooded rice and additional new, large duck clubs, waterfowl are much more dispersed now , with only approximately 45% surveyed in those six closed zones in recent years..
- The decrease in waterfowl concentrations benefit waterfowl by reducing potential transmission and/or effects of avian diseases.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- There is more demand on surface water, increased number of ground water wells, tighter controls on surface water use, etc.
- Also, there are more demands on the water providers due to increase water monitoring costs.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- No response.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- Due the ban of DDT, DDE, a by-product of DDT degradation, is no longer a noticeable concern as it was several decades ago when egg-shell thinning and deformed young birds were observed in the breeding colonies of black crowned night herons and snowy egrets on Colusa refuge.
- A primary change is that regulations addressed the direct sources of contaminants in the ecosystem.
- They have no information on mercury contamination.
- Rice and orchard growers, though carefully regulated, are heavy users of both herbicides and pesticides.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- He stated that the refuge system has quite a bit of data including mid-winter waterfowl counts, water use, disease losses of wildlife, wildlife population trends, general monthly inventories of wildlife species, public visitation, etc. He stated that the complexity of their management system, budget and personnel restrictions allow mostly simple cause and effect analyses. The research hosted on the refuges is management oriented as much as possible and the refuge staff's management is research-oriented, so that there is a good feedback loop of information.

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Jean Miller, Current Glenn-Tehama-Colusa Weed Management Area Coordinator

**Interviewer:** Matthew Ramsay, with H. T. Harvey & Associates

**Date:** 22 October 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- As coordinator of the Glenn-Tehama-Colusa Weed Management Area, Jean facilitates the process of receiving weed control project requests from interested parties and matching them with assistance (both technical and grants).

Main concerns include invasive non-native weed species:

- purple starthistle in foothills in Colusa Co.
- perennial pepperweed in waterways in Glenn Co.
- Medusahead and barbed goatgrass on ranchland
- also, purple [silver leaved(?)] nightshade
- giant reed and salt cedar in waterways

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:** No response

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:** No response

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:** No response

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- A few agronomic weeds that are a problem include Johnson grass, and velvet leaf.
- For the best information about problematic agronomic weeds and their control, Jean suggested speaking with a local pest control advisor.
- The effectiveness of each control method used is dependant on many variables such as time of year, age of plant, drought conditions etc.
- For maximum efficiency, several methods should be used.
- Glenn Co. / WMA projects have been spraying the pepperweed with herbicide and achieve partial, but not complete control of the infestation-patch.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:** No response

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- giant reed and salt cedar in waterways negatively impact groundwater recharge, flood/stream flow and erosion

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:** No response

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:** No response

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- The current understanding of weed extents in the basin seems to be fairly good at the north and south ends, in Glenn and Yolo Counties, but perhaps less-well understood in the mid-section within Colusa County.

- Ask Lester Messina, water resource coordinator with Glenn Co. Ag. Commissioner, he is a wealth of information and has been involved in on-the-ground projects

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Dick Mudd, Former Glenn County Supervisor, Longtime farmer / rancher in the basin 50+ years

**Interviewer:** Jennifer Masters with Colusa County RCD

**Date:** 31 January 2008

**Question 1:** How do you think cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- In the 1940's to 1980's rain patterns could be predicted.
- 1946 graduated high school and started farming barley. If it wasn't in the ground and planted by 1st of November you knew it wasn't going to go in because it would start raining. The rain came like clockwork.
- Dry land farming has gone down hill due to weather and expenses. ARVAT barley was in the upper basin for years and would produce in the hills well, but now it is financially not worth it… In the valley with irrigation you can do whatever is needed to make the crops grow, but rice farmers will tell you, even with irrigation and adequate water supply, they can't make it without government subsidies.

**Question 2:** In your opinion, how have agricultural management practices (e.g. irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- All instances – new methods, chemicals, and research are all being improved constantly.

**Question 3:** Do you think that the natural vegetation changed in the Basin (e.g. wetlands, riparian, oak woodland, grassland)? If so, how has it changed?

**Response:**

- The number of undesirable noxious weeds that have been introduced – barbed goat grass, star thistle, etc - have increased.
- It is incredibly costly to try to get rid of the weeds… it costs $10 an acre to spray X amount of acres… you could buy a ranch with the money spent on spraying.

**Question 4:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- Star Thistle, Medusa Head, and Barbed Goat Grass all cause problems.
- Success is a work in progress.

**Question 5:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- Deer and other game have been subjected to nonstop predation from protected mountain lions and other predators off limits on "Government" property… I contend that all these animals and property are owned by citizens and should be managed by them.

**Question 6:** How has the hydrology of the Basin changed (e.g. greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- Flooding can be attributed to the non-cleaning of ditches due to Fish and Game regulations.
- There is no drainage dist below the Tehama Colusa canal that is irrigating… There needs to be somebody.
- The Department of Fish and Game (DFG) is out of control... they are dealing with things they don't need to be dealing with at all. DFG held off people from crossing a stream with 2 inches of water due to habitat disruption.

Example: Colusa Basin Drainage District has money for flood control projects – they should take that money and clean out the ditches and drainages that DFG has stopped people from cleaning.

**Question 7:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- Channel erosion is tied to the type of soil – magnitude is tied to type of storm and frequency. Some places Have clay and you can't get water to permeate it…. Sandy soils will absorb the water and break it apart and it will slough it off. Streams are filled with debris and soil...
- It all depends on what type of soil is there.
- Rainfall chart is in the Glenn County Crop reports and will show what years had big rain events.

**Question 8:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change?

**Response:**

- A lot of water quality change has to do with more chemicals used now than were in the past.
- Water quality degradation takes place now, but there are checks and balances, and holding periods before you are allowed to discharge water back into the system to try to alleviate this problem.

**Question 9:** How has the Ag waiver program affected water quality in the basin?

**Response:**

- I do not have an answer for this question.

**Question 10:** Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- I do not.

**Question 11:** Have you ever had an incident where you needed information about the Colusa Basin that was not currently available, that you think would be useful for future management?

**Response:**

- No

**Question 12:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin?

**Response:**

- Make sure that ALL stakeholders, owners of property, people affected by the existing problems, are listened to, even though they may have conflicting views with the "Powers that Be".

**Question 13:** How has the Regional Water Quality Control Board rice herbicide program (started in the mid 80's) affected water quality in the basin?

**Response:**

- Probably, I would assume that before this was in affect, there was a reason to put it into effect… I don't recall anyone against the program, and it would seem to me that it had a good effect on water quality, but nothing is 100%.

**Colusa Basin Watershed Assessment Stakeholder Interview**

**Stakeholder Interviewed:** Charlie Tuttle, Colusa Basin Watershed Land Owner

**Interviewer:** Pat Reynolds, Senior Restoration Ecologist with H. T. Harvey & Associates

**Date:** 19 November 2007

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- The proposed Sites Reservoir will require the construction of pumps along the Sacramento River and several miles of buried pipe along the Tuttle's land. He is concerned about how this will impact his farming operation and lands.
- He is concerned about the proposed landfill outside of Williams and how this may impact water quality in the basin. If the landfill pollutes groundwater and water sources for cities and farms it will require additional water to be pumped from the Sacramento River which could potentially impact water use both locally and in Southern California.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- He thinks that there are more orchards going in around Colusa and more grapes are being grown in general. However, this is only his impression and suggests this be checked against cropping records.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- The amount of rice that can be burned to remove rice straw has been significantly reduced. They now flood the rice straw to promote decomposition. They have also gone to new strains of rice that have shorter stocks and thus produce less straw.
- Farming has gotten more mechanized through time requiring less labor and a higher reliance on equipment whose costs have substantially increased in recent years.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- Although not within the Colusa Basin Watershed Project Boundary (but immediately adjacent to) he has lost 15-20 acres of riparian forest along the Sacramento River over the last 5-6 years for erosion. This forest was lost when he had to install new pumps with fish screens to prevent salmon from being impacted from pumping operations. The new pump changed the hydrology of the river causing the erosion of the riparian forest.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- Johnson grass and star thistle are weeds of concern but they are able to successfully control them.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- The flooding of rice has provided substantially more wetland habitat than in the past which has caused the waterfowl to be less concentrated and more dispersed.
- He has heard that some farmers near the river are having trouble with animals such as rabbits, squirrels and deer foraging on crops. He thinks that loss of riparian habitat along the Sacramento River (as he has seen on his lands) may have displaced some of the wildlife species.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- Previously the Sacramento River would be dredged and dead trees and logs removed to ensure the river had enough capacity. They have stopped doing this which has caused water levels in the winter to stay higher for longer periods of time. This can cause seepage through the levees which causes water to emerge at the interface of the loamy soils near the river and heavier soils away from the river. This water is often relatively alkaline which can impact agricultural soils.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- He has not noticed a change in erosion in the basin but thinks that lack of dredging in the Sacramento River has caused higher water levels and increased erosion on the interior portion of the levee.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- He thinks that water quality in the basin has improved with the reduced number of chemicals that can be applied and new regulations requiring things like retention of certain chemicals in the fields before being allowed to discharge to adjacent ditches or fields.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- Although it's not exactly a data gap, Charlie feels that the general population is not aware of the significant environmental benefits associated with farming. For example, growth of rice acts as a carbon sink which helps to combat global warming.

## Colusa Basin Watershed Assessment Stakeholder Interview

**Stakeholder Interviewed:** Rob Vlach, Glenn County NRCS

**Interviewer:** Matt Smeltzer, Engineer/Geomorphologist with Geomorph

**Date:** 6 November 2007

*This interview was made especially to address the specific concerns volunteered by Rob Vlach, and so it is limited to those specific issues of concerns and data gaps.*

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- More careful consideration of potential benefits of changed rangeland management practices on stormwater and sediment runoff.
- More careful consideration of the timing of channel incision relative to timing of changed rangeland management practices before concluding that post-European rangeland management has caused channel incision in Basin streams.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- This question was not asked.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- This question was not asked.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- He said that the NRCS has Range Site Descriptions and Ecological Site Descriptions that describe vegetation conditions in the Basin.
- He said that it is important to note that vegetation communities and species composition is correlated with precipitation and temperature, and that rangeland species composition

may have transitioned to a new state, such that changing rangeland management practices may not have the productivity and soil stability benefits many have presumed.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- See above.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- This question was not asked.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- He said that flood waters move more quickly from the upper watershed areas than historically, and partly because the stream channels have been channelized, straightened, and simplified. For example, construction of T-C Canal included realignment and channelization of many creeks

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- He said that it's important to note that the upper watershed areas are naturally prone to high sediment yields and runoff rates because of the geology dominated by uplifted erodible marine sediments tilted to the east and weathering quickly to clay-sized material.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- This question was not asked.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- This question was not specifically asked, but he said in general:
  - Establish timing of channel incision using valid geomorphic evidence
  - Make realistic estimates of potential benefits of changing rangeland management practices in the upper watershed areas
- Rice also provides significant wetland habitat for waterfowl and other species.

## Colusa Basin Watershed Assessment Stakeholder Interview

**Stakeholder Interviewed:** Jeannette Wrysnski, Yolo County RCD

**Interviewer:** Matt Smeltzer, Engineer/Geomorphologist with Geomorph

**Date:** 14 November 2007

*Jeannette said she would like to receive a copy of the final assessment sent to her address: Yolo RCD, 221 W. Court Street, Woodland, CA 95695.*

**Question 1:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

She listed:

- Non-native plants
- Non-native wildlife
- Stream channel capacity vs. peak flow discharges
- Fisheries
- Water Quality
- Air Quality (e.g., wind erosion after fall and spring tillage)
- Wildlife diversity and abundance
- Population declines in pollinating bees
- Some sort of "social category" to gage public feedback
- etc.

**Question 2:** How have cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

- Wheat was heavily cultivated in the 1850s and there was generally more dryland farming in the western hills and flatlands then there is now. To the east there were prunes and apricots.
- Rice growing increased beginning in the 1910s, but Yolo was not a big rice growing county then, and still is lesser than Colusa County now. Pocket of rice growing in a low basin area between County Rds 26 and 29 west of Rd 95. Also in Yolo Bypass (Conaway Ranch, Hydric Farms, etc.)
- In general, there has been a shift from row crops to tree crops (almonds) because the profit margin is better.

**Question 3:** How have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- Large part of eastern part of the County was a large wetland that was drained and dried for agriculture.
- Native deep-rooted perennial bunchgrasses were replaced by non-native shallow- and fibrous-rooted annual grasses, causing reduced carbon capture, less groundwater recharge, less infiltration, more runoff, more mass wasting, etc.
- Decades of persistent herbicide use developed resistant species, making herbicides less effective over the long term
- Increased influx of tougher to manage weeds, like white top, perennial pepperweed, revenna (sp.?) grass
- Most effective weed control includes not just removing problem vegetation, but also physically replacing problem vegetation with other more desirable vegetation. (e.g., mow before weed goes to seed, burn, or spray, then plant something perennial.) This is more expensive but more effective.

**Question 4:** How has the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)?

**Response:**

- See above.

**Question 5:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- See above.

**Question 6:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- She grew up next to the refuge in Colusa County, and it seems to her that the waterfowl population has significantly reduced over time, although she hasn't seen research on the subject.
- She said that beavers invading areas where streams have been restored. But Old-timers say there were always a lot of beavers, so maybe there still are less new than before.

**Question 7:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- Land leveling for agriculture changed the slope of the land and moved boundaries between subwatersheds.
- Summer irrigation return flows increased summer flow in some streams.

**Question 8:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- She said that conversion of native bunchgrasses to annual non-native grasses has increased runoff and mass wasting in the upper watershed ares.

**Question 9:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change? How has the RWQCB rice-pesticide program (started in the mid 80's) and the ag waiver program affected water quality in the basin? Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- This question was not asked.

**Question 10:** Data gaps- Is there information about the Basin, not currently available, that you think would be useful for future management?

**Response:**

- This question was not specifically asked, but she said in general:
    - Stream channel capacity
    - Wildlife diversity and abundance
    - Etc.

## Colusa Basin Watershed Assessment Stakeholder Interview

**Stakeholder Interviewed:** (interviewee requests anonymity)

**Interviewer:** Jennifer Masters, Colusa Basin Watershed Coordinator with Colusa County RCD

**Date:** 06 December 2007

**Question 1:** How do you think cropping patterns changed over time in the Basin at large or in your area of the Basin? What are your thoughts about the causes of this change?

**Response:**

1. Cropping patterns have shifted over the years mostly due to economics.
2. Central valley project… not as reliable for water rights due to federal regulation.
3. CVPIA – water is more expensive… paying a lot of infrastructure, operations, maintenance, environmental, etc.
4. There used to be rangeland, rice, and a few permanent crops… a lot of wheat. With the increased cost of water there has been a shift toward tree crops.
5. Acres serviced by the Tehama Colusa Canal in Colusa County is 40,774.
6. Revenue in crops per year = $96,788,071.
7. Permanent Crops = 59% of crops served by the TC Canal.
8. In last 15 years this number has dramatically risen due to market and price of water. On the whole, the TC Canal serves 155,000 ac. Of that, only 10,000 ac of that is rice.
9. A lot more permanent cropping… water reliability becomes more important with permanent crops… you can lose an entire crop if you don't have water.

**Question 2:** In your opinion, how have agricultural management practices (e.g., irrigation methods, weed control, water quality control and management, rice stubble/litter processing) changed over time?

**Response:**

- There is a lot of drip irrigation going in due to the cost of water and conservation minded activities.
- The TC canal system is a fully lined canal, fully automated. The bigger districts are closed systems – some small districts are still open.
- For irrigating crops, with the exception of rice, the TC canal system appreciates water conservation.
- There has been a cropping pattern shift… look at #1 for answer.
- The Ag waiver has come about to address water quality.
- Orchards take different water quality approaches than row crops.
- Because of price of water there is not as much decomposition of rice stubble as there used to be.

**Question 3:** Do you think that the natural vegetation changed in the Basin (e.g., wetlands, riparian, oak woodland, grassland)? If so, how has it changed?

**Response:**

- No Answer

**Question 4:** How have the weeds in the Basin changed through time? Are there species that are particularly problematic for agriculture or natural systems? Have you seen successful methods for weed control?

**Response:**

- Weeds are a general problem that farmers will always face. He has no real answer to this.

**Question 5:** Have you seen any historical changes in the distribution and abundance of waterfowl or any other wildlife of note?

**Response:**

- The ducks populations are not what they used to be, but the waterfowl population #'s are still healthy.
- Lack of habitat and cover has caused a decline in Pheasant populations.
    - Cropping shifts have also aided in the decline.
- Wild Pigs are very abundant – possibly due to lack of rainfall they are moving out of the hills to lower ground: is what he's heard.
- The decline in Pheasants are most noticeable.

**Question 6:** How has the hydrology of the Basin changed (e.g., greater or lesser flooding, more or less wetlands, more or less water in the drainages)?

**Response:**

- Because of the nature of decomposition, the ground is already saturated which allows flooding to happen quicker.
- Due to environmental regulations, he's noticed a decreased ability to manage and clean out around creeks all the way to the Sacramento River
- Lack of State and federal funding to maintain the Sacramento River Flood Control System as flood control facilities – due to environmental issues – in turn raise the price and has made it harder to maintain which has increased the lack of will to do anything about it.
- Prop 1E has created a change in this attitude.

**Question 7:** Have you noticed substantial soil and drainage channel erosion? If so, in what situations and what might have been the causes? How has erosion magnitude changed through time?

**Response:**

- See answer #6.
- The inability to do work and maintain some of the floodways vs. the opportunity that is present to do work.
- Flood control needs to remain priority.

**Question 8:** How has water quality within the Basin changed through time; do you know of sources for historic water quality data? What do you think are the causes of this change?

**Response:**

- The rice pesticide program has done great job in improving water quality.
- Actual #'s can be attained from the rice producer's assoc. – Defer to answer from representative from California Rice Commission.

**Question 9:** How has the Ag waiver program affected water quality in the basin?

**Response:**

- No answer.

**Question 10:** Do you have any information on mercury contamination/bioaccumulation in the Basin?

**Response:**

- In our basin he doesn't really have any info.
- In Cache Creek there is mercury that is naturally occurring, and occurring because mines that have not been left properly.

**Question 11:** Have you ever had an incident where you needed information about the Colusa Basin that was not currently available, that you think would be useful for future management?

**Response:**

- Most information has been available, but more information is always better.
- Information that is good and not swayed, is the best info.

**Question 12:** What are the issues of concern that you would like to see addressed in the watershed assessment and management planning process for the Colusa Basin Watershed?

**Response:**

- Continuing to learn more about conjunctive use, groundwater, water supply, integrating water management, drought planning, flood control, and continuing to look at beneficial ways to improve and address water quality concerns.
- Explore ways to work collaboratively to address environmental concerns that are conducive to farming practices and economically viable in light of local economy.
- Incorporate balance and common sense when planning process happens.

**Question 13:** How has the Regional Water Quality Control Board rice herbicide program (started in the mid 80's) affected water quality in the basin?

**Response:**

This question was not asked.

**Appendix 1. Land Use.**
**DWR Standard Land Use Legend**

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES

# STANDARD LAND USE LEGEND

Land and Water Use Section

Statewide Planning Branch
Division of Planning

September 2005

## STANDARD LAND USE LEGEND

Table of Contents

# I. GENERAL

The minimum breakdown of land use is according to the class symbol. More detail is obtained by adding the subclass number to the class symbol, or by use of special condition symbols. Any or all of the following information can be delineated.

1. Types of agricultural, urban, or native land use
2. Specific crops
3. Multiple land use
4. Sources of water supply
5. Type of irrigation system

This legend is for land use surveys conducted in 2005 and after.

## II. AGRICULTURAL CLASSES

The vast majority of crops grown in California are irrigated. Unless preceded with an "n" if it is non-irrigated, all agricultural classes are considered irrigated. (This statement is for the agricultural classes and does not apply to the other non-agricultural classes of semiagricultural, urban, or native.)

### G - GRAIN AND HAY CROPS

1. Barley
2. Wheat
3. Oats
6. Miscellaneous grain and hay
7. Mixed grain and hay

### R - RICE

1. Rice
2. Wild rice

### F - FIELD CROPS

1. Cotton
2. Safflower
3. Flax
4. Hops
5. Sugar beets
6. Corn (field & sweet)
7. Grain sorghum
8. Sudan
9. Castor beans
10. Beans (dry)
11. Miscellaneous field
12. Sunflowers
13. Hybrid sorghum/sudan
14. Millet
15. Sugar cane

### P - PASTURE

1. Alfalfa & alfalfa mixtures
2. Clover
3. Mixed pasture
4. Native Pasture
5. Induced high water table native pasture
6. Miscellaneous grasses
7. Turf farms
8. Bermuda grass
9. Rye grass
10. Klein grass

T - TRUCK, NURSERY AND BERRY CROPS

1. Artichokes
2. Asparagus
3. Beans (green)
4. Cole crops (mixture of 22-25)
6. Carrots
7. Celery
8. Lettuce (all types)
9. Melons, squash, and cucumbers (all types)
10. Onions and garlic
11. Peas
12. Potatoes
13. Sweet Potatoes
14. Spinach
15. Tomatoes (processing)
16. Flowers, nursery & Christmas tree farms
17. Mixed (four or more)
18. Miscellaneous truck
19. Bush berries
20. Strawberries
21. Peppers (chili, bell, etc.)
22. Broccol
23. Cabbage
24. Cauliflower
25. Brussels sprouts
26. Tomatoes (market)
27. Greenhouse

D - DECIDUOUS FRUITS AND NUTS

1. Apples
2. Apricots
3. Cherries
5. Peaches and nectarines
6. Pears
7. Plums
8. Prunes
9. Figs
10. Miscellaneous deciduous
11. Mixed deciduous
12. Almonds
13. Walnuts
14. Pistachios

C - CITRUS AND SUBTROPICAL

1. Grapefruit
2. Lemons
3. Oranges
4. Dates
5. Avocados
6. Olives
7. Miscellaneous subtropical fruits
8. Kiwis
9. Jojoba
10. Eucalyptus
11. Mixed subtropical fruits

V - VINEYARDS

1. Table grapes
2. Wine grapes
3. Raisin grapes

I - IDLE

(Precede with "n" in non-irrigated area, and <u>must</u> include subclass)

1. Land not cropped the current or previous crop season, but cropped within the past three years.
2. New lands being prepared for crop production.

## III. SEMIAGRICULTURAL CLASS

(Do not precede with "n")

S - SEMIAGRICULTURAL & INCIDENTAL TO AGRICULTURE
(Must include subclass)

1. Farmsteads (includes a farm residence)
2. Livestock feed lot operations
3. Dairies
4. Poultry farms
5. Farmsteads (without a farm residence)

# IV. URBAN CLASSES

(Do not precede with "n")

U - URBAN

Residential, commercial, and industrial (may be used alone when further breakdown is not required)

UR - RESIDENTIAL

Single and multiple family units, including trailer courts (may be used alone when further breakdown is not required)

1. Single family dwellings with lot sizes greater than 1 acre up to 5 acres (ranchettes, etc.)
2. Single family dwellings with a density of 1 unit/acre up to 8+ units/acre.
3. Multiple family (apartments, condos, townhouses, barracks, bungalows, duplexes, etc.)
4. Trailer courts

WATER USE FACTOR (% of total area irrigated - will be the second digit of UR Subclass when water factor is used)

1. 0% to 25% area irrigated
2. 26% to 50% area irrigated
3. 51% to 75% area irrigated
4. 76% or greater

Example: UR32 indicates multiple family with water use factor of 26% to 50% of area irrigated.

UC - COMMERCIAL

(May be used alone when further breakdown is not required)

1. Offices, retailers, etc.
2. Hotels
3. Motels
4. Recreation vehicle parking, camp sites
5. Institutions (hospitals, prisons, reformatories, asylums, etc., having a reasonably constant 24-hour resident population)
6. Schools (yards to be mapped separately if large enough)
7. Municipal auditoriums, theaters, churches, buildings and stands associated with race tracks, football stadiums, baseball parks, rodeo arenas, amusement parks, etc.
8. Miscellaneous high water use (to be used to indicate a high water use condition not covered by the above categories.)

UI - INDUSTRIAL

(May be used alone when further breakdown is not required)

1. Manufacturing, assembling, and general processing
2. Extractive industries (oil fields, rock quarries, gravel pits, rock and gravel processing plants, etc.)
3. Storage and distribution (warehouses, substations, railroad marshalling yards, tank farms, etc.)
6. Saw mills
7. Oil refineries
8. Paper mills
9. Meat packing plants
10. Steel and aluminum mills
11. Fruit and vegetable canneries and general food processing
12. Miscellaneous high water use (to be used to indicate a high water use condition not covered by other categories.)
13. Sewage treatment plant including ponds.
14. Waste accumulation sites (public dumps, sewage sludge sites, landfill and hazardous waste sites, etc.)
15. Wind farms, solar collector farms, etc.

UL - URBAN LANDSCAPE

(May be used alone when further breakdown is not required)

1. Lawn area - irrigated
2. Golf course - irrigated
3. Ornamental landscape (excluding lawns) - irrigated
4. Cemeteries - irrigated
5. Cemeteries - not irrigated

UV - VACANT

(May be used alone when further breakdown is not required)

1. <u>Unpaved areas</u> (vacant lots, graveled surfaces, play yards, developable open lands within urban areas, etc.)
3. Railroad right of way.
4. <u>Paved areas</u> (parking lots, paved roads, oiled surfaces, flood control channels, tennis court areas, auto sales lots, etc.)
6. Airport runways
7. Land in urban area that is not developable

# V. NATIVE CLASSES

(Do not precede with "n")

NC - NATIVE CLASSES UNSEGREGATED

(May be used alone when further breakdown is not required)

NV - NATIVE VEGETATION

(May be used alone when further breakdown is not required)

1. Grass land
2. Light brush
3. Medium brush
4. Heavy brush
5. Brush and timber
6. Forest
7. Oak woodland

NR - RIPARIAN VEGETATION

(May be used alone when further breakdown is not required)

1. Marsh lands, tules and sedges
2. Natural high water table meadow
3. Trees, shrubs or other larger stream side or watercourse vegetation
4. Seasonal duck marsh, dry or only partially wet during summer
5. Permanent duck marsh, flooded during summer

NW - WATER SURFACE

(May be used alone when further breakdown is not required)

1. River or stream (natural fresh water channels)
2. Water channel (all sizes - ditches and canals - delivering water for irrigation and urban use - ie State Water Project, CVP, water district canals, etc.)
3. Water channel (all sizes - ditches and canals - for removing on-farm drainage water - surface runoff and subsurface drainage - ie Colusa drain, drainage ditches in Imperial)
4. Freshwater lake, reservoir, or pond (all sizes, includes ponds for stock, recreation, groundwater recharge, managed wetlands, on-farm storage, etc.)
5. Brackish and saline water (includes areas in estuaries, inland water bodies, the ocean, etc.)
6. Wastewater pond (dairy, sewage, cannery, winery, etc)
7. Paved water conveyance channels within urban areas (mainly for flood control)

NB - BARREN AND WASTELAND

(May be used alone when further breakdown is not required)

1. Dry stream channels
2. Mine Tailing
3. Barren land
4. Salt flats
5. Sand dunes

## VI. UNCLASSIFIED

NS - NOT SURVEYED

Area within the investigation area that was not mapped.

E - ENTRY DENIED

Area within the investigation area that was not mapped because entry into the area was denied.

Z - OUTSIDE

Area outside of the study area.

## VI. SPECIAL CONDITIONS, IRRIGATION TYPE, AND WATER SOURCE

When any of the following special conditions, type of irrigation, or source of water is used, a (-) should precede them. When more than one is used they should be used in the order stated above.

### 1. SPECIAL CONDITIONS

(only one can be used per parcel)

A - ABANDONED ORCHARDS AND VINEYARDS

Trees or vines must be in such a condition that renewal of cultural practices would restore economic production. Indicated by "A" following crop symbol.

Example: D1-A indicates an apple orchard previously irrigated but now abandoned.

B - BURNED OVER AREAS

Indicated by "B". The type and density of natural cover destroyed by fire is obtained by examination of aerial photo.

Example: NV7-B indicates oak grass land recently burned over.

C – GREEN CHOPPED

Grain or field crops harvested early for livestock feed

E – ECOSYSTEM RESTORATION

Native vegetation or riparian areas that have undergone restoration (used with NV and NR classes).

F - FALLOW LANDS

Land not cropped during the current crop season, but cropped during the previous crop season.

(1) If no crop residue is apparent or identifiable then the "F" symbol will follow the agricultural class symbol for the crop most representative of those grown in the area.
Example: T-F indicates fallow land within a truck crop area (with facilities for irrigation).

(2) If the crop residue is apparent and identifiable but is not from the current crop season covered by the survey then the field is considered fallow and mapped as the class of the crop residue.
Example: Surveyor found an old sugar beet residue not from current season. Land would be mapped F-F.

(3) If the crop residue is identifiable as that of a crop which was grown during the survey period, then map the field as though crop existed.
Example: Surveyor found carrot residue from current growing season. Land would be mapped T6.

G – COVER CROP

Indicates where grain, field, or pasture type crops have been planted for soil stabilization or for cover crops grown between rows of deciduous and subtropical trees and vines.

H – HARVESTED CROP

Indicates the identified crop was harvested at the time of the survey (used with truck, field, and grain crops).

K - FREEWAYS

The area within the freeway right of way.

Examples: UV-K indicates urban vacant, unsegregated, with a freeway special condition (all areas within the freeway right of way).

UV4-K indicates the urban vacant paved areas with a freeway special condition (the paved portion within the freeway right of way.)

UL3-K indicates irrigated urban landscape with a freeway special condition (irrigated landscape portion within the freeway right of way).

R - RECREATIONAL

To be used with urban residential, commercial, and vacant (R.V. parks and camp sites) within primarily a seasonal recreational area.

S - SEED CROP

Indicates any crop grown for seed.

Example: P1-S indicates irrigated alfalfa seed crop.

T - TILLED LANDS

Land prepared for immediate planting, or just newly planted, including the appearance of seed lines or unidentifiable tiny seedlings.

Example: T-T indicates tilled land (either prepared for planting or just planted) in a predominately truck crop area.

U – INTERPRETED LANDUSE

Indicates that the land use was determined using other means than visual field verification.

X - PARTIALLY IRRIGATED CROPS

Crops irrigated for only part of their normal irrigation season.

Example: P3-X indicates partially irrigated mixed pasture.

Y - YOUNG CROPS

Indicates the identified crop is at early stages of growth (used with non-bearing orchards and vineyards, and truck, field, and grain crops).

Example: C3-Y indicates young non-bearing irrigated oranges.

Z - RECLAMATION

Land being leached for the removal of harmful salts. This symbol will be used following either the “Idle” symbol or symbols of crops grown as a step in the reclamation process.

Example: I2-Z indicates new lands being leached in preparation for crop production.

## 2. TYPE OF IRRIGATION SYSTEM

C - Center Pivot Sprinkler
L - Linear Move Sprinkler
R - Side Roll Sprinkler
H - Hand Move Sprinkler
P - Permanent Sprinkler
T - Solid Set Sprinkler
F - Furrow Irrigation
B - Border Strip Irrigation
N - Basin Irrigation
W - Wild Flooding
S - Subirrigation
D - Surface Drip Irrigation
A - Buried Drip Irrigation
M - Micro Sprinkler
E - LEPA (Low Energy Precision Application)
U - Unknown or not mapped

As part of the map symbols these irrigation type letters required a circle around them so that they are not confused with the special condition letters.

Example: P1- Ⓑ indicates border strip irrigated alfalfa.

## 3. SOURCE OF IRRIGATION WATER

| Water Source | Code |
|---|---|
| Surface water | 1 |
| Mixed surface & ground water | 2 |
| Ground water | 3 |
| Unknown source | 4 |
| Reclaimed | 5 |
| Recycled | 6 |

Example: P3- Ⓑ1 indicates border strip irrigated pasture with surface water as the water source.

# VIII. MULTIPLE LAND USE

INTERCROPPING

Used with orchards or vineyards when intercropped with some other crop class. Indicated by a fractional symbol, with the orchard or vineyard symbol appearing in the numerator.

Example: D12-Y/F10 indicates young almonds intercropped with dry beans.

DOUBLE CROPS

Used when two consecutive crops are grown in the survey season. The first crop is indicated by enclosed parenthesis.

Example: (G)F6 indicates irrigated grain followed by field corn.

TRIPLE CROPS

Used when three consecutive crops are grown in the survey season. The first and second crops are indicated by enclosed parenthesis.

Example: (T8)(T23)T8 indicates irrigated lettuce followed by cabbage followed by lettuce.

MIXED LAND USE

Used when two to three land uses are present in one area but, because of the large degree of intermixing, cannot be delineated separately. Indicated by percentages following land use symbols. No more than three different land uses may be used in describing the area. Percentages are in increments of 10.

Example: D5 - 40% indicates irrigated peaches 40%
NV - 20% indicates native vegetation 20%
UR - 40% indicates urban residential 40%

## IX. FURTHER INSTRUCTIONS, CLARIFICATIONS AND EXAMPLES

1) Land use class and subclass should come before the dash which separates the special condition, irrigation type, and source of water.

2) Water source should be the last symbol in the code. If the field has more that one crop, the source should follow the last crop.

3) Irrigation type and source of water must be enclosed in a circle.

## LAND USE CODE EXAMPLES

Single Crop:

F1-Ⓕ3
Indicates cotton that is furrow irrigated with ground water as the water source.

D12-YⓅ
Indicates young irrigated almonds that are irrigated with a permanent sprinkler system.

Intercropped:

D13-Y/F10Ⓟ1
Indicates young irrigated walnuts intercropped with dry beans, irrigated by a permanent sprinkler system with surface water as the water source.

Double cropped:

(G-Ⓗ)F6-Ⓕ2
Indicates grain irrigated with a hand move sprinkler system followed by furrow irrigated corn, with mixed ground and surface water as the water source.

Triple Cropped:

(T8)(T23)T8-Ⓟ
Indicates irrigated lettuce followed by irrigated cabbage followed by irrigated lettuce, all three crops irrigated by a permanent sprinkler system (when type of irrigation is not shown next to the first and second crops, the irrigation type for the last crop will be assumed for the first two crops).

(T8-Ⓤ)(T23-Ⓤ)T8-Ⓗ3
Indicates irrigated lettuce with unknown irrigation type, followed by irrigated cabbage with unknown irrigation type, followed by lettuce irrigated with a hand move sprinkler system, with ground water as the water source.

## Appendix 2. Land Use.
## Definitions of Important Farmland Categories

## DEFINITIONS OF IMPORTANT FARMLAND CATEGORIES

Excerpted from United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). 1998. Soil Survey of Colusa County, California

### Prime Farmland

Prime Farmland is land, which has the best combination of physical and chemical characteristics for the production of crops. It has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops when treated and managed, including water management, according to current farming methods. Prime Farmland must have been used for the production of irrigated crops at some time during the 2 update cycles prior to the mapping date. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use.

Prime Farmland must meet all the following criteria:

a. Water
   The soils have xeric, ustic, or aridic (torric) moisture regimes in which the available water capacity is at least 4.0 inches (10 cm) per 40 to 60 inches (1.02 to 1.52 m) of soil, and a developed irrigation water supply that is dependable and of adequate quality. A dependable water supply is one which is available for the production of the commonly grown crops in 8 out of 10 years; and
b. Soil Temperature Range
   The soils have a temperature regime that is frigid, mesic, thermic, or hyperthermic (pergelic and cryic regimes are excluded). These are soils that, at a depth of 20 inches (50.8 cm), have a mean annual temperature higher than 32° F (0° C). In addition, the mean summer temperature at this depth in soils with an O horizon is higher than 47° F (8° C); in soils that have no O horizon, the mean summer temperature is higher than 59° F (15° C); and
c. Acid-Alkali Balance
   The soils have a pH between 4.5 and 8.4 in all horizons within a depth of 40 inches (1.02 m); and
d. Water Table
   The soils have no water table or have a water table that is maintained at a sufficient depth during the cropping season to allow cultivated crops common to the area to be grown; and
e. Soil Sodium Content
   The soils can be managed so that, in all horizons within a depth of 40 inches (1.02 m), during part of each year the conductivity of the saturation extract is less than 4 mmhos/cm and the exchangeable sodium percentage is less than 15; and
f. Flooding
   Flooding of the soil (uncontrolled runoff from natural precipitation) during the growing season occurs infrequently, taking place less often than once every 2 years; and
g. Erodibility
   The product of K (erodibility factor) multiplied by the percent of slope is less than 2.0; and
h. Permeability

The soils have a permeability rate of at least 0.06 inch (0.15 cm) per hour in the upper 20 inches (50.8 cm) and the mean annual soil temperature at a depth of 20 inches (50.8 cm) is less than 59° F (15° C); the permeability rate is not a limiting factor if the mean annual soil temperature is 59° F (15° C) or higher; and

i. Rock Fragment Content
   Less than 10% of the upper 6 inches (15.24 cm) in these soils consists of rock fragments coarser than 3 inches (7.62 cm); and
j. Rooting depth
   The soils have a minimum rooting depth of 40 inches (1.02 m).

**Farmland of Statewide Importance**

Farmland of Statewide Importance is land other than Prime Farmland, which has a good combination of physical and chemical characteristics for the production of crops. It must have been used for the production of irrigated crops at some time during the 2 update cycles prior to the mapping date. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use.

Farmland of Statewide Importance must meet all the following criteria:

a. Water
   The soils have xeric, ustic, or aridic (torric) moisture regimes in which the available water capacity is at least 3.5 inches (8.89 cm) within a depth of 60 inches (1.52 m) of soil; or within the root zone if it is less than 60 inches (1.52 m) deep. They have a developed irrigation supply that is dependable and of adequate quality. A dependable water supply is one which is available for the production of the commonly grown crops in 8 out of 10 years; and
b. Soil Temperature Range
   The soils have a temperature regime that is frigid, mesic, thermic, or hyperthermic (pergelic and cryic regimes are excluded). These are soils that, at a depth of 20 inches (50.8 cm), have a mean annual temperature higher than 32° F (0° C). In addition, the mean summer temperature at this depth in soils with an O horizon is higher than 47° F (8° C); in soils that have no O horizon, the mean summer temperature is higher than 59° F (15° C); and
c. Acid-Alkali Balance
   The soils have a pH between 4.5 and 9.0 in all horizons within a depth of 40 inches (1.02 m) or in the root zone if the root zone is less than 40 inches (1.02 m) deep; and
d. Water Table
   The soils have no water table or have a water table that is maintained at a sufficient depth during the cropping season to allow cultivated crops common to the area to be grown; and
e. Soil Sodium Content
   The soils can be managed so that, in all horizons within a depth of 40 inches (1.02 m), or in the root zone if the root zone is less than 40 inches (1.02 m) deep, during part of each year the conductivity of the saturation extract is less than 16 mmhos/cm and the exchangeable sodium percentage is less than 25; and
f. Flooding
   Flooding of the soil (uncontrolled runoff from natural precipitation) during the growing season occurs infrequently, taking place less often than once every 2 years; and

g. Erodibility
The product of K (erodibility factor) multiplied by the percent of slope is less than 3.0; and
h. Rock Fragment Content
Less than 10% of the upper 6 inches (15.24 cm) in these soils consists of rock fragments coarser than 3 inches (7.62 cm).

Farmland of Statewide Importance does not have any restrictions regarding permeability or rooting depth.

**Unique Farmland**

Unique Farmland is land which does not meet the criteria for Prime Farmland or Farmland of Statewide Importance, that has been used for the production of specific high economic value crops at some time during the 2 update cycles prior to the mapping date. It has the special combination of soil quality, location, growing season, and moisture supply needed to produce sustained high quality and/or high yields of a specific crop when treated and managed according to current farming methods. Examples of such crops may include oranges, olives, avocados, rice, grapes, and cut flowers. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use.

Characteristically Unique Farmland:

a. Is used for specific high value crops; and
b. Has a moisture supply that is adequate for the specific crop; the supply is from stored moisture, precipitation or a developed irrigation system; and
c. Combines favorable factors of soil quality, growing season, temperature, humidity, air drainage, elevation, exposure, or other conditions, such as nearness to market, that favor growth of a specific food or fiber crop; and
d. Excludes abandoned orchards or vineyards, dryland grains, and extremely low yielding crops, such as irrigated pasture, as determined in consultation with the County Cooperative Extension Director and Agricultural Commissioner.

High-value crops are listed in California Agriculture, an annual report of the California Department of Food and Agriculture. In order for land to be classified Unique Farmland, the crop grown on the land must have qualified for the list at some time during the 2 update cycles prior to the mapping date.

**Farmland of Local Importance**

Farmland of Local Importance is either currently producing crops, has the capability of production, or is used for the production of confined livestock. Farmland of Local Importance is land other than Prime Farmland, Farmland of Statewide Importance or Unique Farmland. This land may be important to the local economy due to its productivity or value. It does not include publicly owned lands for which there is an adopted policy preventing agricultural use. In a few counties the local advisory committee has elected to additionally define areas of Local Potential (LP) farmland. This land includes soils, which qualify for Prime Farmland or Farmland of

Statewide Importance, but generally are not cultivated or irrigated. For reporting purposes, Local Potential and Farmland of Local Importance are combined in the acreage tables, but are shown separately on the Important Farmland Map.

Farmland of Local Importance is initially identified by a local advisory committee (LAC) convened in each county by FMMP in cooperation with the USDA-NRCS and the county board of supervisors. LAC membership is very similar to the map reviewers list on page 6 of this document. Authority to recommend changes to the category of Farmland of Local Importance rests with the board of supervisors in each county. The FMMP presents each draft map to the board of supervisors for their review. After the presentation of this map, the board of supervisors has a 90-day review period in which to request any needed modifications. An extension may be granted upon request. The board of supervisors may then approve or disapprove the Farmland of Local Importance category. The FMMP will accept the recommendation of the board of supervisors if it is consistent with the general program guidelines. If no action is initiated by the county to identify or adopt a Farmland of Local Importance definition within a year of contact by FMMP, the county will be deemed to have no adopted definition for Farmland of Local Importance.

Any revision to the initial board of supervisors' action on Farmland of Local Importance will require 30-day written notice to FMMP and members of the LAC. This process may require reconvening of the LAC.

### Grazing Land

Grazing Land is defined in Government Code §65570(b)(3) as:

> "...land on which the existing vegetation, whether grown naturally or through management, is suitable for grazing or browsing of livestock."

The minimum mapping unit for Grazing Land is 40 ac.

Grazing Land does not include land previously designated as Prime Farmland, Farmland of Statewide Importance, Unique Farmland, or Farmland of Local Importance, and heavily brushed, timbered, excessively-steep, or rocky lands that restrict the access and movement of livestock. The FMMP convenes a grazing land advisory committee in each project county to help identify grazing lands. The committees consist of members of the local livestock ranching community, livestock ranching organizations, and the U. C. Cooperative Extension livestock advisor. The FMMP works with the president of the local Cattlemen's Association and the U.C. Cooperative Extension livestock advisor in selecting members of these committees.

### Urban and Built-up Land

Urban and Built-up Land is used for residential, industrial, commercial, construction, institutional, public administrative purposes, railroad yards, cemeteries, airports, golf courses, sanitary landfills, sewage treatment plants, water control structures, and other development purposes. Highways, railroads, and other transportation facilities are mapped as a part of Urban and Built-up Land if they are a part of the surrounding urban areas. Units of land smaller than 10 ac will be incorporated into the surrounding map classifications. The building density for residential use must be at least 1 structure per 1.5 ac (or approximately 6 structures per 10 ac). Urban and Built-up Land must contain man-made structures or buildings under construction, and the infrastructure required for development (e.g., paved roads, sewers, water, electricity, drainage, or flood control facilities) that are specifically designed to serve that land. Parking lots, storage and distribution facilities, and industrial uses such as large packing operations for agricultural produce will generally be mapped as Urban and Built-up Land even though they may be associated with agriculture. Urban and Built-up Land does not include strip mines, borrow pits, gravel pits, farmsteads, ranch headquarters, commercial feedlots, greenhouses, poultry facilities, or road systems for freeway interchanges outside of areas classified as Urban and Built-up Land areas. Within areas classified as Urban and Built-up Land, vacant and nonagricultural land which is surrounded on all sides by urban development and is less than 40 ac in size will be mapped as Urban and Built-up. Vacant and nonagricultural land larger than 40 ac in size will be mapped as Other Land.

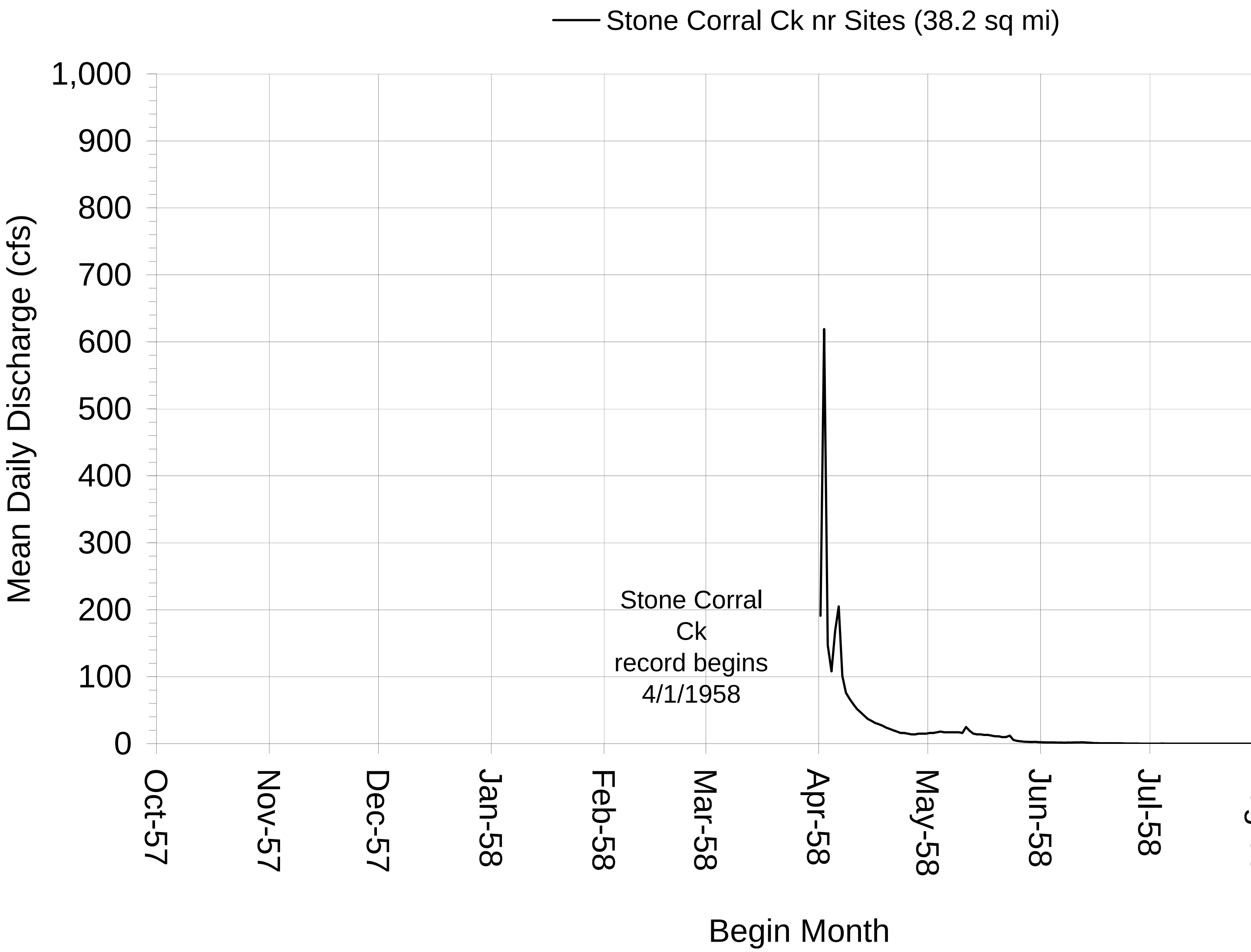
### Other Land

Other Land is that which is not included in any of the other mapping categories. The following types of land are generally included:

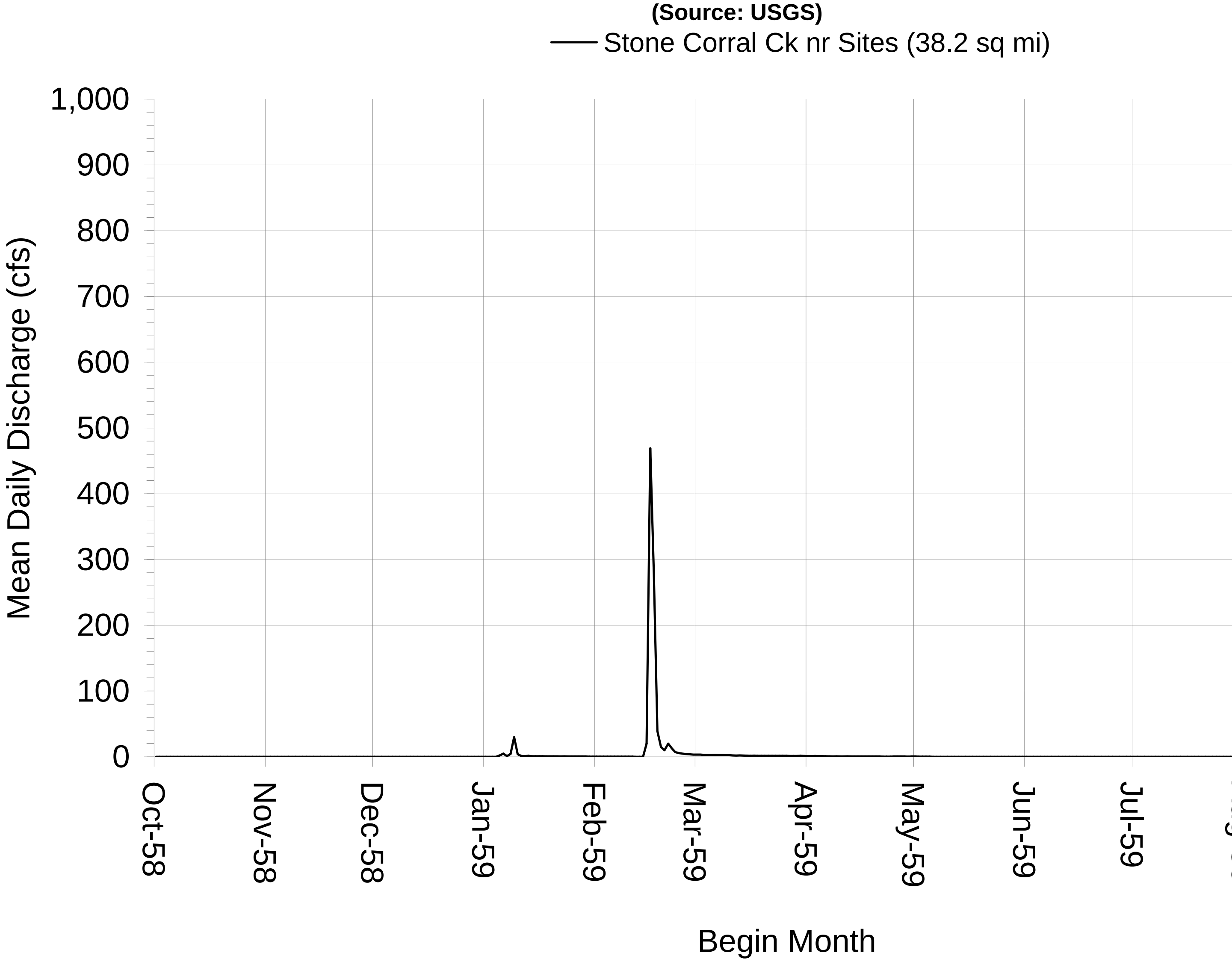
a. rural development which has a building density of less than 1 structure per 1.5 ac, but with at least 1 structure per 10 ac;
b. brush, timber, wetlands, and other lands not suitable for livestock grazing;
c. government lands not available for agricultural use;
d. road systems for freeway interchanges outside of Urban and Built-up Land areas;
e. vacant and nonagricultural land larger than 40 ac in size and surrounded on all sides by urban development;
f. confined livestock, poultry, or aquaculture facilities, unless accounted for by the county's Farmland of Local Importance definition;
g. strip mines, borrow pits, gravel pits, and ranch headquarters, or water bodies smaller than 40 ac;
h. a variety of other rural land uses

**Appendix 1. Hydrology.**
**Complete Period of Record Annual Hydrographs of Mean Daily Flow Measured at Gages in the Colusa Basin Watershed**

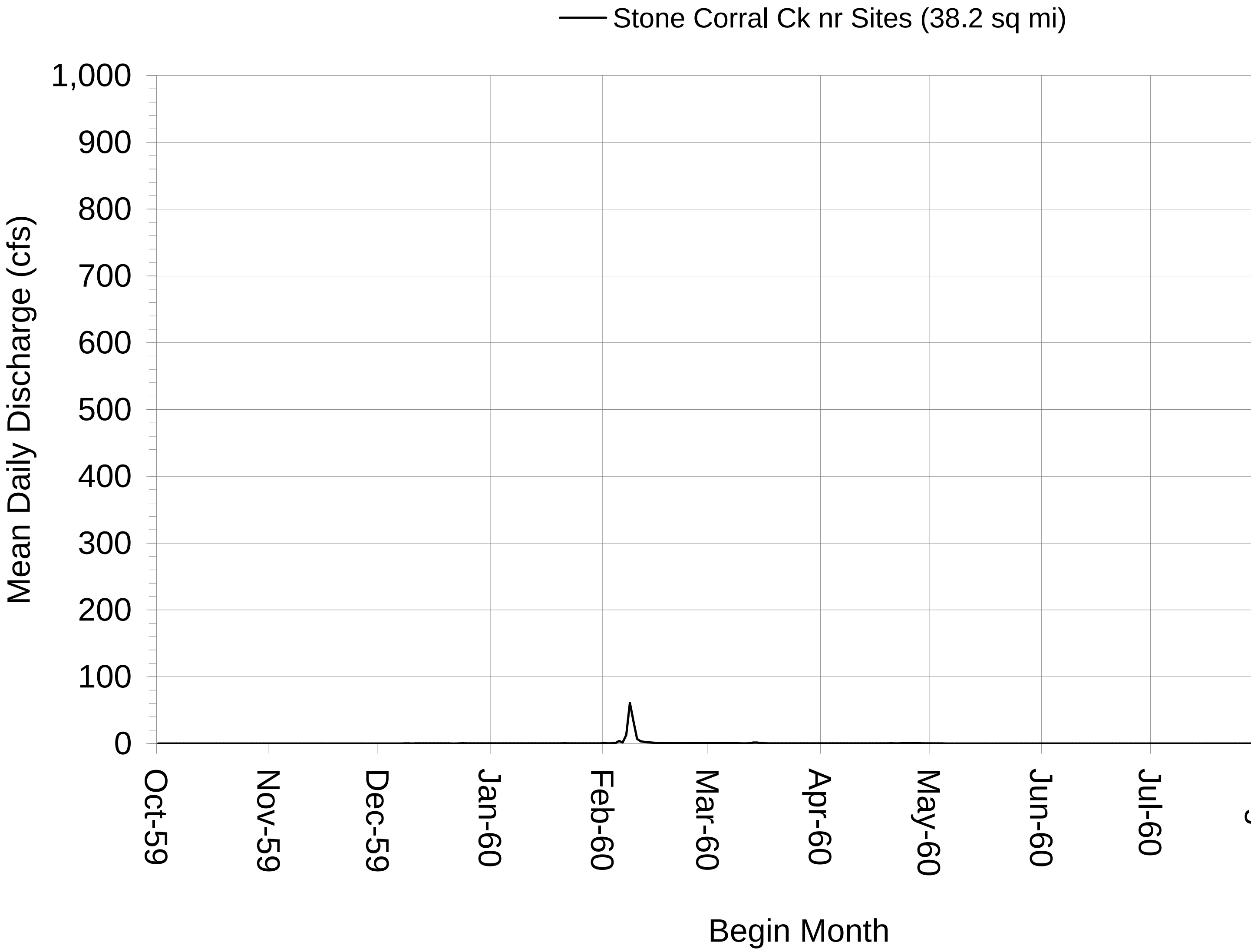
**Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas Watershed**
**1958 Water Year**
**(Source: USGS)**



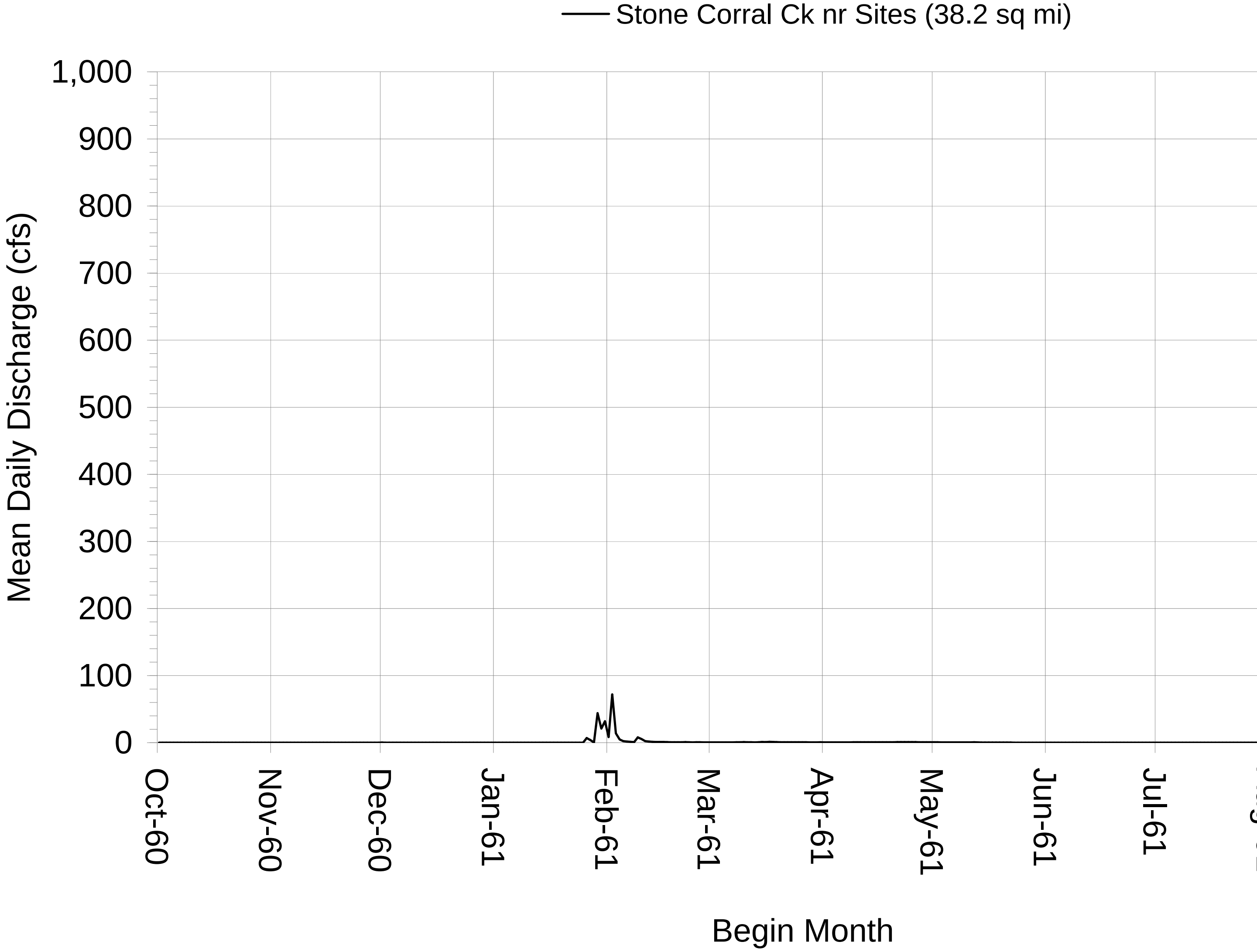
## Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas Watershed
## 1959 Water Year
**(Source: USGS)**

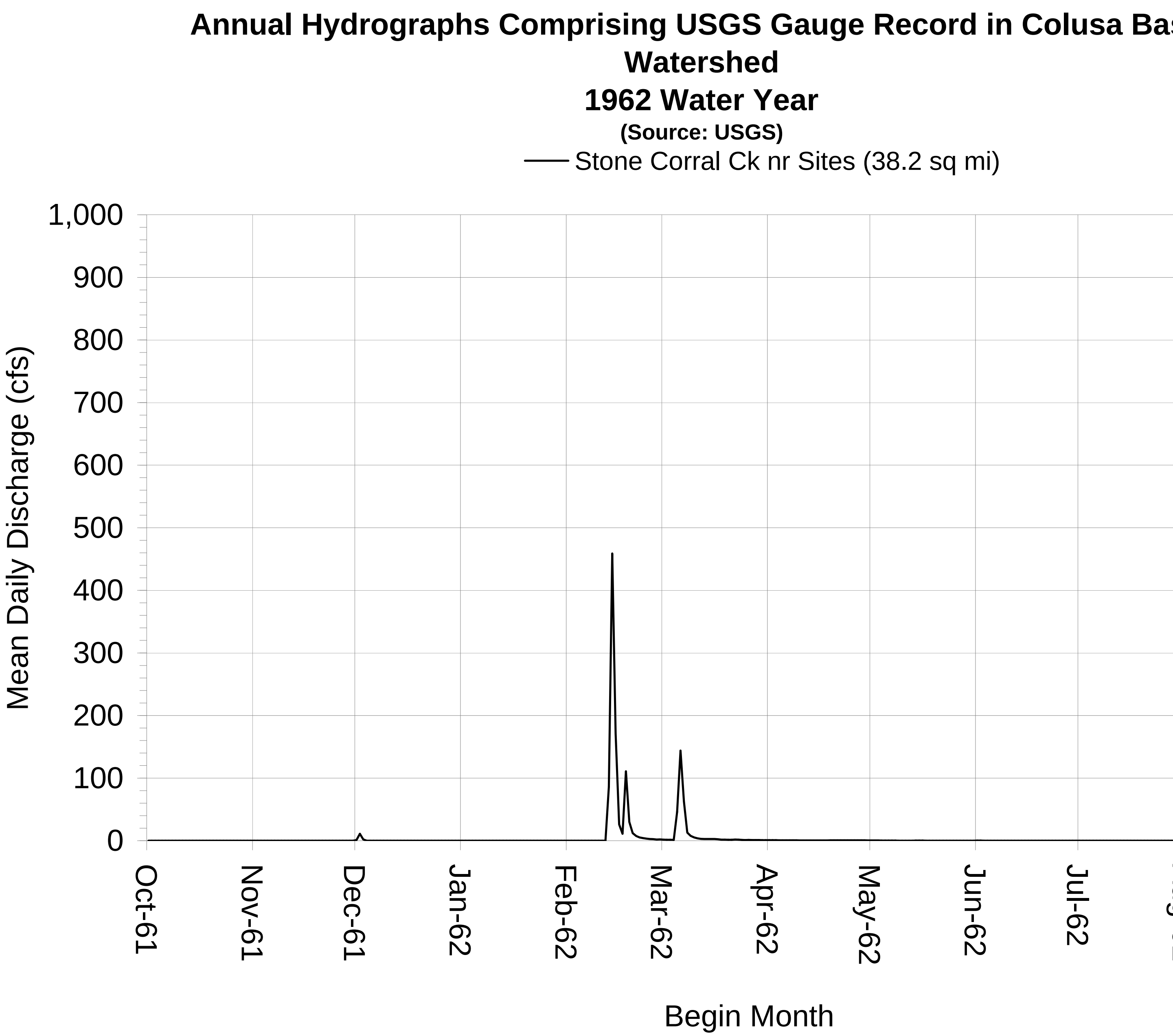


**Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1960 Water Year**
**(Source: USGS)**

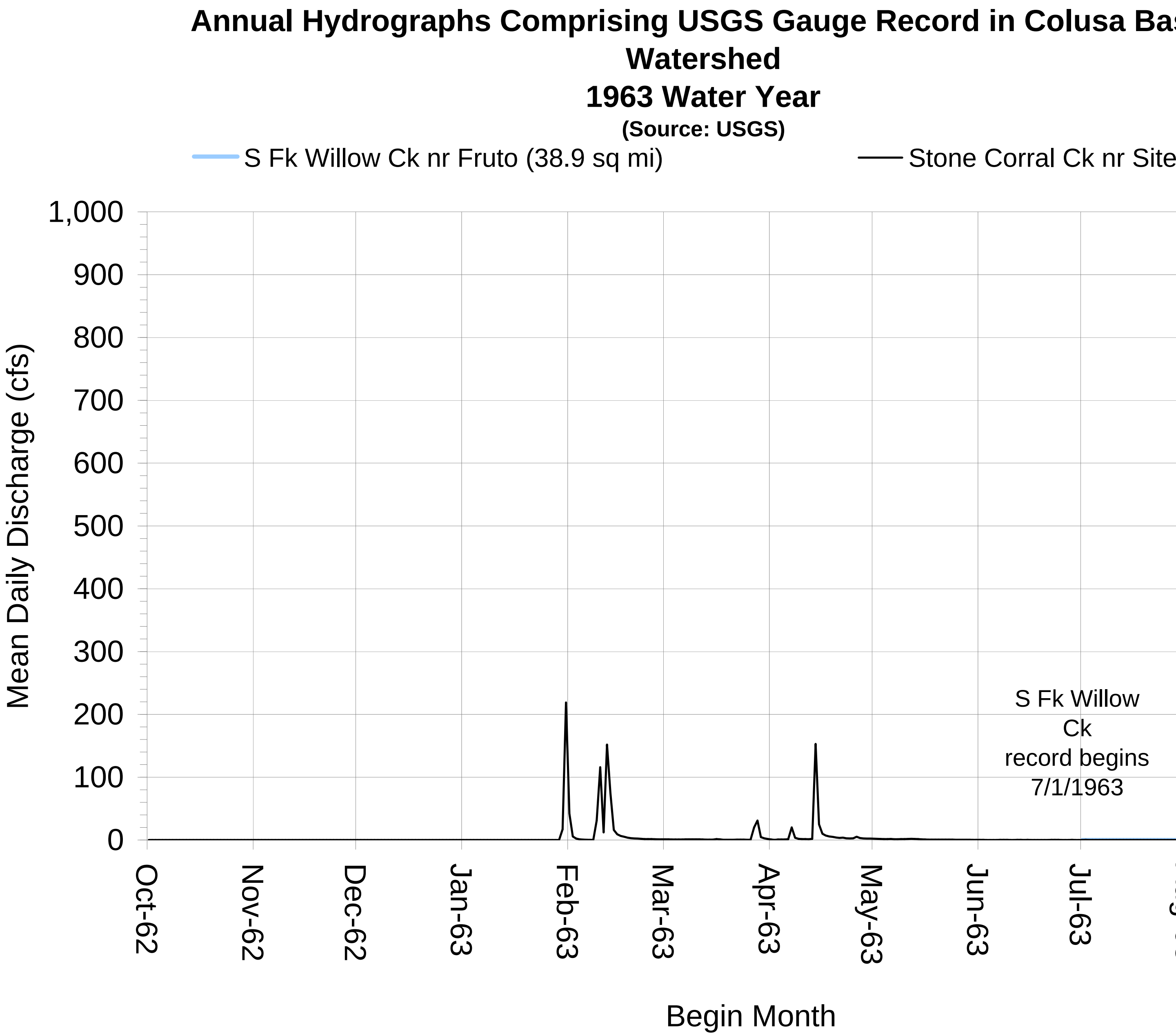


## Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
## Watershed
## 1961 Water Year
**(Source: USGS)**

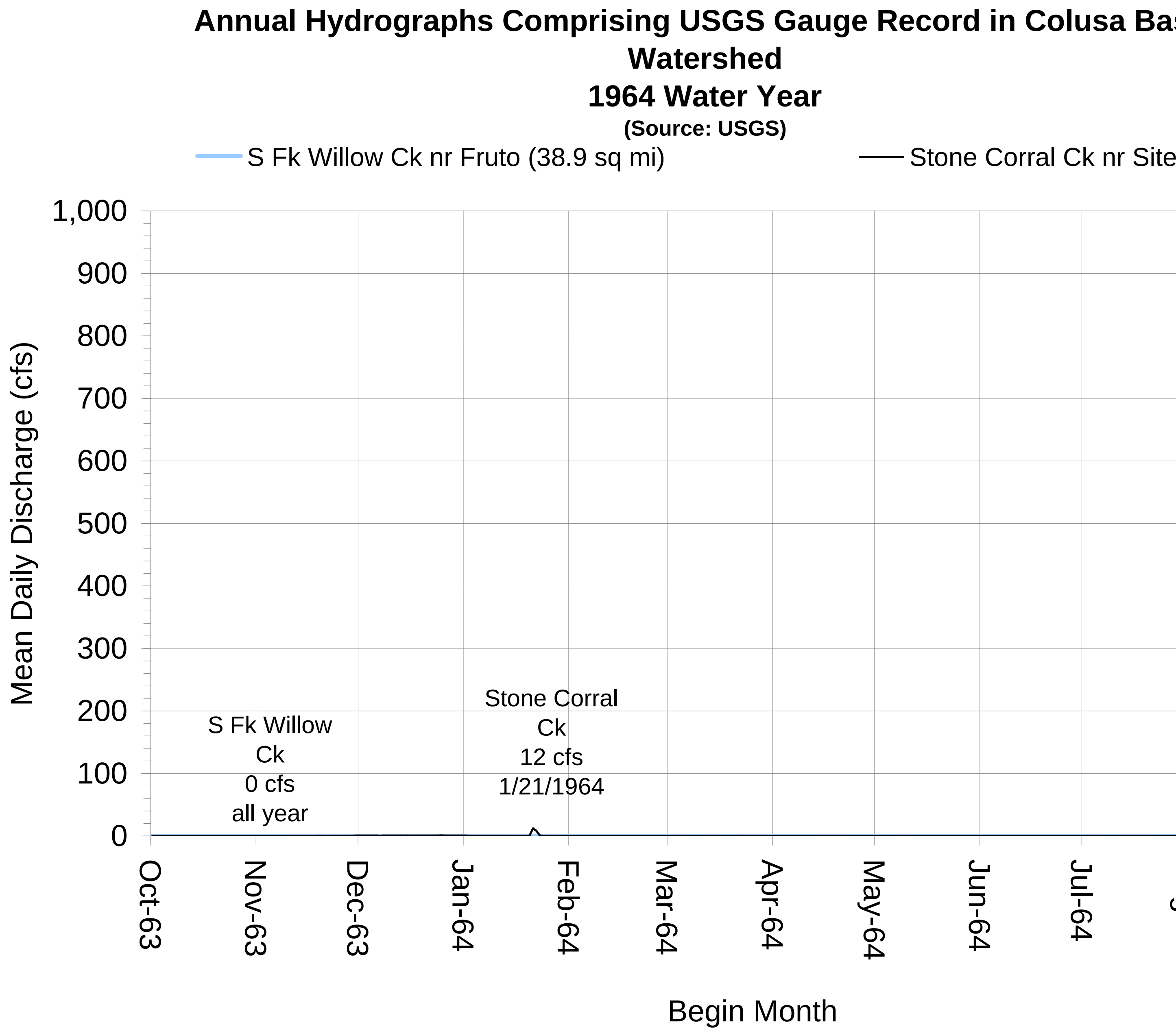




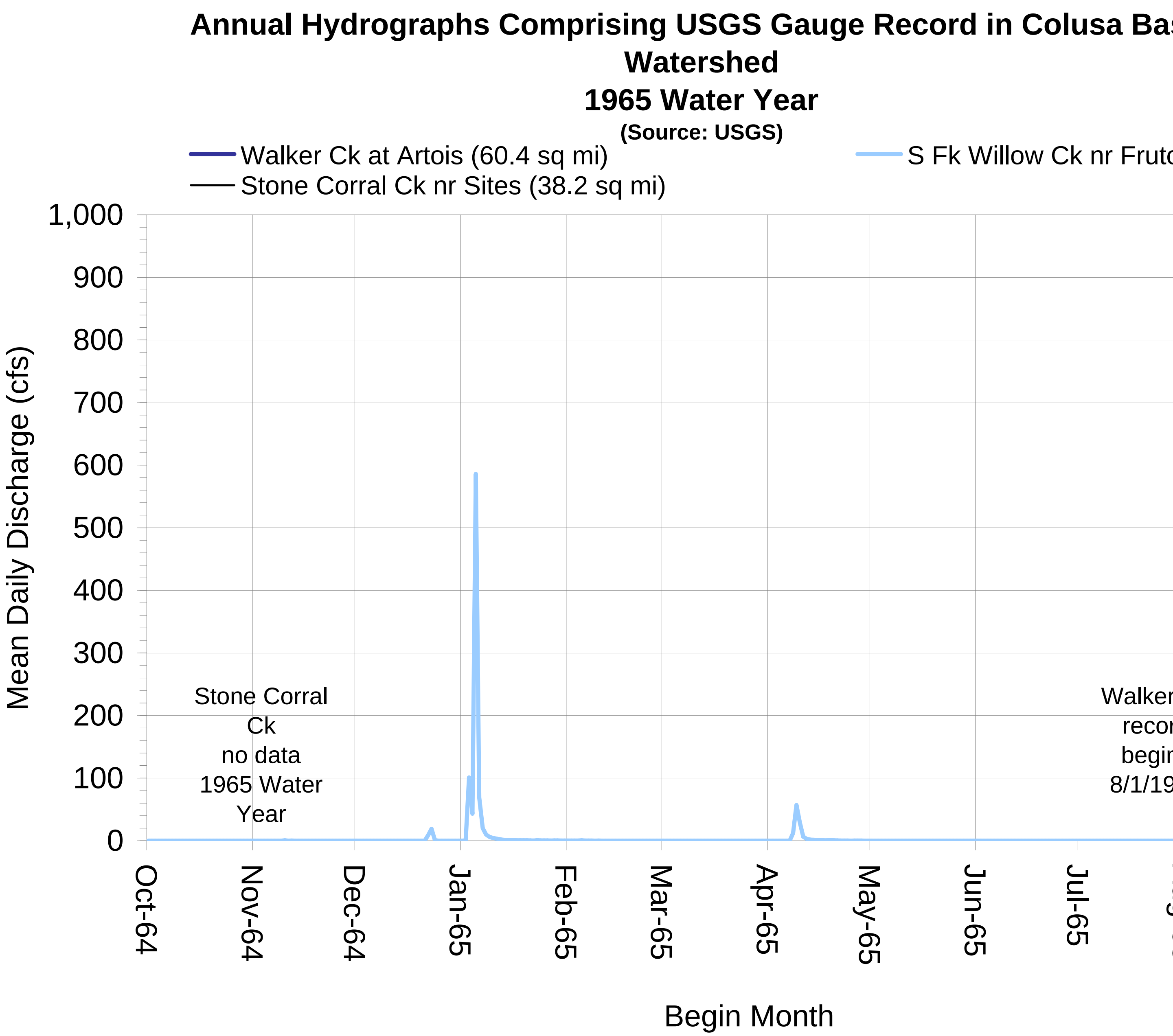
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1962 Water Year
(Source: USGS)
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-61
Nov-61
Dec-61
Jan-62
Feb-62
Mar-62
Apr-62
May-62
Jun-62
Jul-62
Begin Month



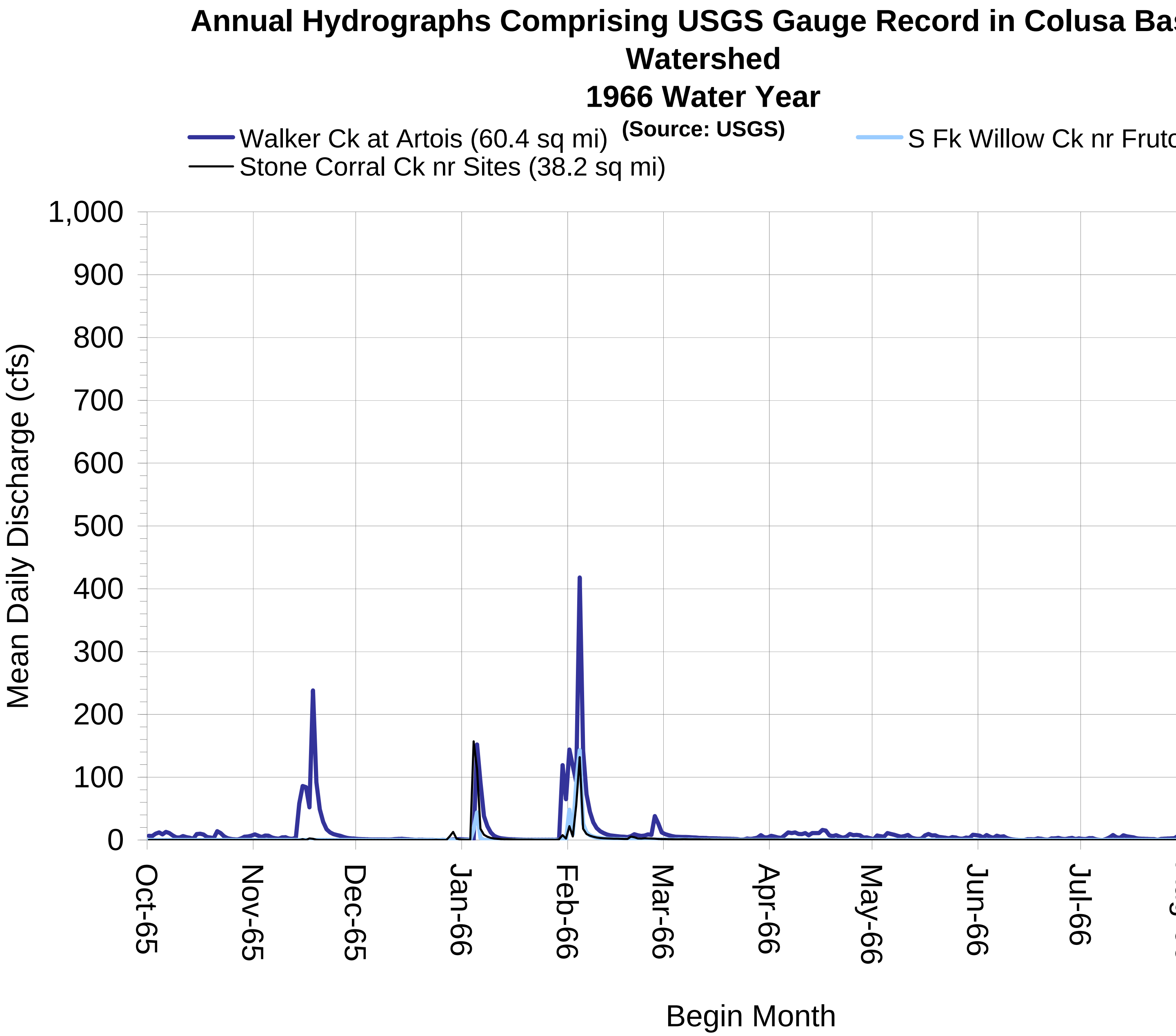
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1963 Water Year
(Source: USGS)
S Fk Willow Ck nr Fruto (38.9 sq mi)
Stone Corral Ck nr Site
1,000
900
800
700
600
500
400
300
200
100
0
Mean Daily Discharge (cfs)
S Fk Willow Ck record begins 7/1/1963
Oct-62
Nov-62
Dec-62
Jan-63
Feb-63
Mar-63
Apr-63
May-63
Jun-63
Jul-63
Begin Month



Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1964 Water Year
(Source: USGS)
S Fk Willow Ck nr Fruto (38.9 sq mi)
Stone Corral Ck nr Site
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
S Fk Willow Ck 0 cfs all year
Stone Corral Ck 12 cfs 1/21/1964
Oct-63
Nov-63
Dec-63
Jan-64
Feb-64
Mar-64
Apr-64
May-64
Jun-64
Jul-64
Begin Month

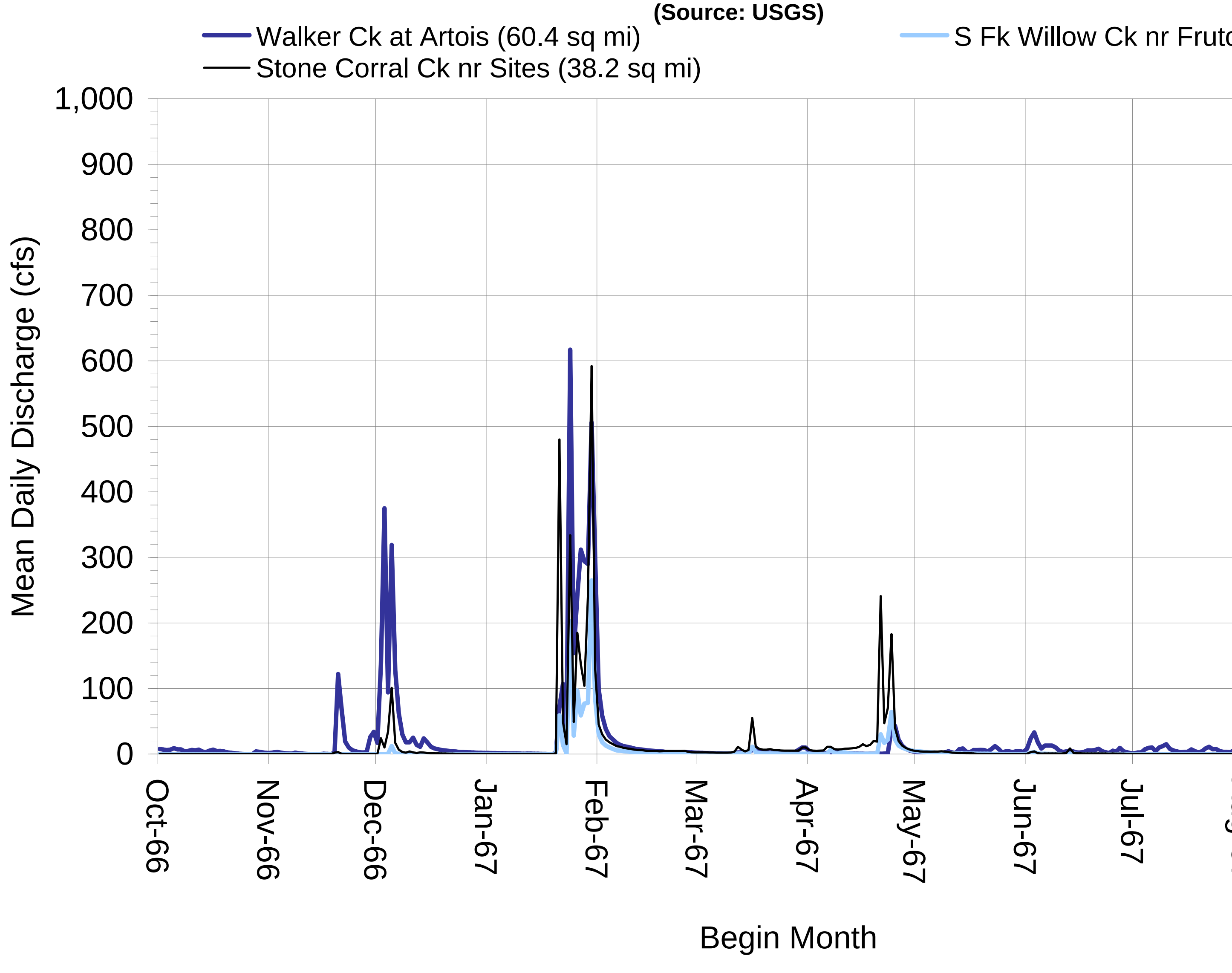


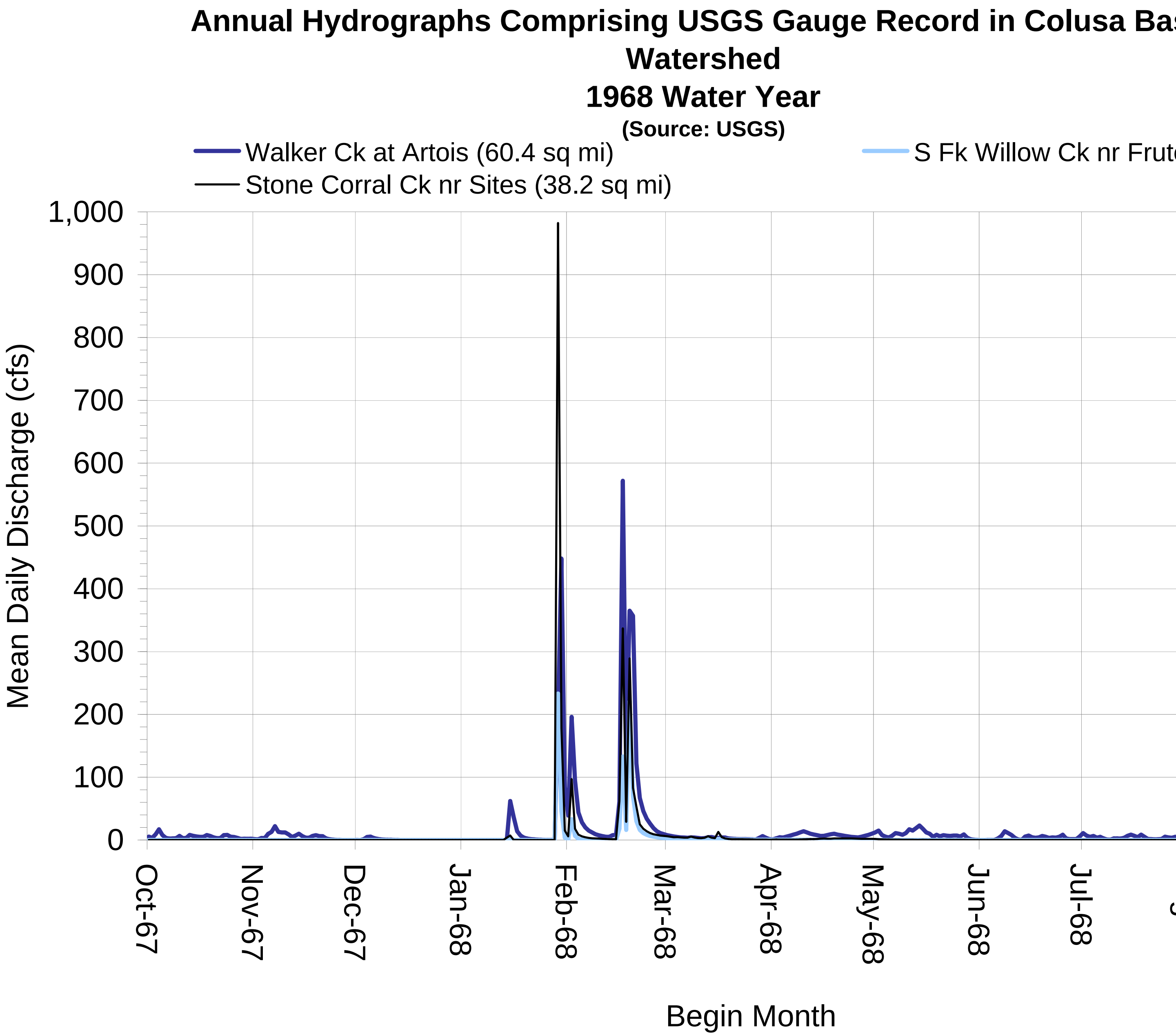
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1965 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Stone Corral Ck no data 1965 Water Year
Walker recor begin 8/1/19
Oct-64
Nov-64
Dec-64
Jan-65
Feb-65
Mar-65
Apr-65
May-65
Jun-65
Jul-65
Begin Month



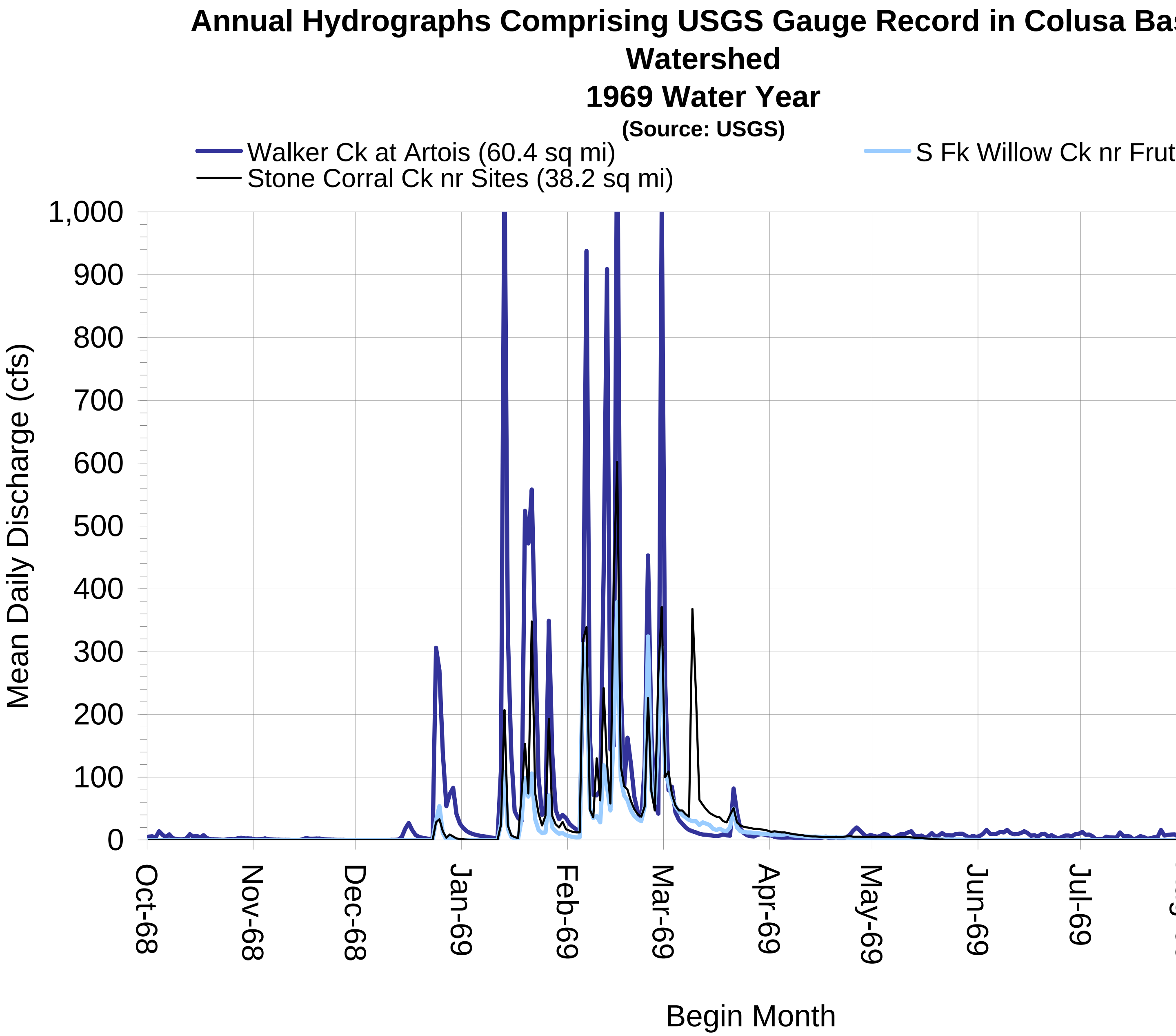
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1966 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-65
Nov-65
Dec-65
Jan-66
Feb-66
Mar-66
Apr-66
May-66
Jun-66
Jul-66
Begin Month

## Annual Hydrographs Comprising USGS Gauge Record in Colusa Basin Watershed
## 1967 Water Year
**(Source: USGS)**

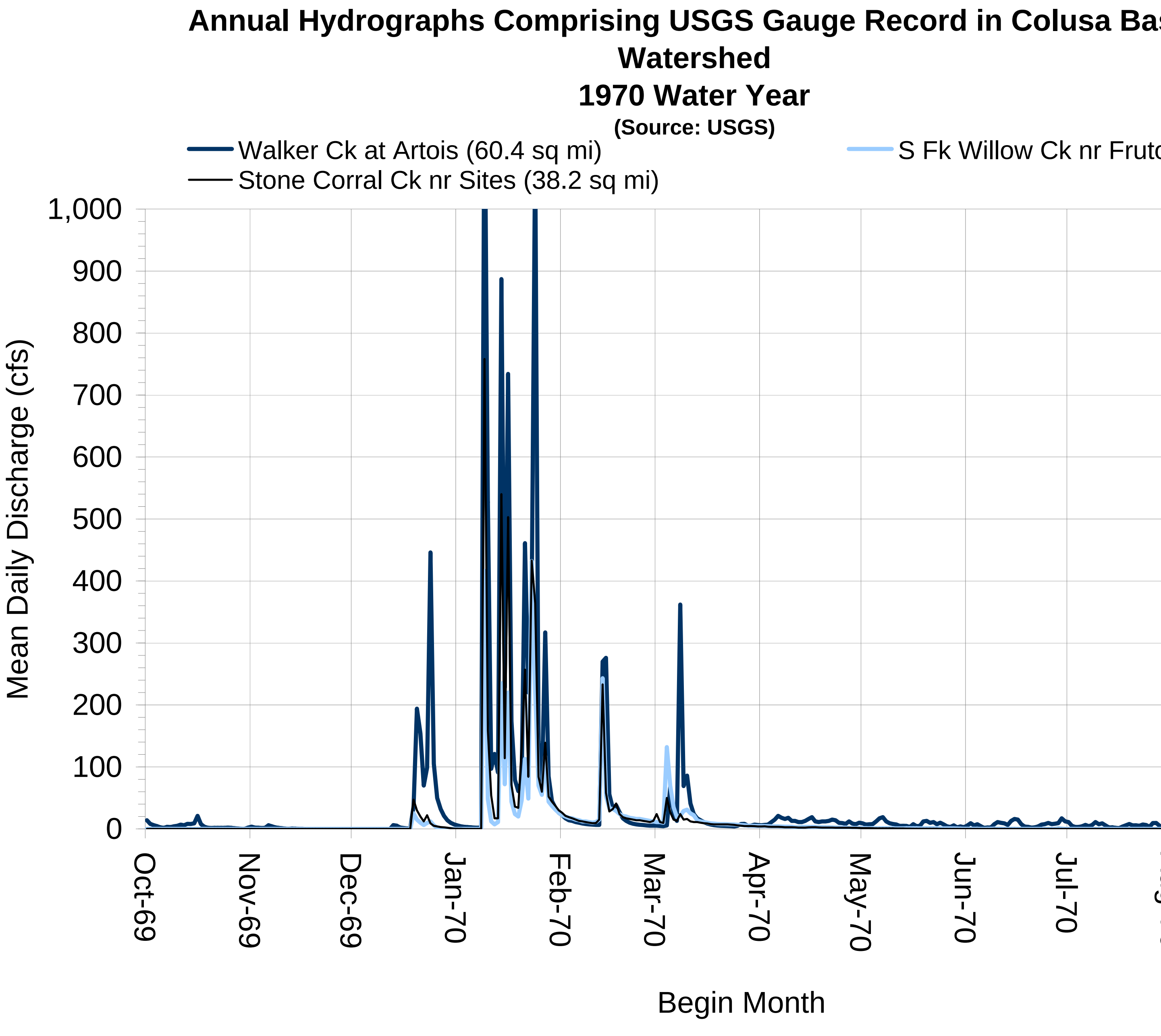




Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1968 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Frut
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-67
Nov-67
Dec-67
Jan-68
Feb-68
Mar-68
Apr-68
May-68
Jun-68
Jul-68
Begin Month

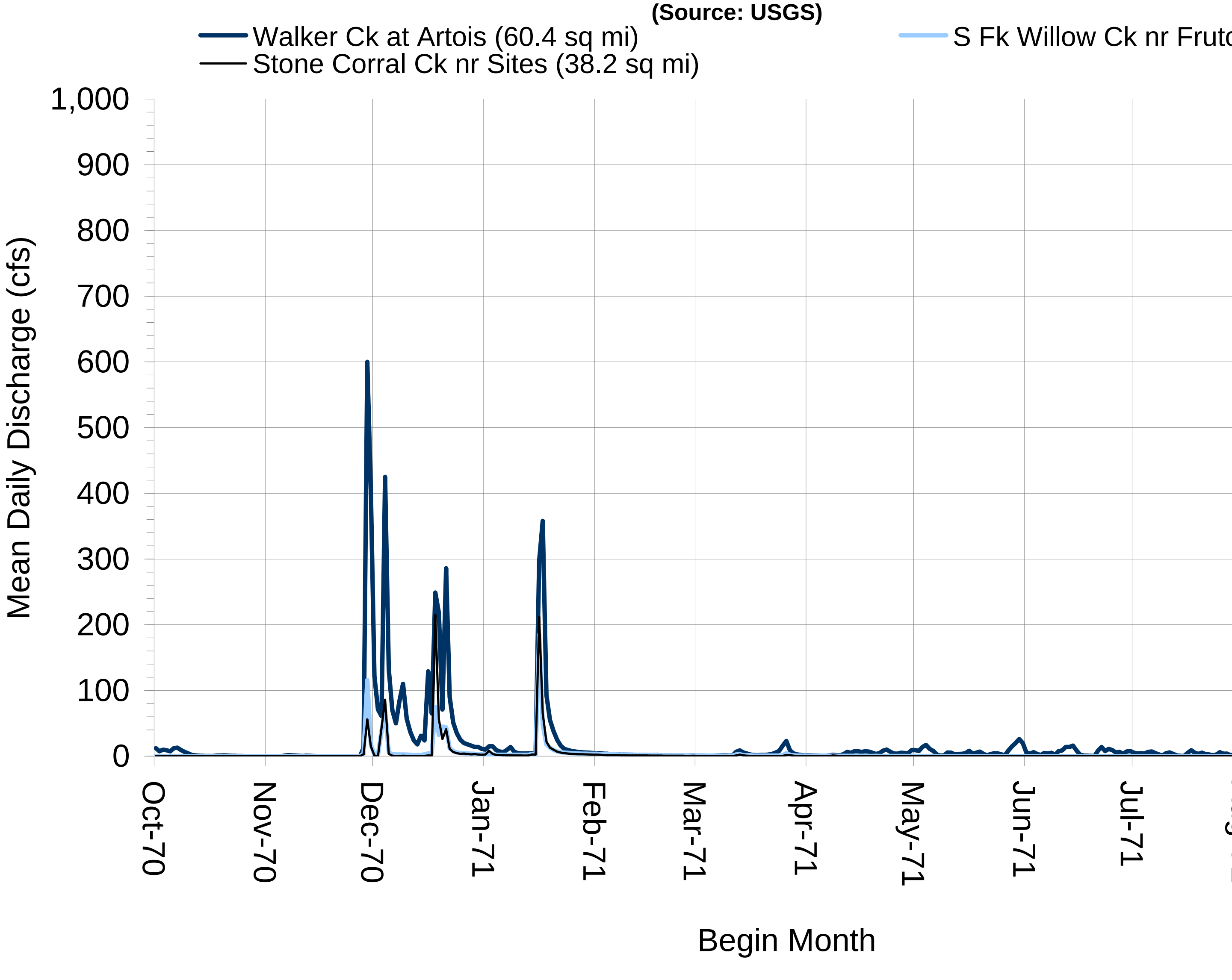


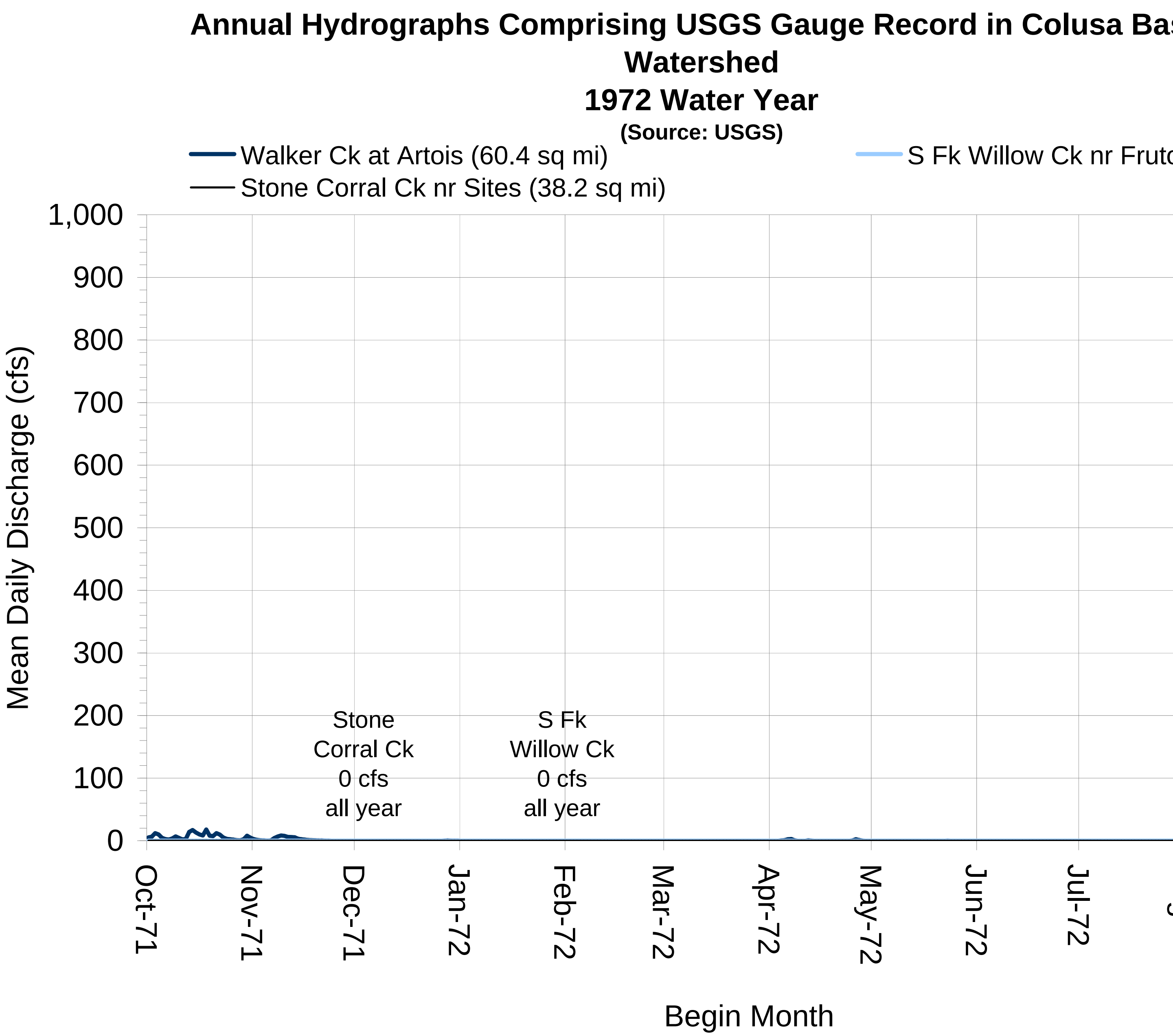
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1969 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Frut
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-68
Nov-68
Dec-68
Jan-69
Feb-69
Mar-69
Apr-69
May-69
Jun-69
Jul-69
Begin Month



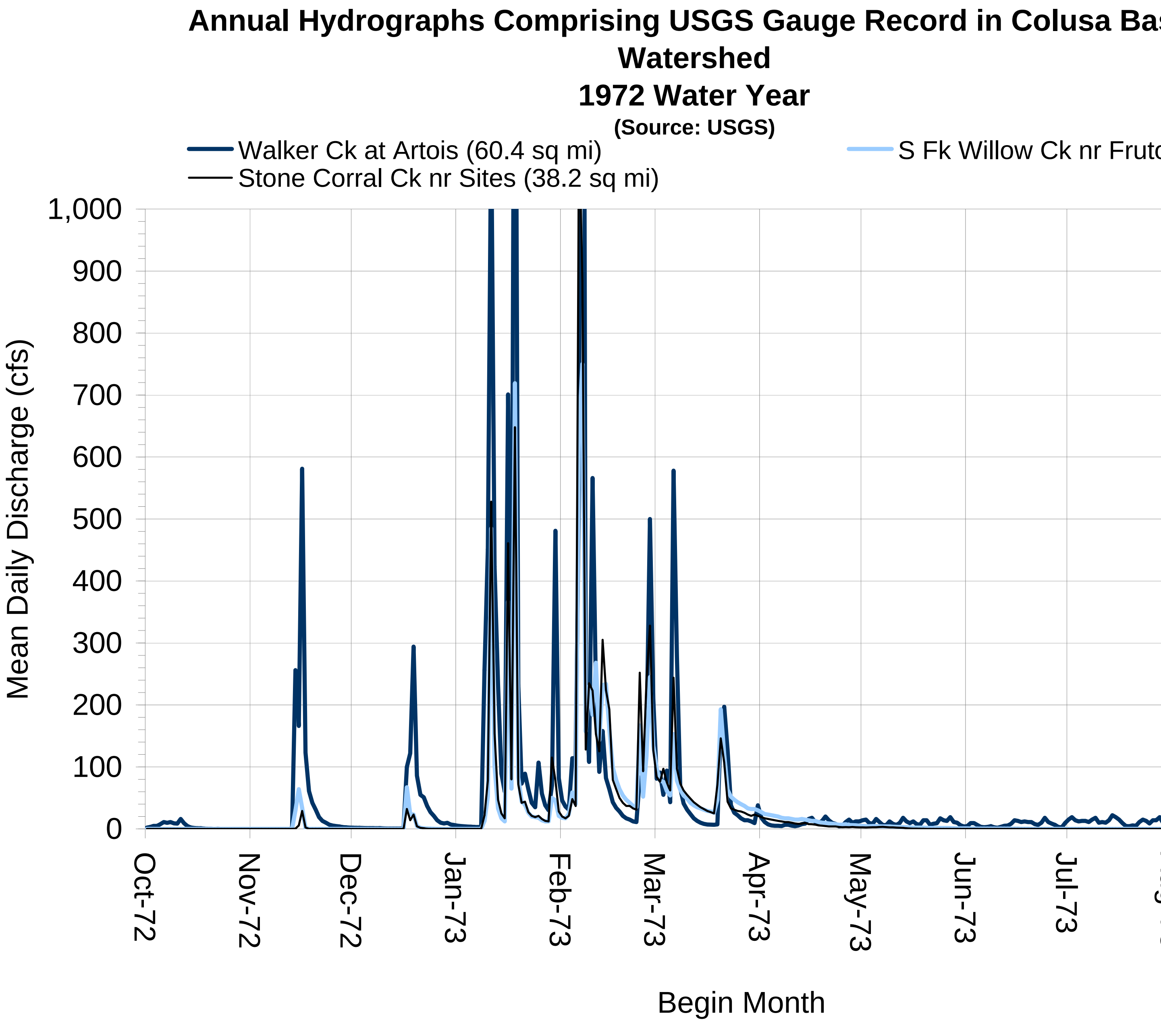
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1970 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-69
Nov-69
Dec-69
Jan-70
Feb-70
Mar-70
Apr-70
May-70
Jun-70
Jul-70
Begin Month

Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1971 Water Year
(Source: USGS)

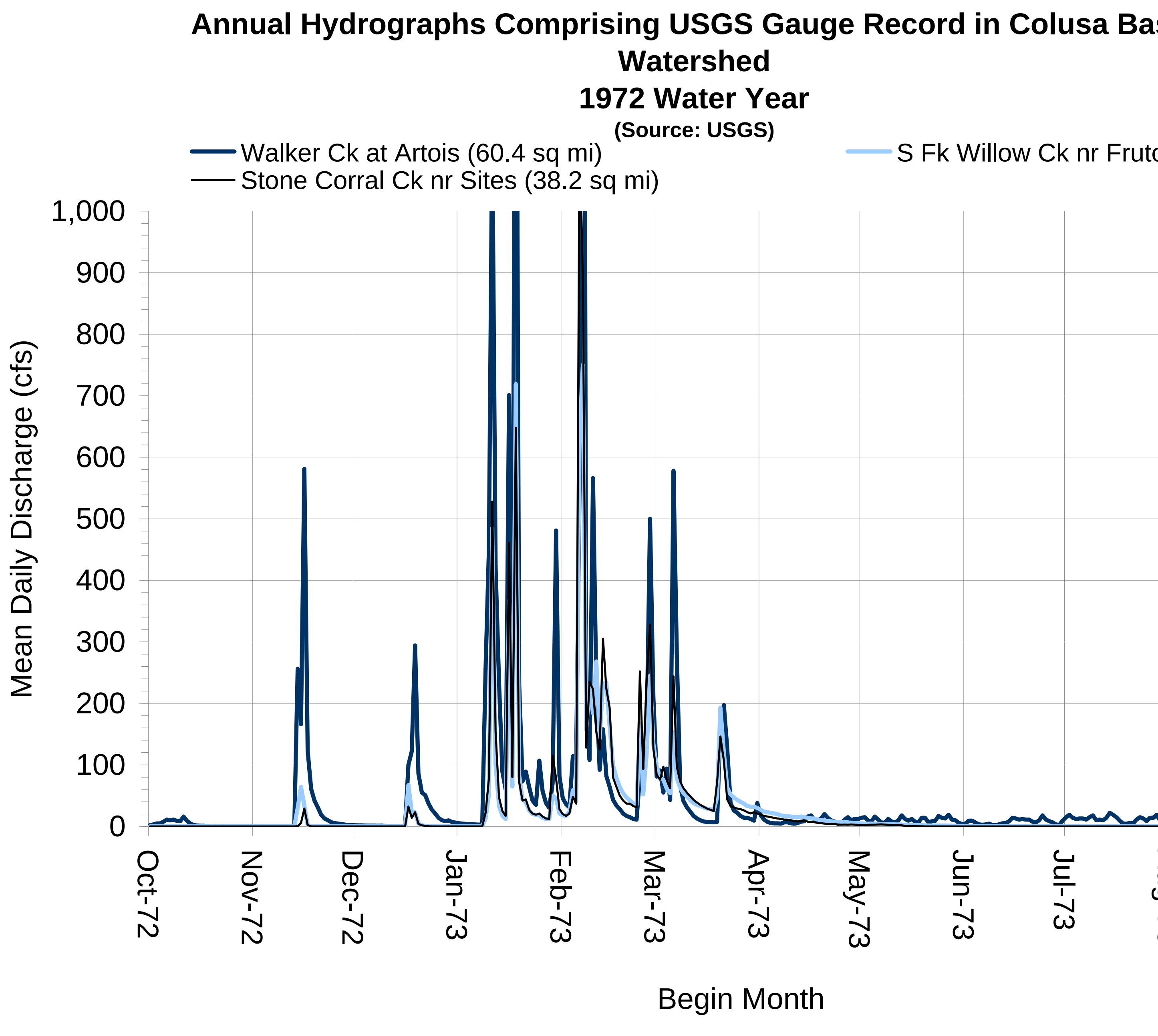


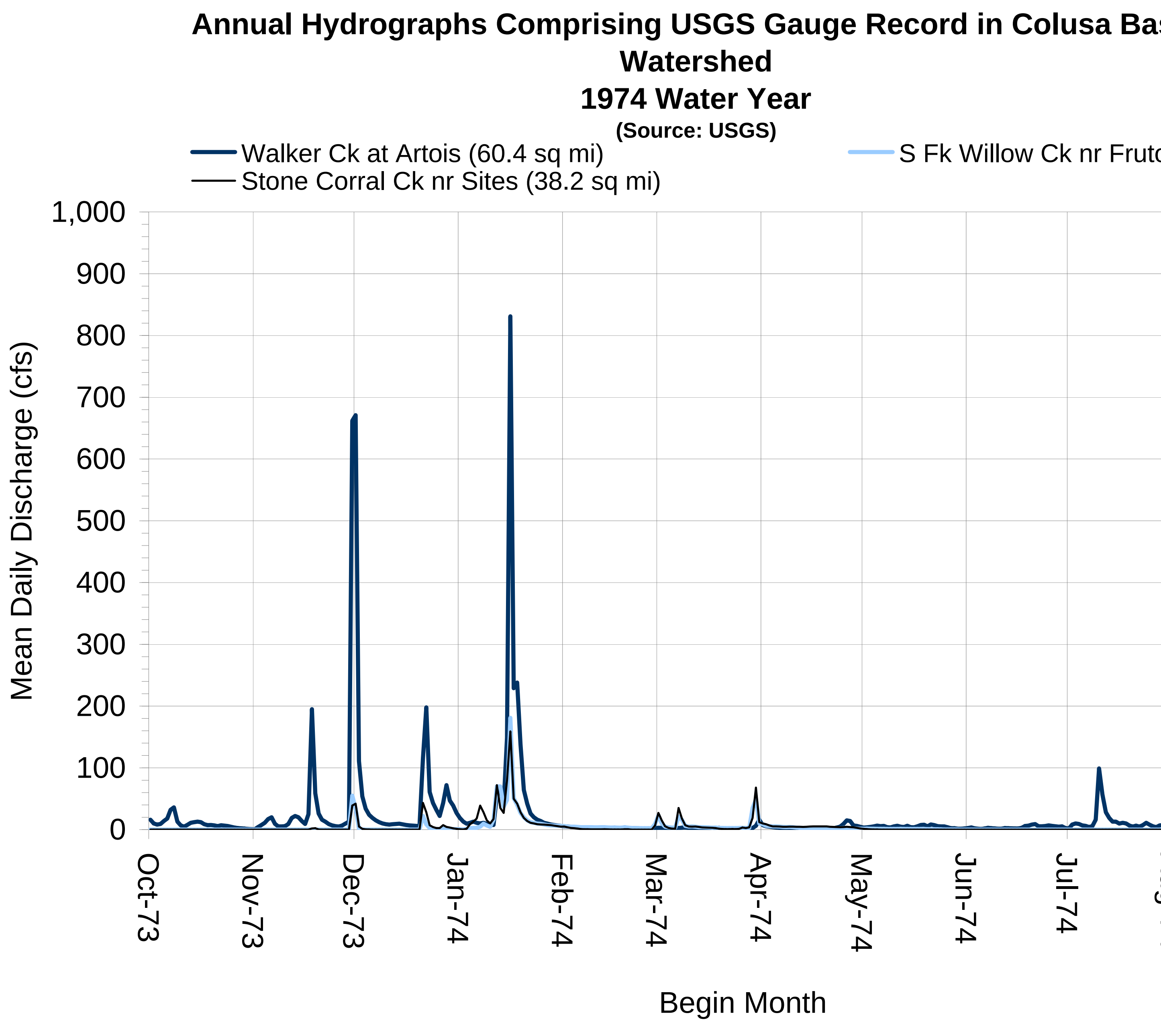


Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1972 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Stone
Corral Ck
0 cfs
all year
S Fk
Willow Ck
0 cfs
all year
Oct-71
Nov-71
Dec-71
Jan-72
Feb-72
Mar-72
Apr-72
May-72
Jun-72
Jul-72
Begin Month

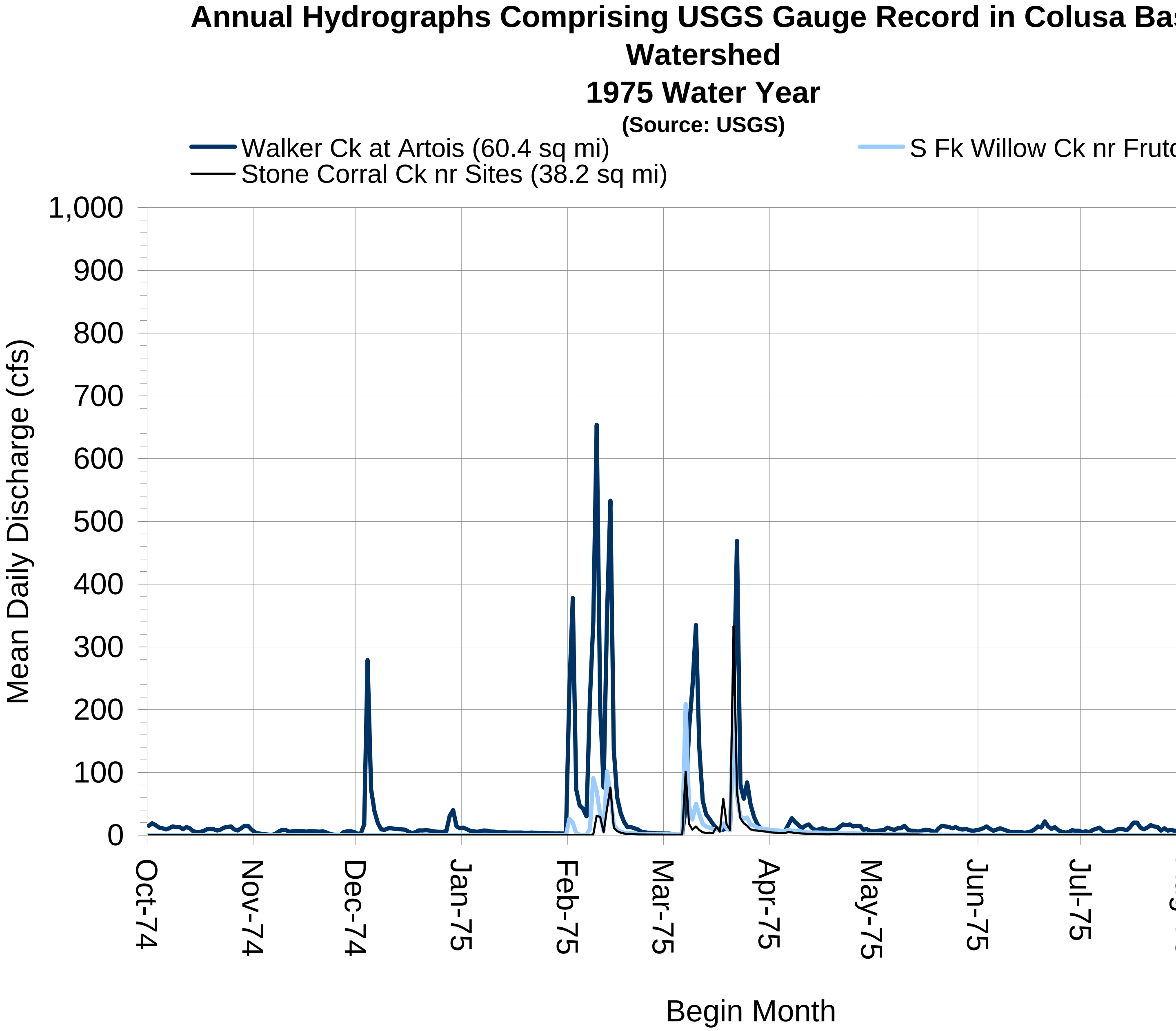


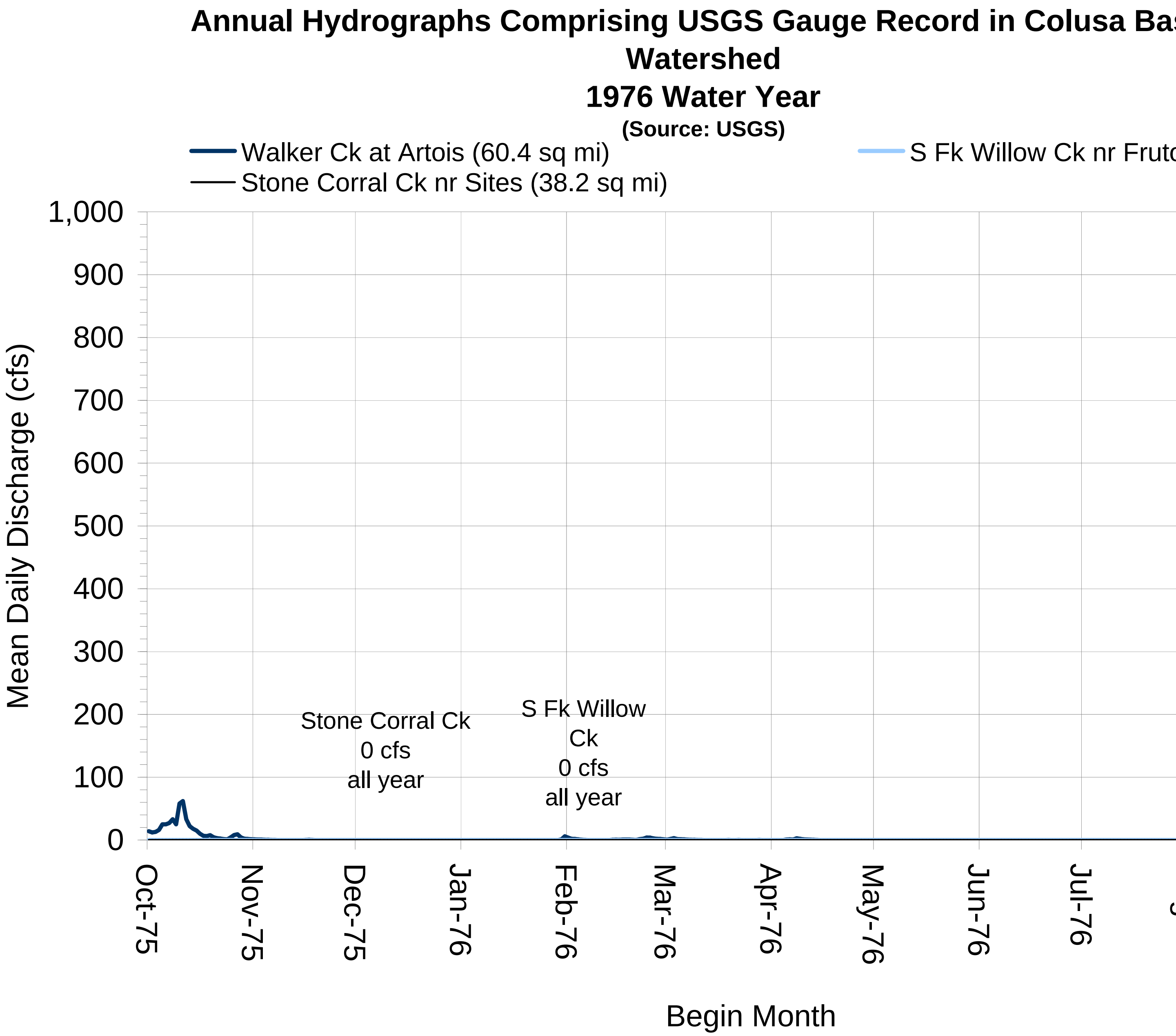
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1972 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-72
Nov-72
Dec-72
Jan-73
Feb-73
Mar-73
Apr-73
May-73
Jun-73
Jul-73
Begin Month


Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1972 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-72
Nov-72
Dec-72
Jan-73
Feb-73
Mar-73
Apr-73
May-73
Jun-73
Jul-73
Begin Month

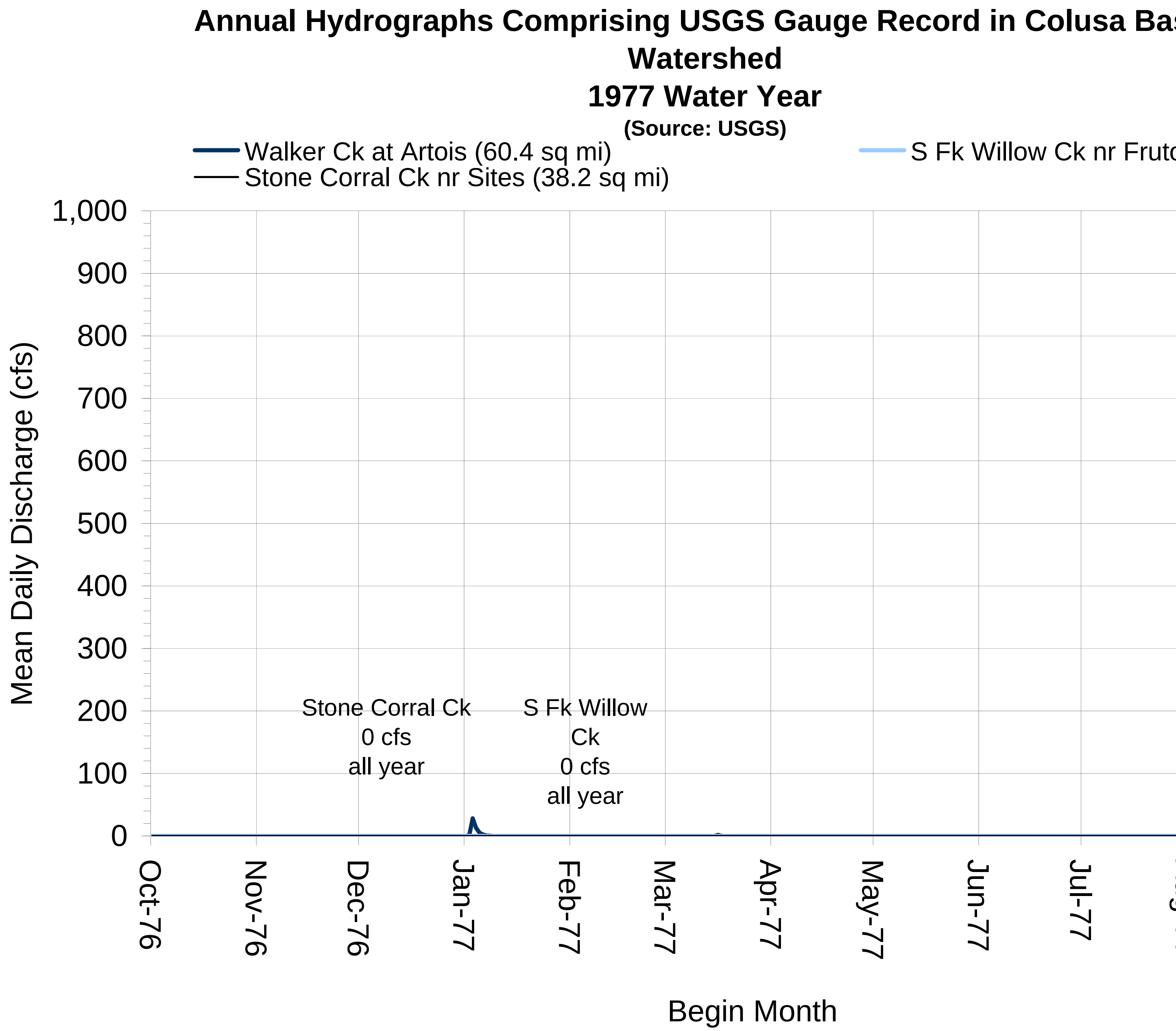


Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1974 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-73
Nov-73
Dec-73
Jan-74
Feb-74
Mar-74
Apr-74
May-74
Jun-74
Jul-74
Begin Month

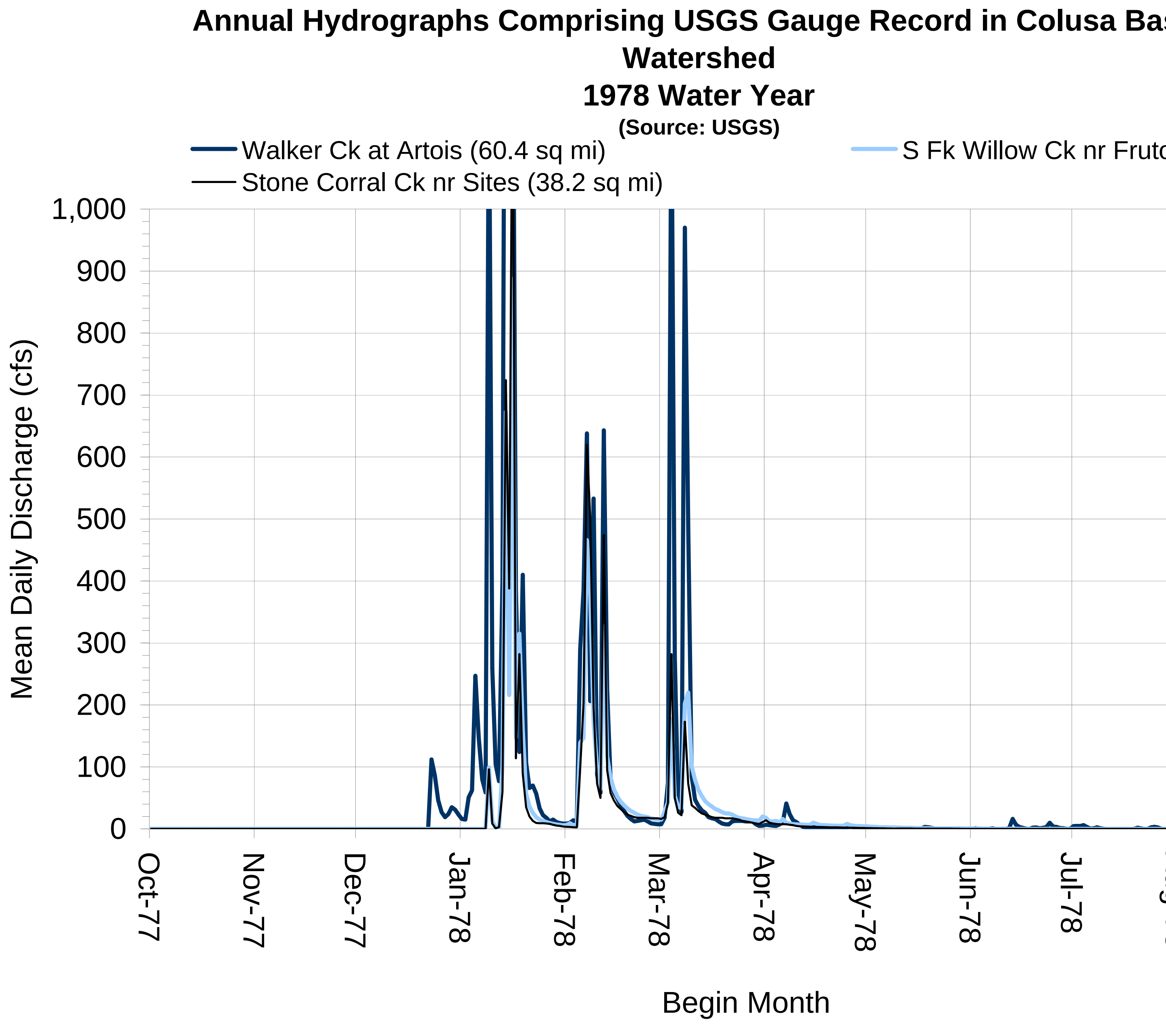

Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1975 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-74
Nov-74
Dec-74
Jan-75
Feb-75
Mar-75
Apr-75
May-75
Jun-75
Jul-75
Begin Month



Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1976 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Stone Corral Ck
0 cfs
all year
S Fk Willow
Ck
0 cfs
all year
Oct-75
Nov-75
Dec-75
Jan-76
Feb-76
Mar-76
Apr-76
May-76
Jun-76
Jul-76
Begin Month

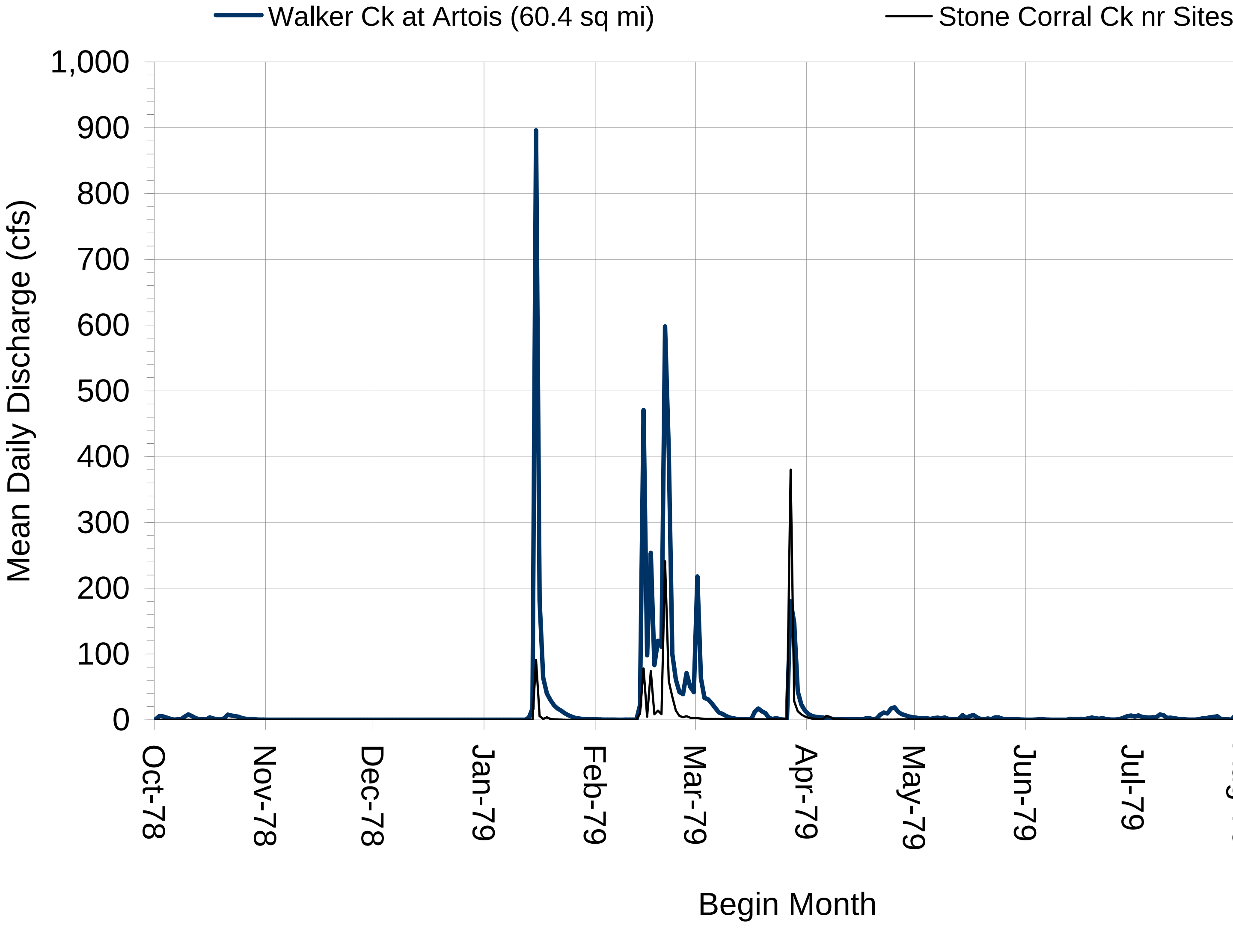


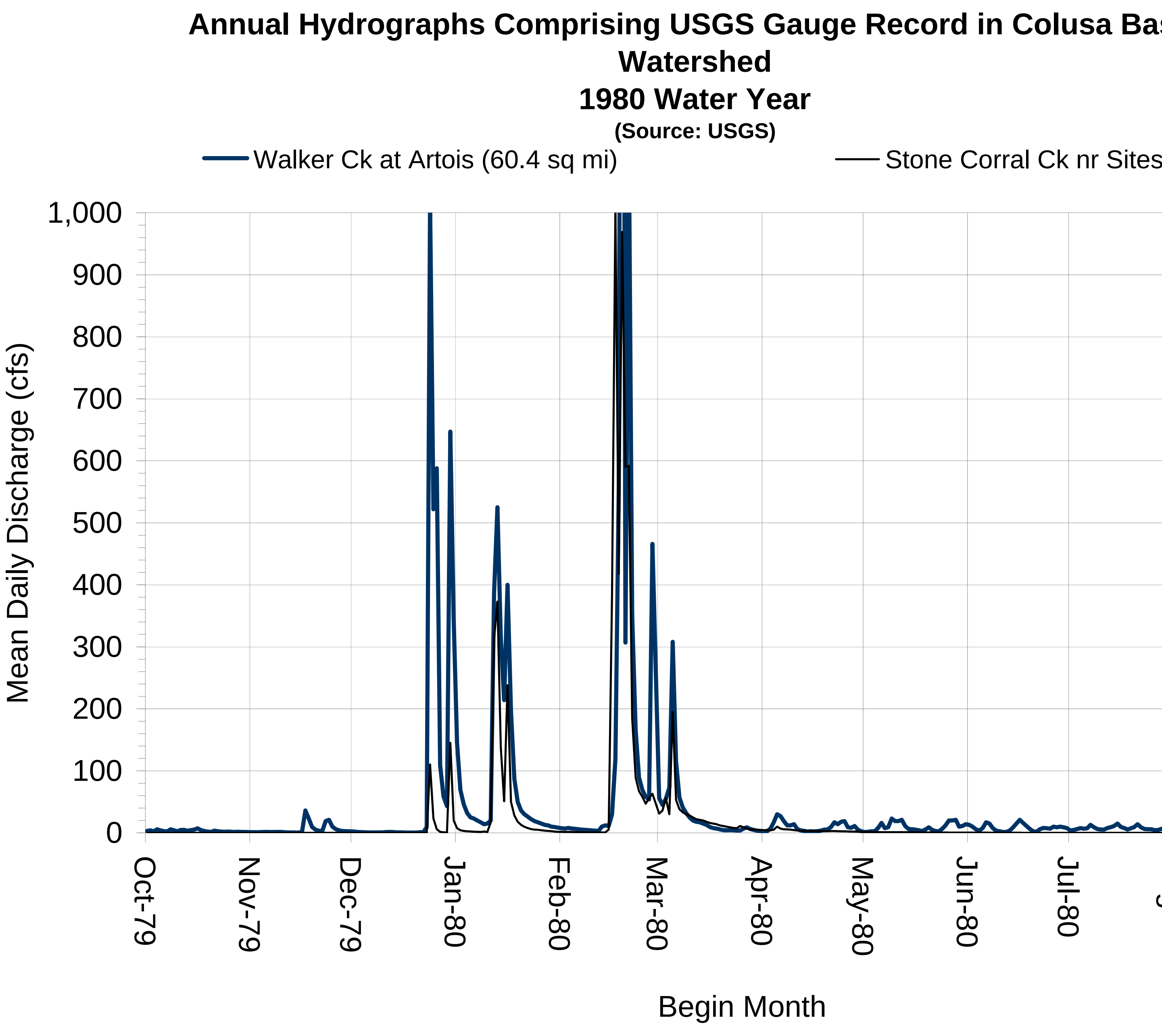
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1977 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Frut
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Stone Corral Ck
0 cfs
all year
S Fk Willow
Ck
0 cfs
all year
Oct-76
Nov-76
Dec-76
Jan-77
Feb-77
Mar-77
Apr-77
May-77
Jun-77
Jul-77
Begin Month

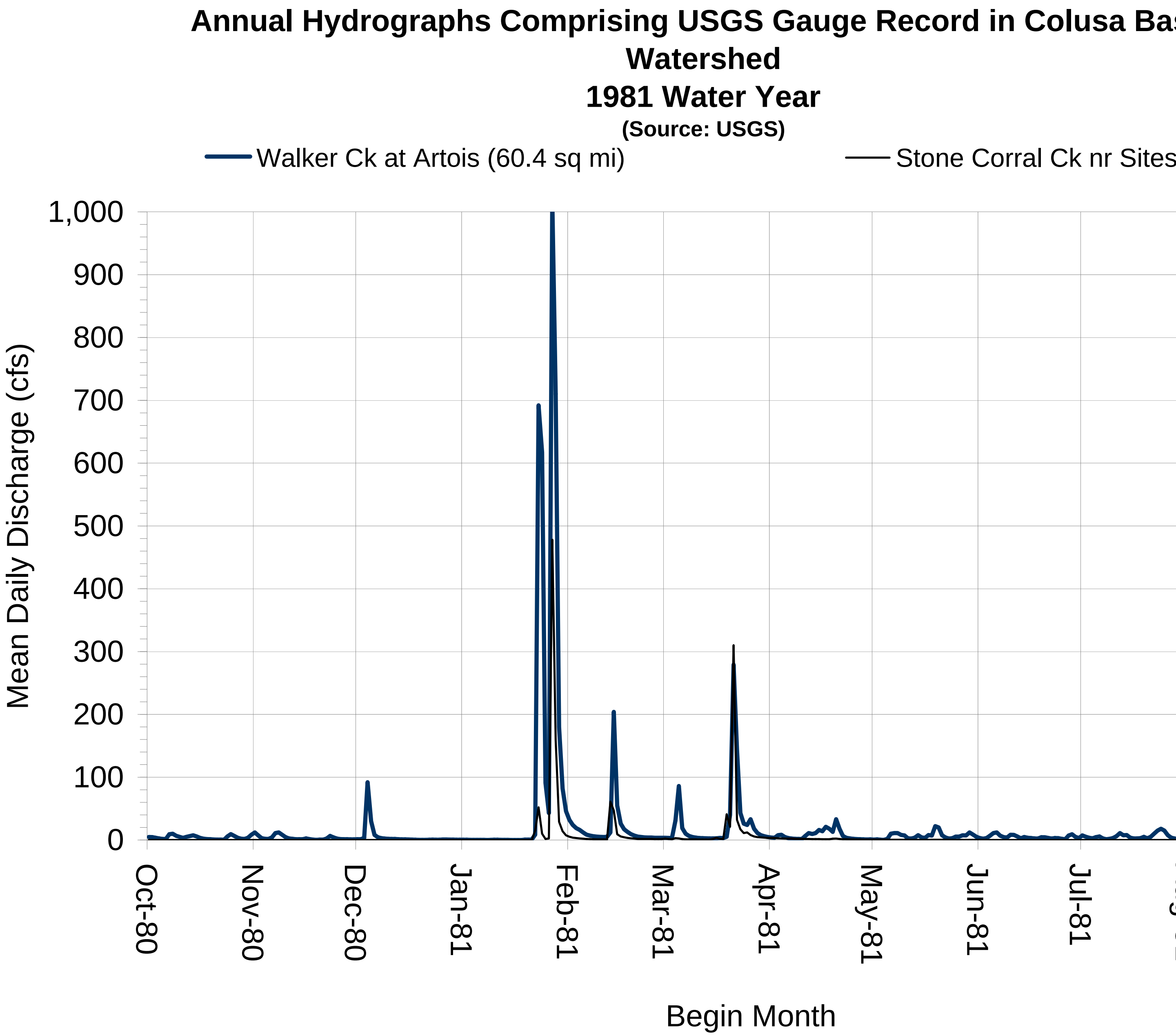


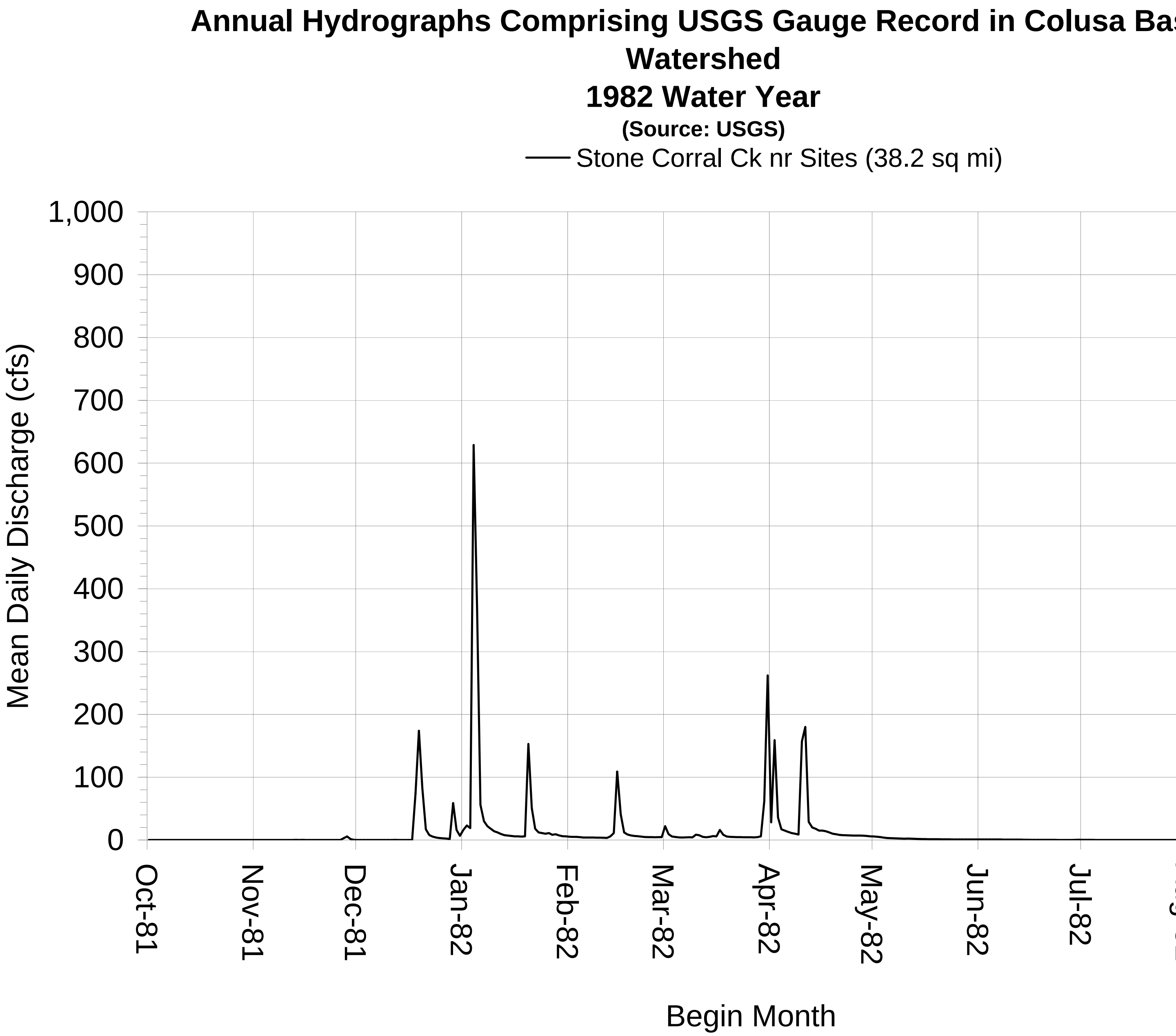
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1978 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
S Fk Willow Ck nr Fruto
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-77
Nov-77
Dec-77
Jan-78
Feb-78
Mar-78
Apr-78
May-78
Jun-78
Jul-78
Begin Month

## Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
## Watershed
## 1979 Water Year
**(Source: USGS)**



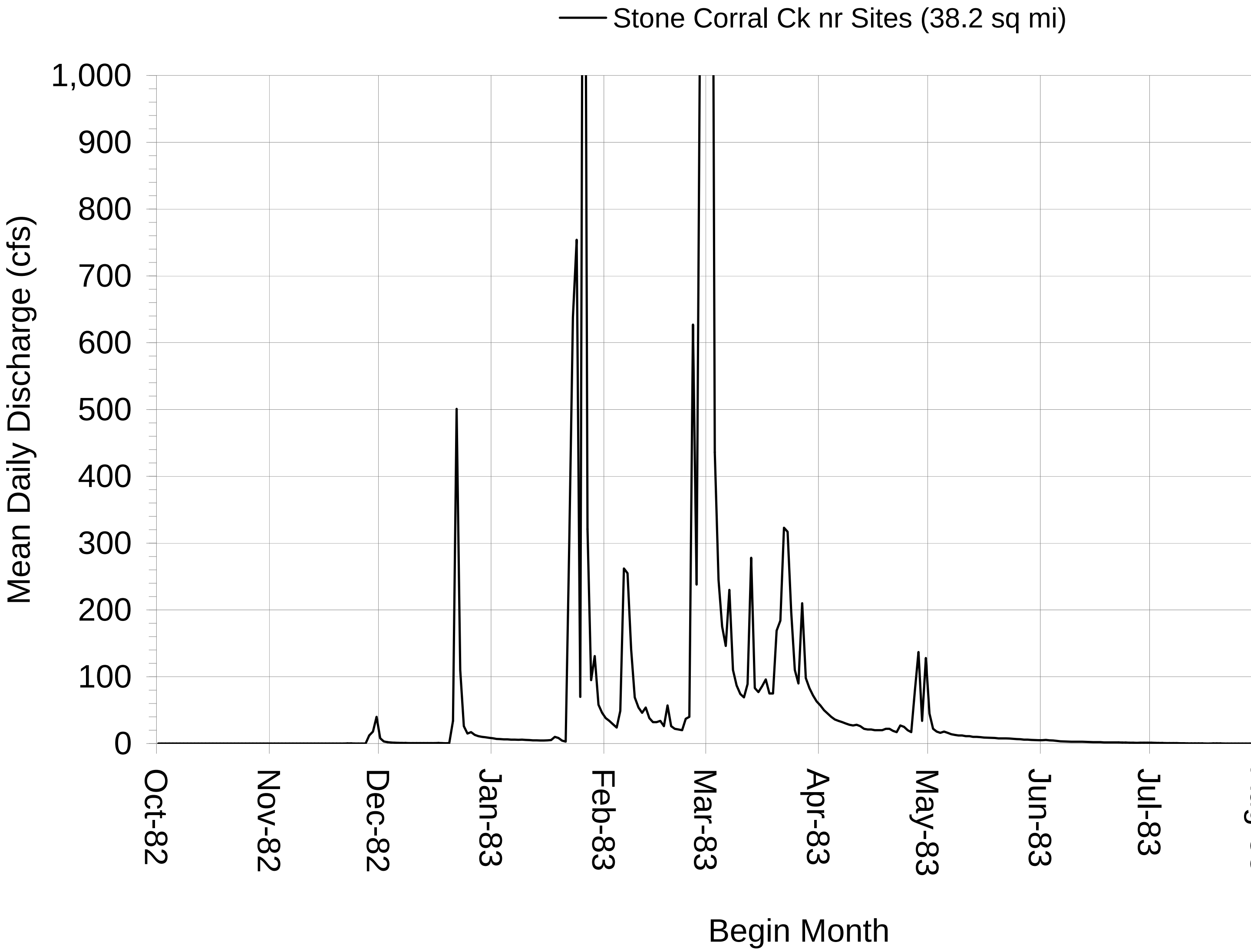

Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1980 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
Stone Corral Ck nr Sites
1,000
900
800
700
600
500
400
300
200
100
0
Mean Daily Discharge (cfs)
Oct-79
Nov-79
Dec-79
Jan-80
Feb-80
Mar-80
Apr-80
May-80
Jun-80
Jul-80
Begin Month

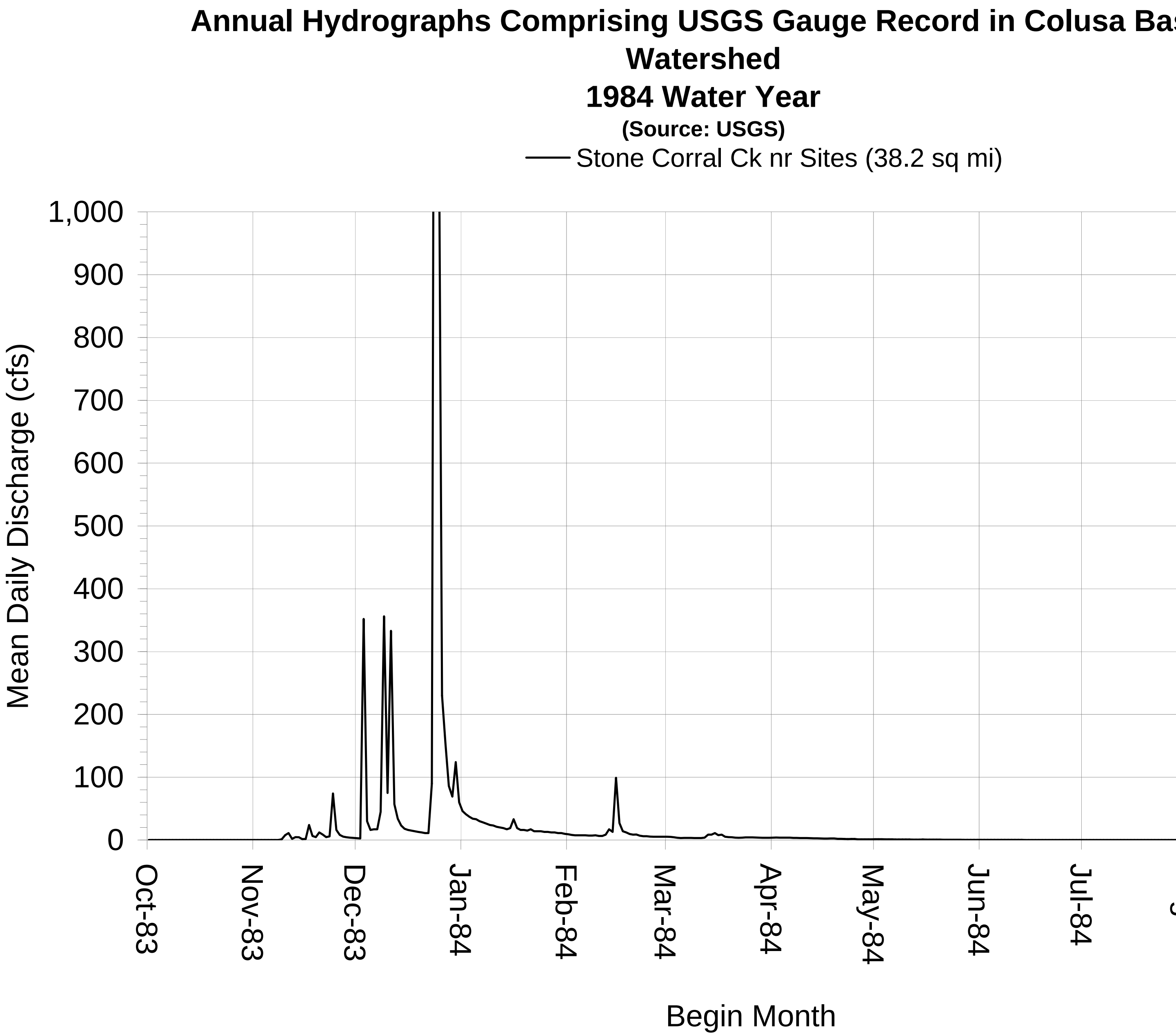

Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1981 Water Year
(Source: USGS)
Walker Ck at Artois (60.4 sq mi)
Stone Corral Ck nr Sites
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-80
Nov-80
Dec-80
Jan-81
Feb-81
Mar-81
Apr-81
May-81
Jun-81
Jul-81
Begin Month



Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1982 Water Year
(Source: USGS)
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-81
Nov-81
Dec-81
Jan-82
Feb-82
Mar-82
Apr-82
May-82
Jun-82
Jul-82
Begin Month

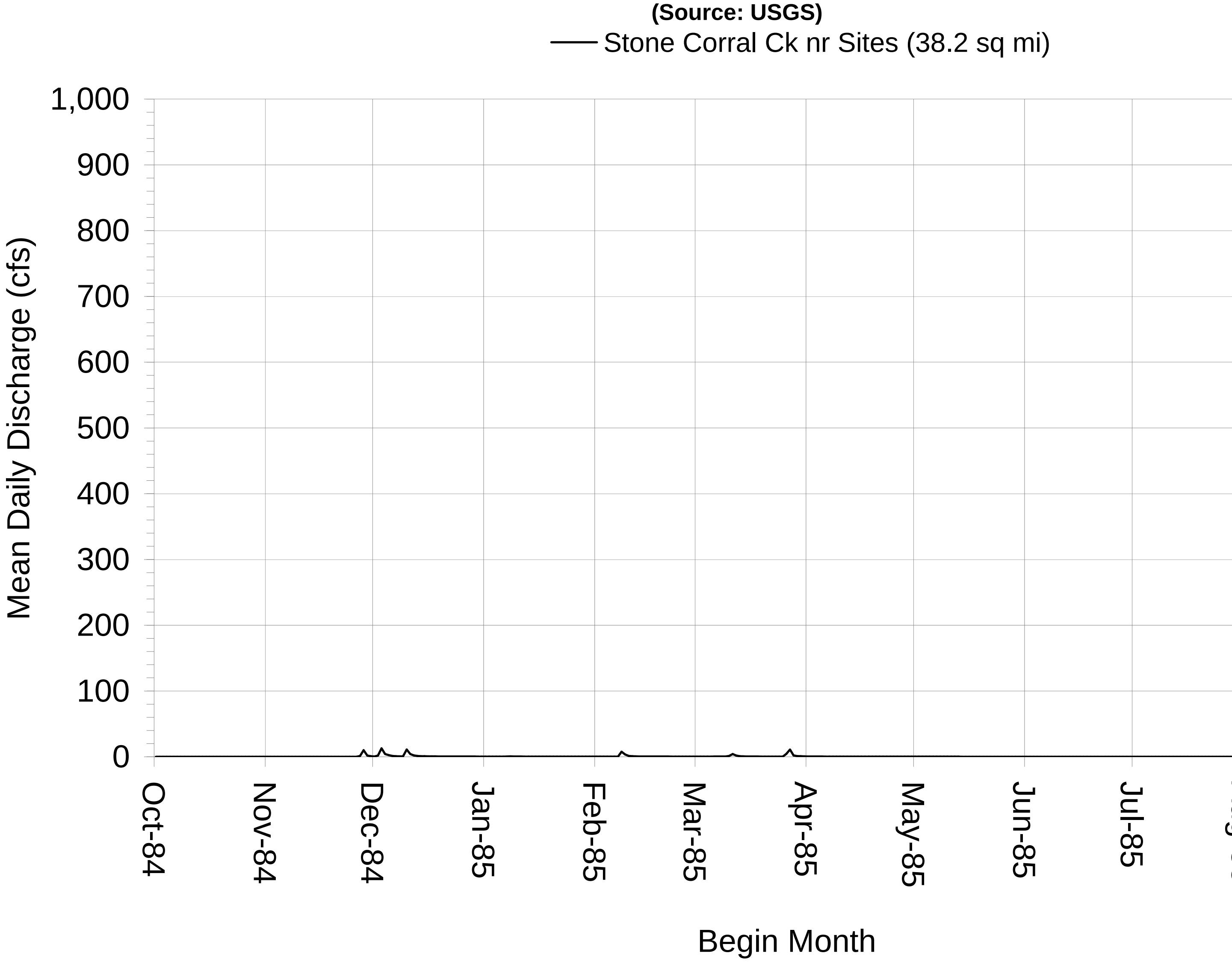
**Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas[in]
Watershed
1983 Water Year**
**(Source: USGS)**





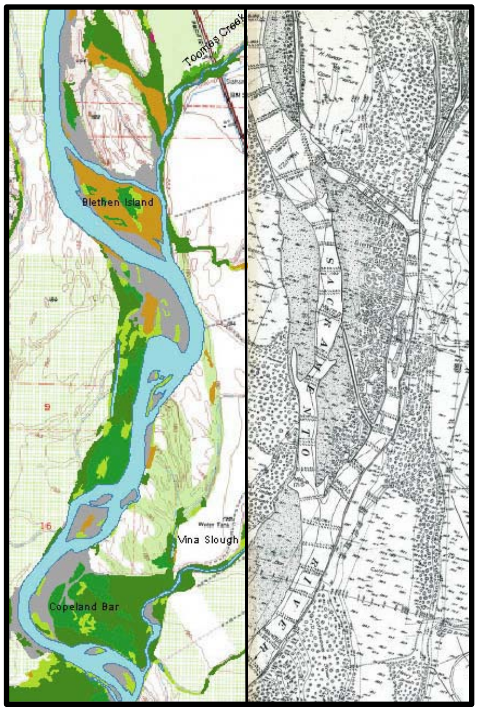
Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas
Watershed
1984 Water Year
(Source: USGS)
Stone Corral Ck nr Sites (38.2 sq mi)
Mean Daily Discharge (cfs)
1,000
900
800
700
600
500
400
300
200
100
0
Oct-83
Nov-83
Dec-83
Jan-84
Feb-84
Mar-84
Apr-84
May-84
Jun-84
Jul-84
Begin Month

**Annual Hydrographs Comprising USGS Gauge Record in Colusa Bas**
**Watershed**
**1985 Water Year**
**(Source: USGS)**



**Appendix 1. Biology.**
**The Central Valley Historic Mapping Project Sources and Methods**

# THE CENTRAL VALLEY HISTORIC MAPPING PROJECT




By

California State University, Chico
Department of Geography and Planning and
Geographic Information Center

April, 2003

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2800 Cottage Way
Sacramento, CA 95825

Many agencies did not allow maps to leave the premises, so, in many cases, it was necessary to bring the scanner to the maps. However, most offices were extremely cooperative with helping with project goals. The 400-dpi images were extremely large and necessitated the use of compression software to handle the unmanageable file sizes.

Geo-referencing means transforming scanned images into maps with reference coordinates. Geo-referenced maps register with other coverages when they are brought into a GIS such as ArcView. Natural vegetation boundaries were “heads-up” (onscreen) digitized in ArcView and each vegetation polygon was referenced to a source data file.

**Map/GIS Compilation**

The base map (pre-1900) was the most difficult map to compile as it came from a variety of sources and scales. In some instances, only U.S.G.S. topographic maps or generalized regional information could be found. In another instance, U.S. War Department Debris Commission maps from the 1912-1920 time period were used because they depicted vegetation along waterways that we assumed to be riparian species.

Final analyses consisted of viewing and ranking the existing relic native vegetation coverages. Each classified polygon has a corresponding database record outlining source data information, including the source name, time period classification, original classification, and a source ranking from 0.1-0.9. Source data was ranked according to the following factors:

- *scale*
- *appropriate time period*
- *focus or intention of the map, and*
- *classification used on the original data.*

***Figure 1 – Source Ranking Criteria***

| Rank | Original Scale | Date Relevance to Time Period | Source Topic | Original Values |
|---|---|---|---|---|
| 0.1 (Low) | <1:500,000 | Potential, historic | Extremely unrelated | Extreme difference |
| 0.3 | >=1:500,000 | +/- 100 years | Moderately unrelated | Significant difference |
| 0.5 | >=1:250,000 | +/- 50 years | Equal target | Moderate difference |
| 0.7 | >=1:100,000 | +/- 10 years | Significant target | Similar value |
| 0.9 (High) | >=1:24,000 | +/- 5 years | Exact target | Exact value |

NOTES:
-Source topic refers to focus or intention of the map
-Original values are classifications used on the original data

Once a rank was determined for each of the four factors, an average was taken. This average represents the overall ranking for the source.

Using existing map coverages and the project expectations, a timeframe for each map set was determined and each frame became a snapshot of the best information available for a particular period of time. The map set consists of two bookends -- a pre 1900 historic coverage map and a modern coverage map -- and two mid-20$^{th}$ century maps, 1945 and 1960. These two dates were selected because they immediately preceded the completion of major features of the Central Valley Project and the California Water Project.

***Table 1 - Source Data for Pre-1900 Base Map***

| Classification | Source | Scale | Date | Rank |
|---|---|---|---|---|
| Urban/Agriculture | - | - | - | - |
| Alkali desert scrub | Griggs et al | 1:250,000 | Historic | 0.35 |
| Aquatic | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USGS 250,000 | 1:250,000 | 1903-1910 | 0.75 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |
| Chaparral | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |
| Grassland | Griggs et al | 1:250,000 | Historic | 0.35 |
| | (Remaining areas) | - | - | - |
| Other floodplain habitat | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.35 |
| | Holmes/STATSGO (Bay Institute) | 1:250,000 | Historic | 0.45 |
| Riparian | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.45 |
| | US Debris Commission | 1:24,000-1:4,000 | 1910-1924 | 0.80 |
| | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.45 |
| | Snow (GIC) | 1:12,000 | 1991-1998 | 0.70 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USFWS | 1:24,000 | 1981-Present | 0.75 |
| Valley/foothill hardwoods | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.35 |
| | Pillsbury (CDF) | 1:100,000 | 1981-1990 | 0.55 |
| | Weislander | 1:100,000 | 1930-1940 | 0.55 |
| Wetlands | Alexander (Bay Institute) | >=1:500,000 | 1874 | 0.55 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Hall (CA Engineer Office) | 1:500,000 | 1887 | 0.60 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |

The composite final map was reviewed by historical geographers Holtgrieve and Preston and edited to eliminate errors and incorrect information that appeared on some of the source maps.

***Table 2 - Source Data for 1945 Map***

| Classification | Source | Scale | Date | Rank |
|---|---|---|---|---|
| Urban/Agricultural | Weislander | 1:1,000,000 | 1945 | 0.50 |
| Alkali desert scrub | Griggs et al | 1:250,000 | Historic | 0.35 |
| Aquatic | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USGS 250,000 | 1:250,000 | 1903-1910 | 0.70 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.80 |
| Chaparral | USGS 62,500 | 1:62,500 | 1902-1948 | 0.80 |
| Grassland | Griggs et al | 1:250,000 | Historic | 0.35 |
| | (Remaining areas) | - | - | - |
| Other floodplain habitat | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.45 |
| | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| Riparian | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.45 |
| | US Debris Commission | 1:24,000-1:4,000 | 1910-1924 | 0.80 |
| | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.45 |
| | Snow (GIC) | 1:12,000 | 1991-1998 | 0.75 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USFWS | 1:24,000 | 1981-Present | 0.80 |
| Valley/foothill hardwoods | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.45 |
| | Pillsbury (CDF) | 1:100,000 | 1981-1990 | 0.60 |
| | Weislander | 1:100,000 | 1930-1940 | 0.60 |
| Wetlands | Alexander (Bay Institute) | >=500,000 | 1874 | 0.50 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Hall (CA Engineer Office) | 1:500,000 | 1887 | 0.45 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.80 |

*Table 3 - Source Data for 1960 Map*

| Classification | Source | Scale | Date | Rank |
|---|---|---|---|---|
| Urban/Agricultural | DWR Land Use | 1:24,000 | 1958-1970 | 0.85 |
| | Weislander | 1:1,000,000 | 1945 | 0.40 |
| Alkali desert scrub | Griggs et al | 1:250,000 | Historic | 0.35 |
| Aquatic | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USGS 250,000 | 1:250,000 | 1903-1910 | 0.70 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |
| Chaparral | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |
| Grassland | Griggs et al | 1:250,000 | Historic | 0.35 |
| | (Remaining areas) | - | - | - |
| Other floodplain habitat | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.45 |
| | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| Riparian | Gronenburg (Bay Institute) | 1:250,000 | Historic | 0.45 |
| | US Debris Commission | 1:24,000-1:4,000 | 1910-1924 | 0.80 |
| | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.45 |
| | Snow (GIC) | 1:12,000 | 1991-1998 | 0.75 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Holmes/STATSGO (Bay Institute) | >=1:500,000 | 1916 | 0.50 |
| | USFWS | 1:24,000 | 1981-Present | 0.80 |
| Valley/foothill hardwoods | Dutzi (Bay Institute) | >=1:500,000 | Historic | 0.45 |
| | Pillsbury (CDF) | 1:100,000 | 1981-1990 | 0.60 |
| Wetlands | Alexander (Bay Institute) | >=500,000 | 1874 | 0.50 |
| | Griggs et al | 1:250,000 | Historic | 0.35 |
| | Hall (CA Engineer Office) | 1:500,000 | 1887 | 0.45 |
| | USGS 31,680 | 1:31,680 | 1910-1925 | 0.65 |
| | USGS 62,500 | 1:62,500 | 1902-1948 | 0.75 |

*Table 4 - Source Data for 1995 Map*

| Classification | Source | Scale | Date | Rank |
|---|---|---|---|---|
| Urban/Agricultural | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Alkali desert scrub | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Aquatic | US EPA | 1:250,000 | 1980-1990 | 0.65 |
| Chaparral | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Chaparral | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Grassland | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Riparian | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Valley/foothill hardwoods | Snow (GIC) | 1:12,000 | 1991-1998 | 0.75 |
| Valley/foothill hardwoods | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |
| Wetlands | Pillsbury | 1:100,000 | 1981-1990 | 0.60 |
| Wetlands | GAP (UCSB) | 1:250,000 | 1995 | 0.75 |

## ANALYSIS - QUERYING THE GIS

ArcView shape (SHP) files adapted from these historical maps can be downloaded from the CD provided with this report. Also, a web site at California State University, Chico, will provide a PDF download for each of these maps and a link to the scanned maps on a California State University, Chico Library server.

Using the associated GIS database, queries can be made to estimate qualitative vegetation changes at the regional level. When querying the *Central Valley Historic Mapping Project* (CVHMP) GIS, however, it is crucial to understand the limitations of these digital coverages as the maps were created using a variety of independent sources and at varying scales, accuracies and completeness. While some of the project data (DWR land use information, remnant coverages) can be used in finer-level analyses in association with other appropriate-quality data, it is strongly suggested that queries be limited to general rather than to specific locations.

To assist the user, the quality of each polygon was referenced and ranked from .1 (lowest value to the project) to .9 (highest) based on scale, date, topic value (focus or theme), and data value (classification units). Where they could be identified, errors or incorrect portions of the final maps were edited by persons with extensive regional-historical knowledge. As better information becomes available, additional edits will be required.

## Appendix A. Vegetation Habitat Types

**Riparian** – Riparian habitats in the valley are associated with low velocity waterways. They include freshwater bodies, watercourses, estuaries, and surface emergent aquifers. They generally have deep alluvial soils and a high water table. The dominant canopy species include California Sycamore (Platanus racemosa), Valley Oak (Quercus lobata), Fremont Cottonwood (Populus fremontii), White Alder (Alnus rhombifolia), Oregon Ash (Fraxinus latifolia), and numerous species of Willows (Salix spp.). The lower layers of vegetation include California Box Elder (Acer negunde subsp. californicum), Coyotebrush (Baccharis pilularis ssp. consanguinea), Blackberries (Rubus spp.), Sand Wild Rose (Rosa californica), and various annual and perennial herbaceous species. California Grape (Vitus califonica), Poison Oak (Toxicodendron diversilobum), and Dutchman's Pipe (Aristolochia californica) are the resident vine species that inhabit the riparian zone.

**Wetland** (perennial) – Also considered Freshwater Marsh. Wetlands are among the most productive wildlife habitats in California. They occur on virtually all exposures and slopes provided the depression or basin is periodically flooded. Characteristic species include various species of Cattails (Typha spp.), Bullrushes or Tules (Scirpus spp.), Rushes (Juncus spp.), and Sedges (Carex spp.).

**Aquatic** – Major water bodies within the study area (lakes, reservoirs, and estuaries like the Sacramento-San Joaquin Delta) are categorized as aquatic.

**Grassland** – Grasslands include grassy areas composed of annual plant species; they were originally composed of various perennial bunch grasses. Agricultural crops and grazing has caused the replacement of natives in many areas with introduced annual grasses. In spring and summer, large areas of grassland habitat are covered with annual herbaceous wildflower species.

**Valley/Foothill Hardwoods** – This vegetation type is dominated by oaks such as Valley Oak (Quercus lobata), Blue Oak (Quercus douglasii), and Interior Live Oak (Quercus wislizenii). Other trees present include Foothill Pine (Pinus sabiniana) and California Buckeye (Aesculus californica). Understory plants are species that also occur in Grasslands and Chaparral.

**Alkali Desert Scrub** – In the southern Central Valley, Alkali Desert Scrub borders on Grassland and can overlap. Characteristic species include Iodine Bush (Allenrolfea occidentalis), Shrubby Seablite (Suaeda fruticosa), Alkali Heath (Frankenia grandifloia), Seashore Saltgrass (Distichilis spicata), Alkali goldenbush (Haplopappus acradenius ssp. bracteosus), California Stink-weed (Wislizenia californica), Alkali Goldfield (Lasthenia chrysantha), California Alkali Grass (Puccinellia simplex), Spiney Saltbush (Atriplex spinifera), Leafcover Saltbush (Atriplex phyllostegia), Recurved Larkspur (Delphinium recurvatum), and Common Spikeweed (Hemizonia pungens).

**Chaparral** – Chaparral is characterized as being very hot and dry and is represented by a rich variety of "hard" woody shrubs. The most common plants that make up the chaparral community are Chamise (Adenostoma fasciculatum), California Holly or Toyon

(Heteromeles arbutifolia), Holly-leaf Cherry (Prunus ilicifolia), Mountain Mahogany (Cercocarpus betuloides), Red Berry (Rhamnus crocea), and various species of Manzanita (Arctostaphylos spp.) and California Lilac (Ceanothus spp.). Scrub Oak (Quercus dumosa), and Poison Oak (Toxicodendron diversilobum) are also present in the chaparral zone.

**Other Floodplain Habitat** – Used to denote areas that are a mixture of wetlands, grasslands, and riparian forests that were never differentiated on historic maps.

The previous information was compiled from the following sources:


Barbour, M.B. and Jack Major 1995. *Terrestrial Vegetation of California*, California Native Plant Society, Sacramento, California

Barbour, M., B. Pavlik, F. Drysdale, and S. Lindstrom. 1993. *California's Changing Landscapes.* California Native Plant Society. Sacramento, California.

Griggs, F.T., J.M. Zaninozich, and G.D. Werschkull. 1984. *Historic Native Vegetation Map of the Tulare Basin,* California. San Joaquin Valley Endangered Species Conference.

Jepson, W.L. and J.C. Hickman, ed. 1993. *The Jepson Manual: Higher plants of California*. University of California Press, Berkeley, California.

Ornduff, R. 1974. *Introduction to California Plant Life*. University of California Press. Berkeley, California.

Sawyer, J.O. and Todd Keeler-Wolf. 1995. *A Manual of California Vegetation*. California Native Plant Society. Sacramento, California.

## Appendix 2. Biology.
## Plant Species Mentioned in the Text

**Plant Species Mentioned in the Text.**

| Family | Species | Common Name | Native |
|---|---|---|---|
| Aceraceae | *Acer macrophyllum* | big-leaf maple | y |
| Aceraceae | *Acer negundo var. californica* | California box elder | y |
| Rosaceae | *Adenostoma fasciculatum* | chamise | y |
| Rosaceae | *Adenostoma sparsifolium* | redshank | y |
| Poaceae | *Aegilops triuncialis* | barbed goatgrass | n |
| Hippocastanaceae | *Aesculus californica* | California buckeye | y |
| Simaroubaceae | *Ailanthus altissima* | tree of heaven | n |
| Betulaceae | *Alnus rhombifolia* | white alder | y |
| Ericaceae | *Arctostaphylos glauca* | big-berry manzanita | y |
| Poaceae | *Aristida ternipes* | hooked three-awn | y |
| Aristolochiaceae | *Aristolochia californica* | California dutchmans pipe | y |
| Asteraceae | *Artemisia douglasiana* | California mugwort | y |
| Poaceae | *Arundo donax* | giant reed | n |
| Chenopodiaceae | *Atriplex spp.* | saltbush | y |
| Poaceae | *Avena fatua* | wild oat | n |
| Asteraceae | *Blennosperma nanum* | Blennosperma | y |
| Poaceae | *Bromus diandrus* | ripgut grass | n |
| Poaceae | *Bromus hordeaceus* | soft chess | n |
| Poaceae | *Bromus rubens* | red brome | n |
| Portulacaceae | *Calandrinia spp.* | redmaids | y |
| Cyperaceae | *Carex amplifolia* | big leaf sedge | y |
| Cyperaceae | *Carex sp.* | sedge | y |
| Rhamnaceae | *Ceanothus cuneatus var. cuneatus* | buck brush | y |
| Rhamnaceae | *Ceanothus greggii var. perplexans* | cupleaf ceanothus | y |
| Rhamnaceae | *Ceanothus sp.* | ceanothus | y |
| Asteraceae | *Centaurea calcitrapa* | purple starthistle | n |
| Asteraceae | *Centaurea solstitialis* | yellow starthistle | n |
| Rubiaceae | *Cephalanthus occidentalis* | buttonbrush | y |
| Fabaceae | *Cercis occidentalis* | redbud | y |
| Rosaceae | *Cercocarpus betuloides* | birch-leaf mountain mahogany | y |
| Convulvulaceae | *Cressa truxillensis* | alkalai weed | y |
| Poaceae | *Crypsis vaginiflora* | swamp timothy | n |
| Poaceae | *Cynodon dactylon* | Bermuda grass | n |
| Cyperaceae | *Cyperus eragrostis* | tall umbrella sedge | y |
| Cyperaceae | *Cyperus erythrorhizos* | redroot nutgrass | y |
| Cyperaceae | *Cyperus esculentus* | yellow nutsedge | y |
| Poaceae | *Deschampsia cespitosa* | tufted hairgrass | y |
| Poaceae | *Distichlis spicata* | saltgrass | y |
| Campanulaceae | *Dowingia spp.* | dowingia | y |
| Cyperaceae | *Eleocharis spp.* | spikerush | y |

| Family | Species | Common Name | Native |
|---|---|---|---|
| Poaceae | *Elymus glaucus* | blue wild rye | y |
| Euphorbiaceae | *Eremocarpus setigerus* | turkey mullein | y |
| Polygonaceae | *Eriogonum fasciculatum* | California buckwheat | y |
| Geraniaceae | *Erodium sp.* | filaree | n |
| Apiaceae | *Eryngium vaseyi* | coyote-thistle | y |
| Myrtaceae | *Eucalyptus sp.* | eucalyptus | n |
| Poaceae | *Festuca californica* | California fescue | y |
| Poaceae | *Festuca idahoensis* | Idaho fescue | y |
| Oleaceae | *Fraxinus latifolia* | Oregon ash | y |
| Poaceae | *Glyceria spp.* | mannagrass | y |
| Asteraceae | *Grindelia camporum* | gumweed | y |
| Asteraceae | *Hemizonia spp.* | tarweed | y |
| Rosaceae | *Heteromeles arbutifolia* | toyon | y |
| Juglandaceae | *Juglans californica var. hindsii* | Northern California black walnut | y |
| Juncaceae | *Juncus balticus* | Baltic rush | y |
| Juncaceae | *Juncus spp.* | rush | y |
| Cupressaceae | *Juniperus communis* | western juniper | y |
| Asteraceae | *Lasthenia californica* | California goldfields | y |
| Asteraceae | *Lasthenia fremontii* | Fremont's lasthenia | y |
| Asteraceae | *Layia platyglossa* | tidy tips | y |
| Brassicaceae | *Lepidium latifolium* | perennial peppergrass | n |
| Poaceae | *Leymus triticoides* | creeping wildrye | y |
| Poaceae | *Lolium multiflorum* | Italian ryegrass | n |
| Fabaceae | *Lotus scoparius* | deerweed | y |
| Onagraceae | *Ludwigia spp.* | Creeping water primrose | n |
| Anacardiaceae | *Malosma laurina* | laurel sumac | y |
| Fabaceae | *Medicago polymorpha* | burclover | n |
| Poaceae | *Melica californica* | California melic | y |
| Poaceae | *Melica imperfecta* | imperfect melic | y |
| Poaceae | *Nassella lepida* | foothill needlegrass | y |
| Poaceae | *Nassella pulchra* | purple needlegrass | y |
| Polemoniaceae | *Navarretia spp.* | pincushion plant | y |
| Hydrophyllaceae | *Nemophila spp.* | baby blue eyes | y |
| Poaceae | *Neostaphia colusana* | Colusa grass | y |
| Poaceae | *Paspalum distichum* | jointgrass | y |
| Pinaceae | *Pinus sabiniana* | gray (or foothill) pine | y |
| Boraginaceae | *Plagiobothrys canescens* | valley popcorn flower | y |
| Boraginaceae | *Plagiobothrys collinus var. californicus* | California popcorn flower | y |
| Platanaceae | *Platanus racemosa* | California sycamore | y |
| Papaveraceae | *Platystemon californicus* | creamcups | y |

| Family | Species | Common Name | Native |
|---|---|---|---|
| Polygonaceae | *Polygonum amphibium var. emersum* | smartweed | y |
| Salicaceae | *Populus fremontii spp. fremontii* | Fremont cottonwood | y |
| Potamogetonaceae | *Potamogeton foliosus* | leafy pondweed | y |
| Potamogetonaceae | *Potamogeton natans* | floating-leaved pondweed | y |
| Potamogetonaceae | *Potamogeton pectinatus* | sago pondweed | y |
| Fagaceae | *Quercus agrifolia* | coast live oak | y |
| Fagaceae | *Quercus berberidifolia* | scrub oak | y |
| Fagaceae | *Quercus douglasii* | blue oak | y |
| Fagaceae | *Quercus lobata* | valley oak | y |
| Fagaceae | *Quercus wislizenii var. wislizenii* | interior live oak | y |
| Rhamnaceae | *Rhamnus californica ssp. californica* | California coffeeberry | y |
| Rhamnaceae | *Rhamnus crocea* | spiny redberry | y |
| Grossulariaceae | *Ribes sp.* | gooseberry | y |
| Rosaceae | *Rosa californica* | wild rose | y |
| Alismataceae | *Sagittaria sp.* | arrowhead | y |
| Chenopodiaceae | *Salicornia virginica* | pickleweed | y |
| Salicaceae | *Salix exigua* | narrow-leaved willow | y |
| Salicaceae | *Salix laevigata* | red willow | y |
| Salicaceae | *Salix gooddingii* | Gooding's willow | y |
| Salicaceae | *Salix lasiolepis* | arroyo willow | y |
| Salicaceae | *Salix lucida ssp. lasiandra* | shining willow | y |
| Caprifoliaceae | *Sambucus mexicana* | blue elderberry | y |
| Cyperaceae | *Scirpus acutus* | hardstem bulrush, tule | y |
| Cyperaceae | *Scirpus americanus* | american bulrush | y |
| Cyperaceae | *Scirpus californicus* | California bulrush | y |
| Cyperaceae | *Scirpus microcarpus* | small-fruited bulrush | y |
| Cyperaceae | *Scirpus maritimus* | big bulrush | y |
| Cyperaceae | *Scirpus sp.* | bulrush | y |
| Fabaceae | *Sesbania punicea* | scarlet wisteria | n |
| Poaceae | *Sorghum bicolor* | Sudangrass | n |
| Poaceae | *Sorghum halepense* | Johnson grass | n |
| Poaceae | *Taeniatherum caput-medusae* | Medusahead | n |
| Tamaricaceae | *Tamarix parviflora* | tamarisk | n |
| Anacardiaceae | *Toxicodendron diversilobum* | poison oak | y |
| Fabaceae | *Trifolium sp.* | clover | |
| Typhaceae | *Typha angustifolia* | narrow-leaved cattail | y |
| Typhaceae | *Typha latifolia* | broad-leaved cattail | y |
| Urticaceae | *Urtica sp.* | nettle | y |
| Vitaceae | *Vitis californica* | California wild grape | y |
| Poaceae | *Vulpia myuros* | foxtail fescue | y |

**Appendix 3.  Biology.**
**Animal Species Referenced in the Text**

**Animal Species Referenced in the Text.**

| Common Name | Scientific Name |
|---|---|
| **INVERTEBRATES** | |
| Conservancy Fairy Shrimp | *Branchinecta conservatio* |
| Vernal Pool Fairy Shrimp | *Branchinecta lynchi* |
| Vernal Pool Tadpole Shrimp | *Lepidurus packardi* |
| Valley Longhorn Elderberry Beetle | *Desmocerus californicus dimorphus* |
| **AMPHIBIANS** | |
| California Tiger Salamander | *Ambystoma californiense* |
| Western Toad | *Bufo boreas* |
| Western Spadefoot Toad | *Scaphiopus hammondi* |
| Pacific Treefrog | *Hyla regilla* |
| Bullfrog | *Rana catesbeiana* |
| **REPTILES** | |
| Northwestern Pond Turtle | *Clemmys marmorata marmorata* |
| Western Fence Lizard | *Sceloporus occidentalis* |
| California Horned Lizard | *Phrynosoma coronatum* |
| Western Skink | *Eumeces skiltonianus* |
| Western Whiptail | *Cnemidophorus tigris* |
| Southern Alligator Lizard | *Gerrhonotus multicarinatus* |
| Racer | *Coluber constrictor* |
| Coachwhip | *Masticophis flagellum* |
| California Whipsnake | *Masticophis lateralis* |
| Gopher Snake | *Pituophis melanoleucus* |
| Common Kingsnake | *Lampropeltis getulus* |
| Common Garter Snake | *Thamnophis sirtalis* |
| Giant Garter Snake | *Thamnophis gigas* |
| Western Terrestrial Garter Snake | *Thamnophis elegans* |
| Western Aquatic Garter Snake | *Thamnophis couchi* |
| Western Rattlesnake | *Crotalus viridis* |
| **BIRDS** | |
| Pied-billed Grebe | *Podilymbus podiceps* |
| Horned Grebe | *Podiceps auritus* |
| Eared Grebe | *Podiceps nigricollis* |
| Western Grebe | *Aechmophorus occidentalis* |
| Clark's Grebe | *Aechmophorus clarkii* |
| American White Pelican | *Pelecanus erythrorhynchos* |
| Double-crested Cormorant | *Phalacrocorax auritus* |
| American Bittern | *Botaurus lentiginosus* |
| Least Bittern | *Ixobrychus exilis* |
| Great Blue Heron | *Ardea herodias* |
| Great Egret | *Ardea alba* |
| Snowy Egret | *Egretta thula* |
| Cattle Egret | *Bubulcus ibis* |
| Green Heron | *Butorides virescens* |

| Common Name | Scientific Name |
|---|---|
| Black-crowned Night-Heron | *Nycticorax nycticorax* |
| White-faced Ibis | *Plegadis chihi* |
| Tundra Swan | *Cygnus columbianus* |
| Greater White-fronted Goose | *Anser albifrons* |
| Snow Goose | *Anser caerulescens* |
| Ross' Goose | *Anser rossii* |
| Canada Goose | *Branta canadensis* |
| Cackling Goose | *Branta hutchinsii* |
| Wood Duck | *Aix sponsa* |
| Green-winged Teal | *Anas (c.) carolinensis* |
| Mallard | *Anas platyrhynchos* |
| Northern Pintail | *Anas acuta* |
| Blue-winged Teal | *Anas discors* |
| Cinnamon Teal | *Anas cyanoptera* |
| Northern Shoveler | *Anas clypeata* |
| Gadwall | *Anas strepera* |
| Eurasian Wigeon | *Anas penelope* |
| American Wigeon | *Anas americana* |
| Canvasback | *Aythya valisineria* |
| Redhead | *Aythya americana* |
| Ring-necked Duck | *Aythya collaris* |
| Greater Scaup | *Aythya marila* |
| Lesser Scaup | *Aythya affinis* |
| Common Goldeneye | *Bucephala clangula* |
| Bufflehead | *Bucephala albeola* |
| Hooded Merganser | *Lophodytes cucullatus* |
| Common Merganser | *Mergus merganser* |
| Ruddy Duck | *Oxyura jamaicensis* |
| Turkey Vulture | *Cathartes aura* |
| Osprey | *Pandion haliaetus* |
| White-tailed Kite | *Elanus leucurus* |
| Bald Eagle | *Haliaeetus leucocephalus* |
| Northern Harrier | *Circus cyaneus* |
| Sharp-shinned Hawk | *Accipiter striatus* |
| Cooper's Hawk | *Accipiter cooperii* |
| Red-shouldered Hawk | *Buteo lineatus* |
| Swainson's Hawk | *Buteo swainsoni* |
| Red-tailed Hawk | *Buteo jamaicensis* |
| Ferruginous Hawk | *Buteo regalis* |
| Rough-legged Hawk | *Buteo lagopus* |
| Golden Eagle | *Aquila chrysaetos* |
| American Kestrel | *Falco sparverius* |
| Merlin | *Falco columbarius* |
| Peregrine Falcon | *Falco peregrinus* |

| Common Name | Scientific Name |
|---|---|
| Prairie Falcon | *Falco mexicanus* |
| Ring-necked Pheasant | *Phasianus colchicus* |
| Wild Turkey | *Meleagris gallopavo* |
| California Quail | *Callipepla californica* |
| Virginia Rail | *Rallus limicola* |
| Sora | *Porzana carolina* |
| Common Moorhen | *Gallinula chloropus* |
| American Coot | *Fulica americana* |
| Sandhill Crane | *Grus canadensis* |
| Black-bellied Plover | *Pluvialis squatarola* |
| Semipalmated Plover | *Charadrius semipalmatus* |
| Killdeer | *Charadrius vociferus* |
| Mountain Plover | *Charadrius montanus* |
| Black-necked Stilt | *Himantopus mexicanus* |
| American Avocet | *Recurvirostra americana* |
| Greater Yellowlegs | *Tringa melanoleuca* |
| Lesser Yellowlegs | *Tringa flavipes* |
| Solitary Sandpiper | *Tringa solitaria* |
| Spotted Sandpiper | *Tringa macularia* |
| Whimbrel | *Numenius phaeopus* |
| Long-billed Curlew | *Numenius americanus* |
| Western Sandpiper | *Calidris mauri* |
| Least Sandpiper | *Calidris minutilla* |
| Pectoral Sandpiper | *Calidris melanotos* |
| Dunlin | *Calidris alpina* |
| Short-billed Dowitcher | *Limnodromus griseus* |
| Long-billed Dowitcher | *Limnodromus scolopaceus* |
| Wilson's Snipe | *Gallinago delicata* |
| Wilson's Phalarope | *Steganopus tricolor* |
| Red-necked Phalarope | *Phalaropus lobatus* |
| Bonaparte's Gull | *Larus philadelphia* |
| Ring-billed Gull | *Larus delawarensis* |
| California Gull | *Larus californicus* |
| Herring Gull | *Larus argentatus* |
| Caspian Tern | *Sterna caspia* |
| Forster's Tern | *Sterna forsteri* |
| Black Tern | *Chlidonias niger* |
| Rock Dove | *Columba livia* |
| Mourning Dove | *Zenaida macroura* |
| Yellow-billed Cuckoo | *Coccyzus americanus* |
| Greater Roadrunner | *Geococcyx californianus* |
| Common Barn-Owl | *Tyto alba* |
| Western Screech-Owl | *Otus kennicottii* |
| Great Horned Owl | *Bubo virginianus* |

| Common Name | Scientific Name |
|---|---|
| Burrowing Owl | *Speotyto cunicularia* |
| Long-eared Owl | *Asio otus* |
| Short-eared Owl | *Asio flammeus* |
| Lesser Nighthawk | *Chordeiles acutipennis* |
| Vaux's Swift | *Chaetura vauxi* |
| Black-chinned Hummingbird | *Archilochus alexandri* |
| Anna's Hummingbird | *Calypte anna* |
| Rufous Hummingbird | *Selasphorus rufus* |
| Belted Kingfisher | *Megaceryle alcyon* |
| Lewis' Woodpecker | *Melanerpes lewis* |
| Acorn Woodpecker | *Melanerpes formicivorus* |
| Red-breasted Sapsucker | *Sphyrapicus ruber* |
| Nuttall's Woodpecker | *Picoides nuttallii* |
| Downy Woodpecker | *Picoides pubescens* |
| Northern Flicker | *Colaptes auratus* |
| Olive-sided Flycatcher | *Contopus borealis* |
| Western Wood-Pewee | *Contopus sordidulus* |
| Willow Flycatcher | *Empidonax traillii* |
| Hammond's Flycatcher | *Empidonax hammondii* |
| Dusky Flycatcher | *Empidonax oberholseri* |
| Pacific-slope Flycatcher | *Empidonax difficilis* |
| Black Phoebe | *Sayornis nigricans* |
| Say's Phoebe | *Sayornis saya* |
| Ash-throated Flycatcher | *Myiarchus cinerascens* |
| Western Kingbird | *Tyrannus verticalis* |
| Tree Swallow | *Tachycineta bicolor* |
| Violet-green Swallow | *Tachycineta thalassina* |
| Northern Rough-winged Swallow | *Stelgidopteryx serripennis* |
| Bank Swallow | *Riparia riparia* |
| Cliff Swallow | *Hirundo pyrrhonota* |
| Barn Swallow | *Hirundo rustica* |
| Western Scrub-Jay | *Aphelocoma californica* |
| Yellow-billed Magpie | *Pica nuttalli* |
| American Crow | *Corvus brachyrhynchos* |
| Common Raven | *Corvus corax* |
| Oak Titmouse | *Baeolophus inornatus* |
| Bushtit | *Psaltriparus minimus* |
| Red-breasted Nuthatch | *Sitta canadensis* |
| White-breasted Nuthatch | *Sitta carolinensis* |
| Brown Creeper | *Certhia americana* |
| Rock Wren | *Salpinctes obsoletus* |
| Bewick's Wren | *Thryomanes bewickii* |
| House Wren | *Troglodytes aedon* |
| Winter Wren | *Troglodytes troglodytes* |

| Common Name | Scientific Name |
|---|---|
| Marsh Wren | *Cistothorus palustris* |
| Golden-crowned Kinglet | *Regulus satrapa* |
| Ruby-crowned Kinglet | *Regulus calendula* |
| Blue-gray Gnatcatcher | *Polioptila caerulea* |
| Western Bluebird | *Sialia mexicana* |
| Mountain Bluebird | *Sialia currucoides* |
| Swainson's Thrush | *Catharus ustulatus* |
| Hermit Thrush | *Catharus guttatus* |
| American Robin | *Turdus migratorius* |
| Varied Thrush | *Zoothera naevia* |
| Wrentit | *Chamaea fasciata* |
| Northern Mockingbird | *Mimus polyglottos* |
| California Thrasher | *Toxostoma redivivum* |
| American Pipit | *Anthus rubescens* |
| Cedar Waxwing | *Bombycilla cedrorum* |
| Northern Shrike | *Lanius excubitor* |
| Loggerhead Shrike | *Lanius ludovicianus* |
| European Starling | *Sturnus vulgaris* |
| Cassin's Vireo | *Vireo cassinii* |
| Hutton's Vireo | *Vireo huttoni* |
| Warbling Vireo | *Vireo gilvus* |
| Orange-crowned Warbler | *Vermivora celata* |
| Nashville Warbler | *Vermivora ruficapilla* |
| Yellow Warbler | *Dendroica petechia* |
| Yellow-rumped Warbler | *Dendroica coronata* |
| Black-throated Gray Warbler | *Dendroica nigrescens* |
| Townsend's Warbler | *Dendroica townsendi* |
| Hermit Warbler | *Dendroica occidentalis* |
| MacGillivray's Warbler | *Oporornis tolmiei* |
| Common Yellowthroat | *Geothlypis trichas* |
| Wilson's Warbler | *Wilsonia pusilla* |
| Yellow-breasted Chat | *Icteria virens* |
| Western Tanager | *Piranga ludoviciana* |
| Black-headed Grosbeak | *Pheucticus melanocephalus* |
| Blue Grosbeak | *Guiraca caerulea* |
| Lazuli Bunting | *Passerina amoena* |
| Spotted Towhee | *Pipilo maculatus* |
| California Towhee | *Pipilo crissalis* |
| Rufous-crowned Sparrow | *Aimophila ruficeps* |
| Chipping Sparrow | *Spizella passerina* |
| Vesper Sparrow | *Pooecetes gramineus* |
| Lark Sparrow | *Chondestes grammacus* |
| Savannah Sparrow | *Passerculus sandwichensis* |
| Grasshopper Sparrow | *Ammodramus savannarum* |

| Common Name | Scientific Name |
|---|---|
| Fox Sparrow | *Passerella iliaca* |
| Song Sparrow | *Melospiza melodia* |
| Lincoln's Sparrow | *Melospiza lincolnii* |
| White-throated Sparrow | *Zonotrichia albicollis* |
| Golden-crowned Sparrow | *Zonotrichia atricapilla* |
| White-crowned Sparrow | *Zonotrichia leucophrys* |
| Dark-eyed Junco | *Junco hyemalis* |
| McCown's Longspur | *Calcarius mccownii* |
| Lapland Longspur | *Calcarius lapponicus* |
| Chestnut-collared Longspur | *Calcarius ornatus* |
| Red-winged Blackbird | *Agelaius phoeniceus* |
| Tricolored Blackbird | *Agelaius tricolor* |
| Western Meadowlark | *Sturnella neglecta* |
| Yellow-headed Blackbird | *Xanthocephalus xanthocephalus* |
| Brewer's Blackbird | *Euphagus cyanocephalus* |
| Great-tailed Grackle | *Quiscalus mexicanus* |
| Brown-headed Cowbird | *Molothrus ater* |
| Hooded Oriole | *Icterus cucullatus* |
| Bullock's Oriole | *Icterus bullockii* |
| Purple Finch | *Carpodacus purpureus* |
| House Finch | *Carpodacus mexicanus* |
| Pine Siskin | *Carduelis pinus* |
| Lesser Goldfinch | *Carduelis psaltria* |
| Lawrence's Goldfinch | *Carduelis lawrencei* |
| American Goldfinch | *Carduelis tristis* |
| House Sparrow | *Passer domesticus* |
| **MAMMALS** | |
| Virginia Opossum | *Didelphis virginiana* |
| Vagrant Shrew | *Sorex vagrans* |
| Ornate Shrew | *Sorex ornatus* |
| Broad-footed Mole | *Scapanus latimanus* |
| Yuma Myotis | *Myotis yumanensis* |
| California Myotis | *Myotis californicus* |
| Western Pipistrelle | *Pipistrellus hesperus* |
| Big Brown Bat | *Eptesicus fuscus* |
| Hoary Bat | *Lasiurus cinereus* |
| Townsend's Big-eared Bat | *Corynorhinus townsendii* |
| Pallid Bat | *Antrozous pallidu* |
| Brazilian Free-tailed Bat | *Tadarida brasiliensis* |
| Brush Rabbit | *Sylvilagus bachmani* |
| Desert Cottontail | *Sylvilagus audubonii* |
| Black-tailed Jackrabbit | *Lepus californicus* |
| California Ground Squirrel | *Spermophilus beecheyi* |
| Western Gray Squirrel | *Sciurus griseus* |

| Common Name | Scientific Name |
|---|---|
| Botta's Pocket Gopher | *Thomomys bottae* |
| Beaver | *Castor canadensis* |
| Western Harvest Mouse | *Reithrodontomys megalotis* |
| Brush Mouse | *Peromyscus boylii* |
| Deer Mouse | *Peromyscus maniculatus* |
| Pinyon Mouse | *Peromyscus truei* |
| Dusky-footed Woodrat | *Neotoma fuscipes* |
| California Vole | *Microtus californicus* |
| Muskrat | *Ondatra zibethicus* |
| Black Rat | *Rattus rattus* |
| Norway Rat | *Rattus norvegicus* |
| House Mouse | *Mus musculus* |
| Coyote | *Canis latrans* |
| Gray Fox | *Urocyon cinereoargenteus* |
| Red Fox | *Vulpes vulpes* |
| Ringtail | *Bassaricus astutus* |
| Raccoon | *Procyon lotor* |
| Long-tailed Weasel | *Mustela frenata* |
| Mink | *Mustela vison* |
| American Badger | *Taxidea taxus* |
| Striped Skunk | *Mephitis mephitis* |
| River Otter | *Lutra canadensis* |
| Black Bear | *Ursus americanus* |
| Bobcat | *Lynx rufus* |
| Mountain Lion | *Felis concolor* |
| Mule Deer | *Odocoileus hemionus* |