3.2 BASIN GEOLOGY AND GEOMORPHOLOGY

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Historical Background and Physical Setting

The Cache Creek Drainage Basin exhibits many dramatic physical processes. The evolution of Cache Creek from its origins at Clear Lake to its terminus at the Cache Creek Settling Basin reveals several well-defined physiographic zones that delimit regions of erosion, sediment transport, and deposition along the stream course. These physiographic zones are typical of California river catchments and are illustrated in a schematic in Figure 3.2-1. Each physiographic unit in Figure 3.2-1 reflects a stage in the process of river development. Upstream river reaches along Cache Creek are associated with areas of active erosion and are primary sources of sediment supply. Further downstream, in Capay Valley, the river acts primarily as a mechanism for sediment transport. Below Capay dam the creek emerges onto a broad alluvial fan, a location where the river has been actively mined for aggregate. Downstream of the study reach, the creek again narrows as it passes through fine-grained Sacramento Valley soils. As Cache Creek approaches the settling basin, channel slope becomes sufficiently reduced to result in sediment deposition.

Methods

This chapter describes the general geology and geomorphology of the Cache Creek drainage basin and alluvial fan in association with the results of field work conducted to assess the following: (1) locations of gravel-producing rock, (2) sources of gravel recruitment, (3) channel controls, and (4) influences on stream-groundwater interactions (e.g. groundwater extraction) within the study area.

An important objective of field work was to develop surficial grain size distributions for riverbed gravels within the Cache Creek study area. To accomplish this task, pebble counts at 10 sites along the study reach were taken, a procedure involving the measurement of 100 sediment samples randomly selected from the river bottom.[1] Cumulative grain size distribution curves were prepared from these data to illustrate the percentage of grain sizes that fell above or below a given value to determine the relative make up of different size classes of materials comprising the bed. From these curves, values of D_{16}, D_{50} (median grain size) and D_{84} were established, where D_{16}, D_{50} and D_{84} identify the sizes at which 16 percent, 50 percent, and 84 percent, respectively, of the sample is finer.

In addition to pebble counts, the lithology (parent rock type) of each sample was recorded to identify the origin of gravel materials found in Cache Creek. This assessment provides an indication of important source areas for gravel materials in the Cache Creek Basin. These data

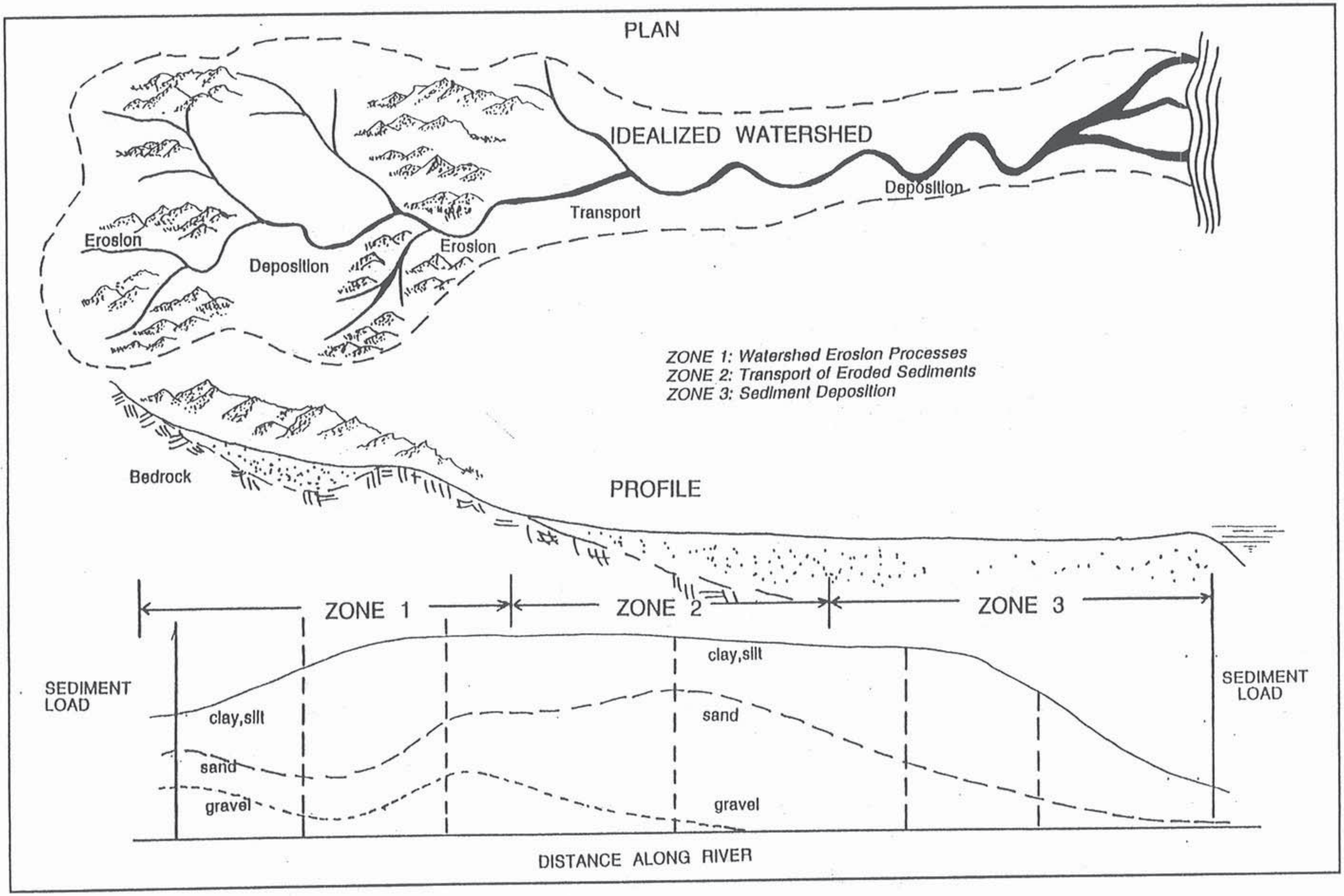


Figure 3.2-1 Idealized schematic of watershed showing physiographic zones of erosion, sediment transport, and deposition along a river course. Highest sediment loads occur in zone of sediment transport (modified from US Army Corps of Engineers, 1995).

were compiled in conjunction with existing grain size distribution curves and lithologic data from Klein and Goldman in 1958.[2] It should be noted that gravel samples from consistent geomorphic units (such as the midpoint on point bars) were difficult to obtain along the entire study reach during the 1994 period of fall and winter field work, because much of the bed had been modified during the previous summer by instream gravel mining. Field work in 1995 was also interrupted by the high flows of January and March 1995, although in this case pebble counts from February and April 1995 were less affected by gravel extraction as many deposits were untouched, remaining inundated during the period following the January and March events.

Bedrock Geology

The geology of the Cache Creek drainage basin is extremely complex and the result of recent tectonic adjustment, volcanism and ongoing processes of structural deformation, geothermal activity, faulting, and sedimentation. The bedrock geology of Cache Creek is primarily comprised of the Franciscan Formation and the Great Valley Sequence (see Figure 3.2-2).

The Franciscan Formation is located in the upper reaches of Cache Creek Basin and consists of a heterogeneous assemblage of many different rock types.[3] The formation originated in Jurassic and Cretaceous time as sea-floor basalts (lava flows) and overlying marine sediments were pulled downward into an oceanic trench at a subduction zone. Figure 3.2-3 delineates the geologic time scales used in referencing the ages of geologic units discussed in this investigation.

A subduction zone is a location on the earth's crust where one geologic plate is forced downward ("descends") beneath another. Today, oceanic plates are being subducted beneath continental margins in comparable fashion off the west coast of South America and off Oregon and Washington. Some of the basalts and sediments on the subducting plate were carried to great depths and became partially melted in high temperatures. However, some of the basalts and sediments were "scraped off" the subducting plate and "plastered" onto the margin of the overriding continent, often becoming intensely deformed and fractured by extreme compression at relatively low temperatures. The Franciscan Formation consists of these intensely deformed rocks scraped from the subducting plate.

As a result of this origin, the Franciscan Formation consists almost entirely of basalts and sediments that we might find on the ocean floor on a subducting plate, such as the ocean off the modern coast of California north of Cape Mendocino. Notable are *greenstone* (metamorphosed sea-floor basalt), other *metavolcanics*, *chert* (metamorphosed pelagic ooze) occurring in a variety of colors from red to green, and *greywacke* (sandstone with units of shale). All of these lithologies are important constituents in the gravels of Cache Creek and provide the highly desirable construction grade aggregate being mined from its lower reaches.

As a result of deformation, the rocks of the Franciscan Formation are intensely fractured, and quartz veins are common. Quartz is commonly more resistant to weathering than the rock in which it occurs, so decay of the host rock liberates pebbles of *vein quartz*. *Serpentinite* ("ultrabasic" rocks derived from deep beneath the earth's crust and metamorphosed into serpentine) also occurs in the Franciscan Formation, but where this lithology occurs in gravels it can pose a problem by virtue of potential chemical reactivity of the rock fragments with the concrete cement.

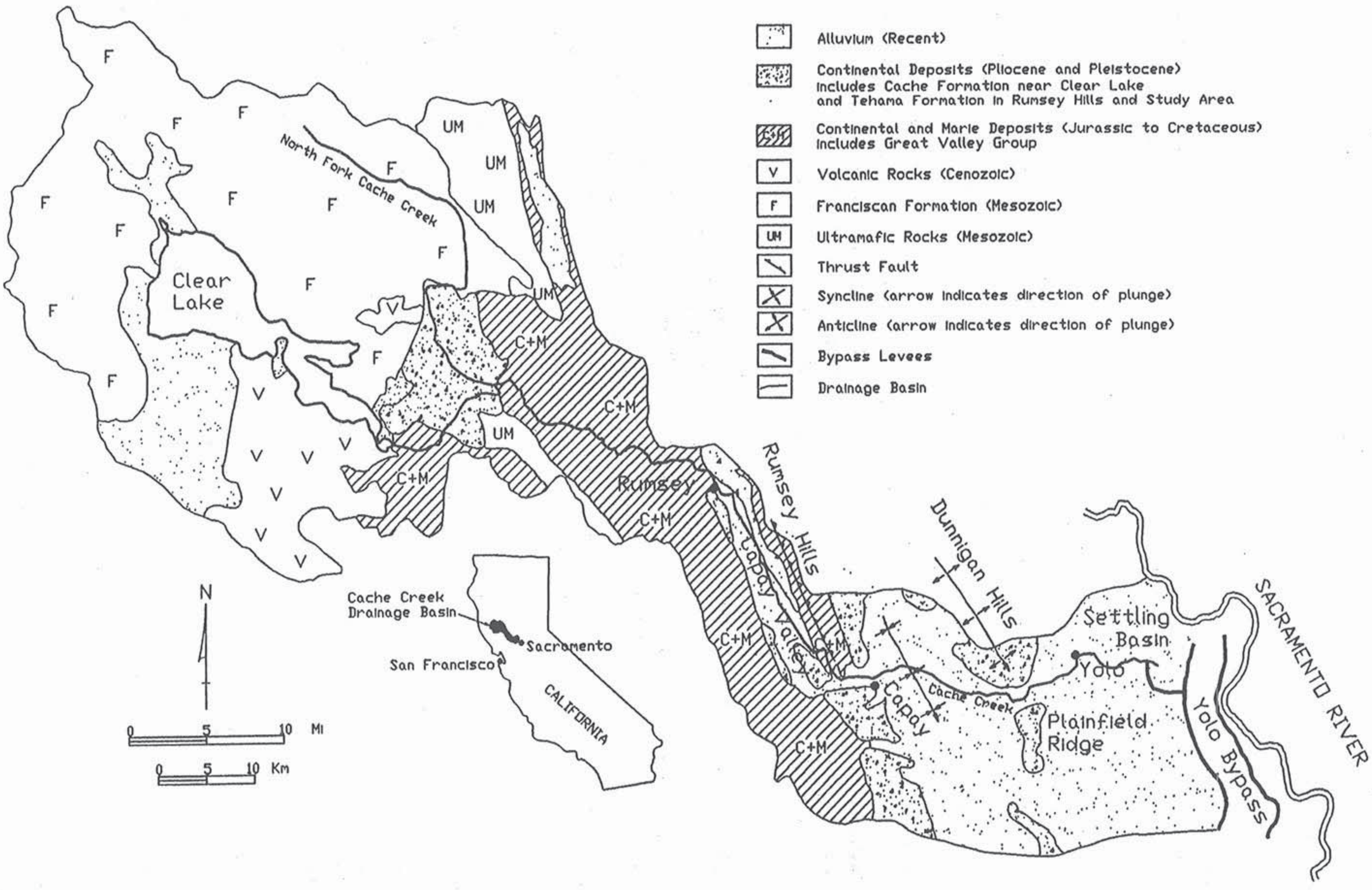
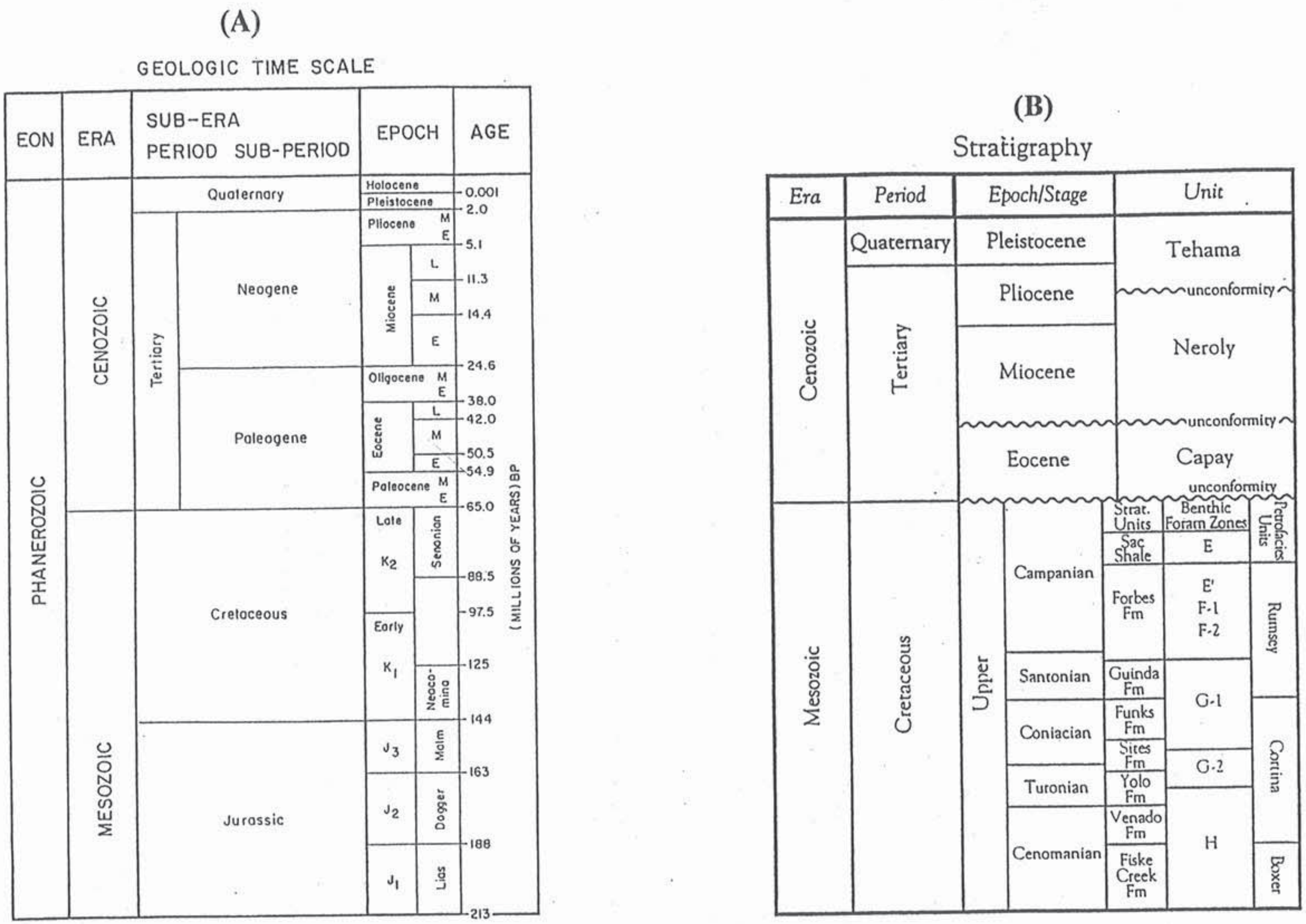


FIGURE 3.2-2 Geologic Map of The Cache Creek Drainage Basin

Distribution of lithologies simplified from Lustig and Busch (1967); Structural features near Capay Valley and Dunnigans Hills simplified from Unruh et al. 1993



(A)

GEOLOGIC TIME SCALE

EON	ERA	SUB-ERA	PERIOD SUB-PERIOD	EPOCH		AGE (MILLIONS OF YEARS) BP
PHANEROZOIC	CENOZOIC		Quaternary	Holocene		0.001
				Pleistocene		2.0
		Tertiary	Neogene	Pliocene	M	
					E	5.1
				Miocene	L	11.3
					M	14.4
					E	24.6
			Paleogene	Oligocene	M	
					E	38.0
				Eocene	L	42.0
					M	50.5
					E	54.9
				Paleocene	M	
					E	65.0
	MESOZOIC		Cretaceous	Late K2	Senonian	88.5
						97.5
				Early K1		125
					Neoco-mina	144
			Jurassic	J3	Malm	163
				J2	Dogger	188
				J1	Lias	213

(B)

Stratigraphy

Era	Period	Epoch/Stage		Unit		
				Strat. Units	Benthic Foram Zones	Petrofacies Units
Cenozoic	Quaternary	Pleistocene		Tehama		
	Tertiary	Pliocene				
				unconformity		
		Miocene		Neroly		
				unconformity		
		Eocene		Capay		
				unconformity		
Mesozoic	Cretaceous	Upper	Campanian	Sac Shale	E	Rumsey
				Forbes Fm	E' F-1 F-2	
			Santonian	Guinda Fm	G-1	
			Coniacian	Funks Fm		Cortina
				Sites Fm	G-2	
			Turonian	Yolo Fm		
			Cenomanian	Venado Fm	H	
				Fiske Creek Fm		Boxer

Figure 3.2-3 Geographic time Scale used in referencing ages of geologic units and events: (a) general geologic scale (Source: Water Engineering and Technology Inc., 1989) and (b) geologic scale specific to the study area (Source: Unruh et al., 1993)

The Great Valley Formation (also Great Valley Sequence) lies to the east of the Franciscan Formation (Figure 3.2-2) and is of similar age (Jurassic to Cretaceous). The Great Valley Formation is composed of often alternating layers of greywacke sandstone, shale or siltstone, and conglomerate (sedimentary rock consisting of pebbles cemented together). These rocks have not been metamorphosed, having been deposited east of the zone of intense deformation. However, they were buried and lithified (turned into rock) by the pressure of burial and the deposition of cement (mostly calcium carbonate). These layers, originally horizontal, now tilt steeply towards the Sacramento Valley and make up a set of hogback mountains to the west of (and plunging toward) the Sacramento Valley.

In terms of proportion, Dickinson and Rick in 1972[4] identified three principal constituents that comprise the Great Valley Formation. In order of importance they are, (1) 55 to 75 percent sequences of thinly bedded gray to green siltstone and mudstone, (2) 25 to 40 percent sequences of medium- to coarse-grained, massive or graded sandstone with intercalated layers of thin-bedded mudstone-siltstone between coarser beds, and (3) zero to ten percent sequences of massive, thickly bedded pebble and cobble conglomerates with interbedded layers and lenses of sandstone.

The sandstones and conglomerates (less abundant) are resistant to abrasion and thus constitute important lithologies in the gravels of Cache Creek. The shales and siltstones (most abundant) break down to fine-grained sediment and contribute nothing to the aggregate resource, but contribute to sedimentation in the Cache Creek settling basin. Quartz veins also occur in the Great Valley sequence, so upon weathering and erosion, fragments of vein quartz may also be produced.

Reports and papers by Lustig and Busch,[5] Woodward-Clyde Consultants,[6] Wahler Associates,[7] Helley and Harwood,[8] Water Engineering & Technology,[9] Unruh and Moores,[10] Unruh, *et al.*,[11] Munk,[12] and Unruh, Loewen and Moores[13] summarize the geologic structure and geomorphic characteristics of the Cache Creek basin and southwestern Sacramento Valley.

Surficial Geology

Surficial geology of Cache Creek Basin consists of marine and non-marine deposits dating from the Paleocene to Eocene and continental deposits that include sedimentary rocks of the Tehama, Modesto, and Red Bluff Formations dating from Pliocene to Holocene age.[14] Recent volcanism, colluvium derived from landslides, mudflows and earthflows, as well as well as floodplain alluvium contribute to a complex surficial geology in Cache Creek Basin.

Eocene Sandstone and Shale

Eocene sandstone and shale were deposited in a marine environment offshore from the continent on top of the Franciscan Formation. Most of these sedimentary rocks have been removed by erosion, although a narrow band outcrops (is exposed) along the western margin of Capay Valley. These lithologies degrade to sand, silt, and clay and, except for an unknown contribution to the sand-sized load, contribute little or nothing to the aggregate resource in the lower reaches of Cache Creek.

Volcanic Rocks

Volcanic rocks erupted in Tertiary to Recent time (within the last 60 my) are common around Clear Lake. The volcanic, metavolcanic, and ultramafic rocks typically constitute 5-20 percent of the gravels in Lower Cache Creek.

Tehama Formation

The Tehama Formation was deposited by rivers draining the ancestral Coast Ranges and flowing north-northeast in Pleistocene time. The formation consists of conglomerates and sandstones that are weakly cemented and easily weather to yield the original gravel fragments. The lithologies (rock types) of the pebbles in the conglomerates are similar to those in modern Cache Creek, having been derived from the same Franciscan, and to a lesser extent Great Valley, source rocks. The Tehama Formation constitutes a "cap rock" on top of the Great Valley units making up the Rumsey Hills. The pebble lithologies we observed indicate that the tributaries flowing into Cache Creek from the Rumsey Hills carry more gravel derived from the Tehama Formation than from the underlying Great Valley Formation.

The Tehama Formation can be viewed as a storage unit for gravels, or one can view these pebbles as being "recycled", having been incorporated once into the Tehama formation and now being incorporated into the modern river deposits. Some of the pebbles in the Tehama Formation have weathered and are no longer sound. They are usually broken down by stream transport, leaving only resistant, durable pebbles in the modern river gravels. The Tehama Formation outcrops (is exposed) on both sides of Capay Valley and is an important contributor to present day channel morphology as well as the gravels of Cache Creek.

The Tehama Formation also outcrops (is exposed) in the bed and banks of Cache Creek in the study reach at various points, notably in the Capay and Dunnigan Hills reaches. These outcrops, consisting of gravel embedded in otherwise massive clay, form relatively resistant points in the bed and serve as local grade control in the bed or resistant reaches of bank, thus providing geomorphic control to the relatively steep channel profile.

Cache Formation

The Cache Formation is very similar to the Tehama Formation, consisting of Pleistocene age stream gravels, but is concentrated in what were structural depressions (or basins) at the time of deposition, east of Clear Lake. As with the Tehama Formation, it is likely an important contributor to the gravels of Cache Creek.

The proportions of each lithology in representative gravel samples from Capay Valley to Yolo as measured in 1957[15] and from NHC pebble counts in 1994-1995 are presented as pie charts in Figure 3.2-4. The sandstones and metasandstones of the Great Valley Sequence and Franciscan Formation constitute over 50 percent of the gravel samples. These sandstones, unremarkable in appearance, include sandstones and conglomerates in varying stages of metamorphism.

Chert, in a variety of colors from red to green, constitutes about 10 to 40 percent of the total gravels. By virtue of their bright colors, these particles attract the eye and may give a visual impression of greater abundance. These clasts, derived from the Franciscan Formation, are hard and durable. Vein quartz, commonly eroded from chert or sandstone, makes up about 10 to 20 percent of many samples, but is not always present.

We might expect to see an increase in the proportion of durable chert and vein quartz particles with distance downstream, as the presumably less resistant lithologies were selectively abraded during active transport, or were weathered by chemical reactions during the intervals between transport. However, the NHC and Klein and Goldman samples show no consistent trends in composition (see Figure 3.2-4).

Similarly, we might expect to see a systematic downstream decrease in grain size in the samples. Gradation data from NHC, Klein and Goldman, the USGS, and the Corps of Engineers[16] are summarized in Table 3.2-1. Values of D_{16}, D_{50} (median grain size) and D84 presented in Table 3.2-1 and Figure 3.2-5 show a slight systematic fining trend from upstream to downstream. In part, this may reflect the relatively modest decrease in slope over the study reach, but it likely also reflects our difficulty obtaining samples from comparable geomorphic features along the length of the channel due to physical disturbance of bar surfaces each year caused by gravel mining and high water conditions affecting data collection this spring. Figure 3.2-6 shows a similar downstream decreasing trend in D_{50} observed upstream of the study reach by Simons, Li & Associates.[17] Water Engineering & Technology (WET) (1989) data in Figure 3.2-6 indicates a possible D_{50} fining trend in the downstream direction from River mile 30 to 19; however, the trend reverses further downstream, increasing from river mile 19 to 10. Note that the data shown in Figure 3.2-6 were for the study reach that stopped at the I-505 bridge near Madison and did not extend downstream to Yolo where the downstream extent of the present study ends. Figure 3.2-6 also shows the dramatic effects of the Capay Dam located at River Mile 7.7 on interrupting the transport of sediment materials to downstream reaches. Immediately upstream from the dam, the average bed material size decreases in the deposition zone and again coarsens downstream from the dam.

Note that bed material load comprises only a part of total sediment transport in rivers. To understand sediment transport by a river system, we must examine the three major components of a river's total sediment load, namely wash load, bed load, and suspended bed material load. These three components and their location in the vertical profile of a flowing stream are shown in Figure 3.2-7. Wash load and suspended bed material load comprise the finer grain sizes of a river's total sediment load. For Cache Creek, wash load materials are typically smaller than 0.1-0.2 millimeters. Bed material load is the main contributing source of coarser materials, namely aggregate deposits along Cache Creek.

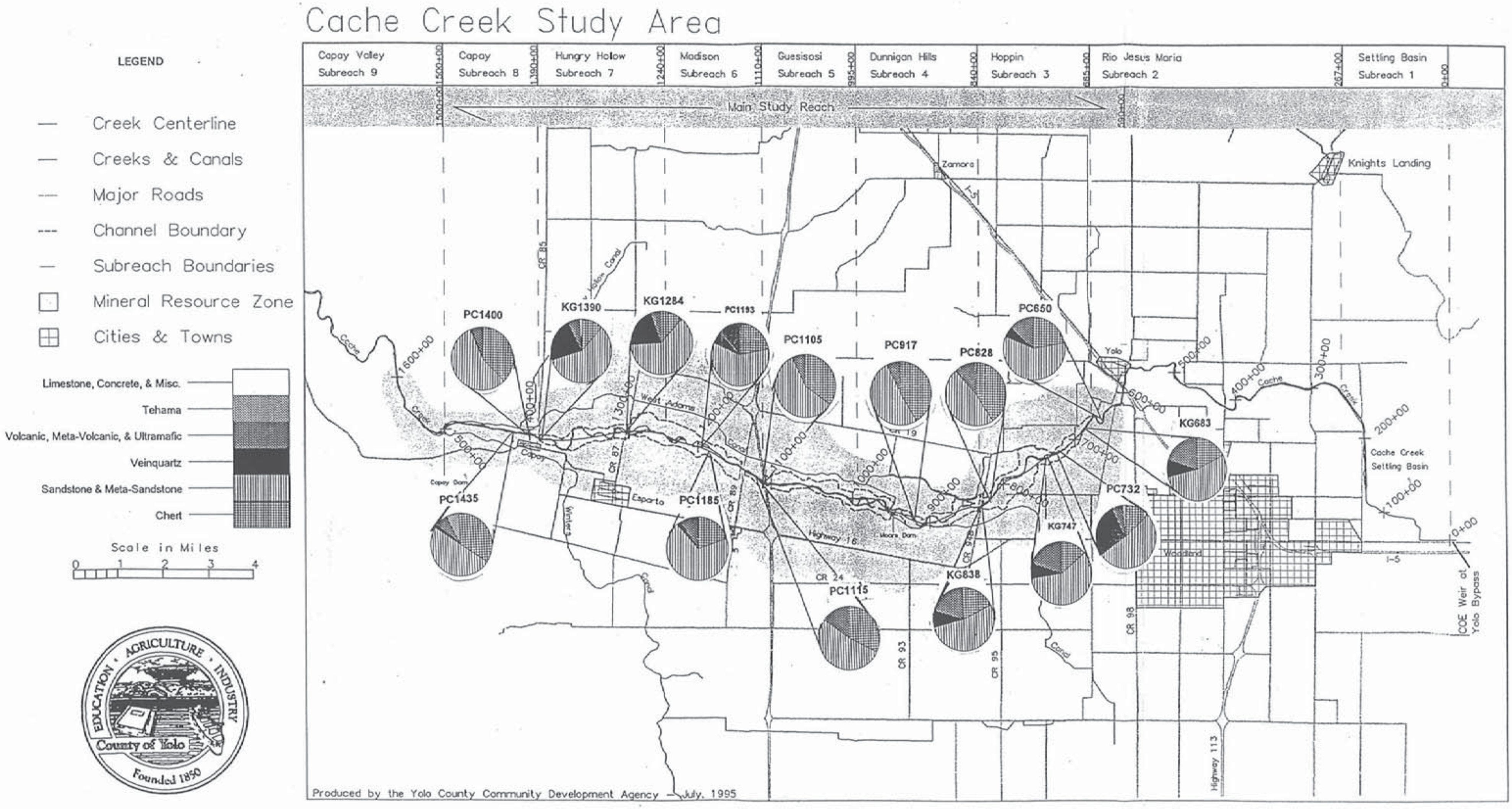


Figure 3.2-4 Pie Charts showing the proportion of each lithology in representative gravel samples from Capay Valley to Yolo as measured by Klein and Goldman (1958) and by NHC 1994-1995 pebble counts. KG denotes Klien and Goldman sample, PC denotes NHC pebble count.

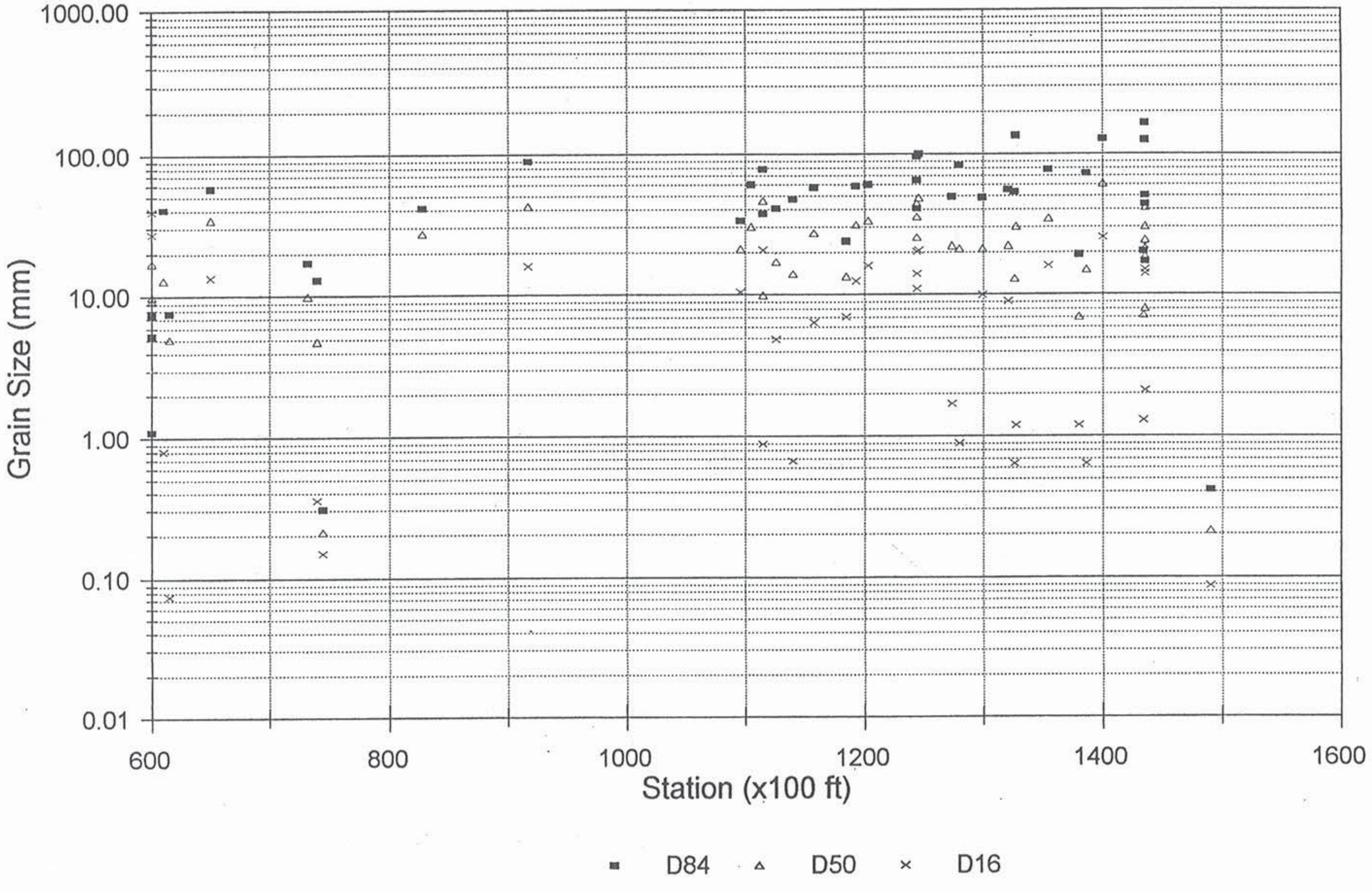


Figure 3.2-5 Grain Size Plotted Against Distance for D84, D50, and D16.
(Note the slight coarsening trend with distance upstream)

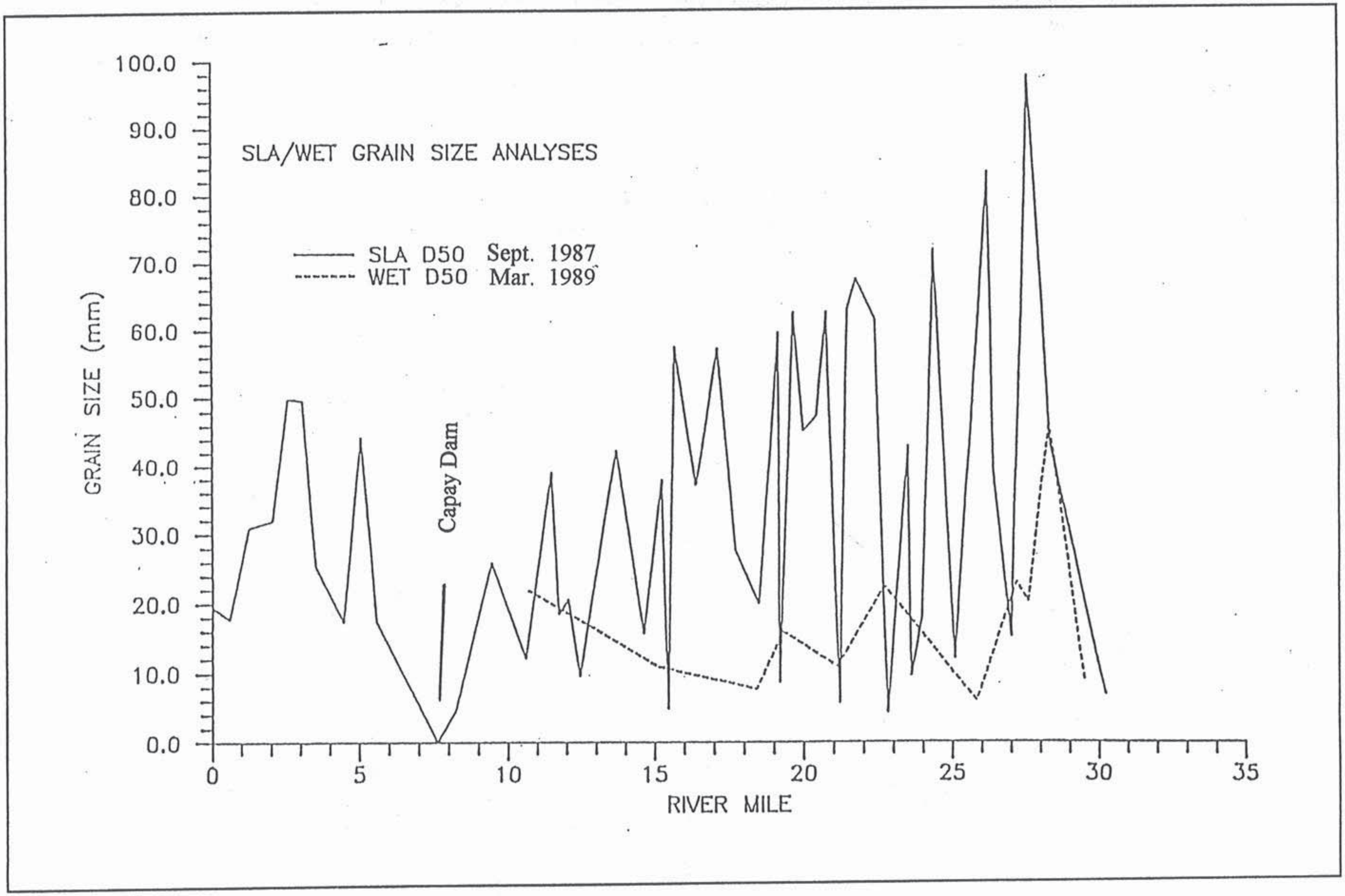
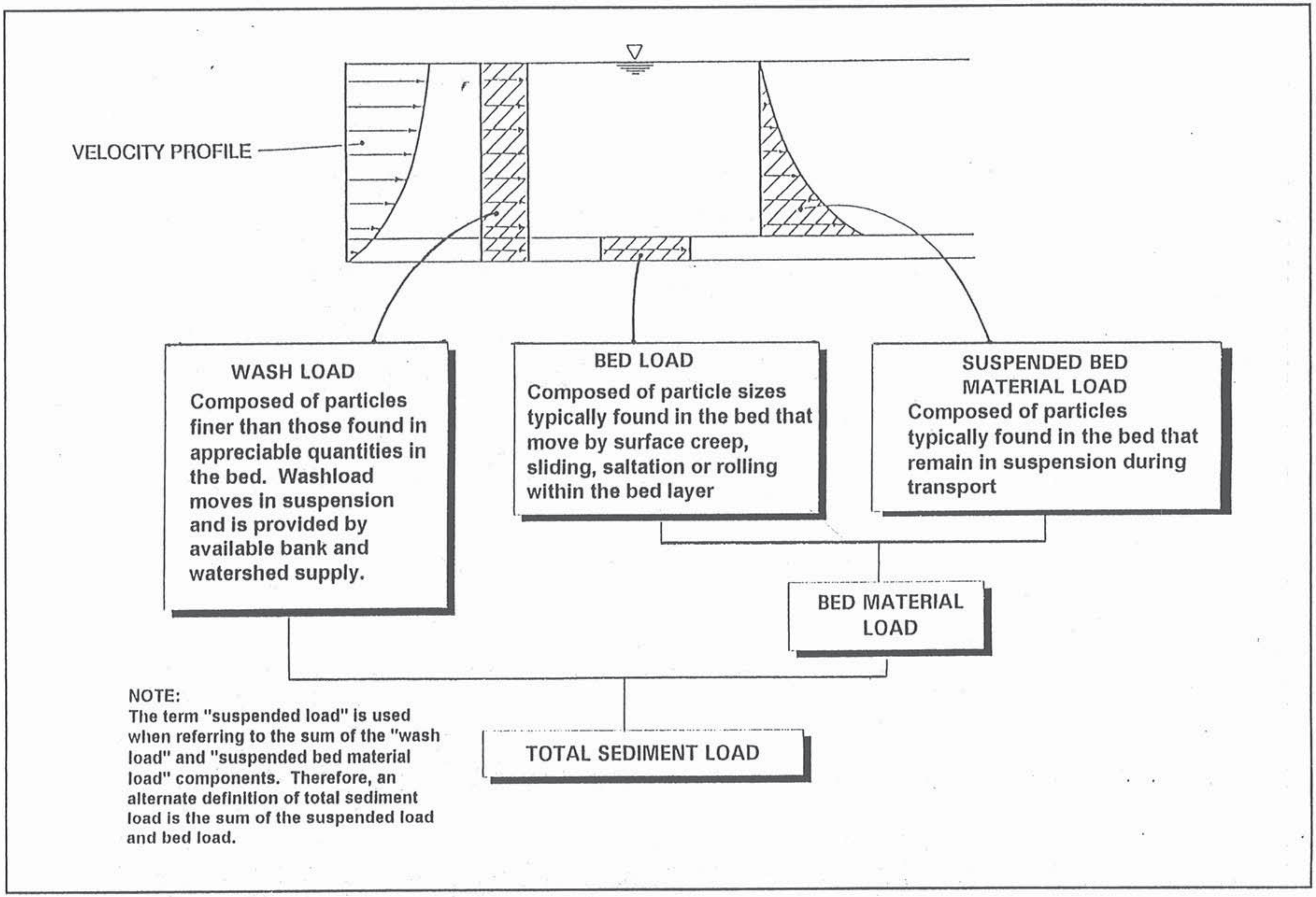


Figure 3.2-6 D_{50} of sampled sediment versus River Mile from SLA (1987) field investigation and from the WET (1989) study, Cache Creek (Note the downstream end of the study reach is located at the I-505 Bridge, not the I-5 Bridge).



NOTE:
The term "suspended load" is used when referring to the sum of the "wash load" and "suspended bed material load" components. Therefore, an alternate definition of total sediment load is the sum of the suspended load and bed load.

Figure 3.2-7 The components of total sediment load (modified from Mussetter et al., 1994)

Table 3.2-1 Reported Values of D16, D50, D84

(particle diameter in mm)

Station x 100 ft	nhc-Siev D84	nhc-Siev D50	nhc-Siev D16	nhc-PC D84	nhc-PC D50	nhc-PC D16	K&G D84	K&G D50	K&G D16	USGS D84	USGS D50	USGS D16	EC-Sie D84	EC-Sie D50	EC-Sie D16	HEC-PC D84	HEC-PC D50	HEC-PC D16
600										7.4	10	39						
600										1.1	9.4	39						
600										5.3	17	27						
610	40	13	0.8															
615	7.6	5	0.074															
650				57	34	13.5												
732				17	10	n/d												
740	13	4.8	0.35															
745	0.3	0.21	0.15															
828				41	27	n/d												
917				89	42	16												
1096										33	21	10.5						
1105				60	30	n/d							40	25				
1110																		
1115	37	10	0.88															
1115				78	46	20.5												
1126										40	17	4.9						
1140							47	14	0.67									
1158										57	27	6.4						
1185				23.5	13.5	7												
1193				58	31	12.5												
1203										60	33	16						
1244										96	44	20	40	25	11	64	35	14
1246										100	48	20.3						
1274										49	22	1.7						
1280							83	21	0.89									
1300										48	21	10						
1321										55	22	9						
1327							53	13	0.64									
1328							135	30	1.2									
1355										77	34	16	40	25				
1380	19	7	1.2															
1386							72	15	0.64				17	8				
1400				128	61	25												
1434										20	7.2	1.3						
1435				43	24	14												
1435				165	18.5	n/d							17	8	2.1	50	30	15
1435				125	41	22												
1490										0.41	0.21	0.087	17	8				

nhc - northwest hydraulic consultants (1994 - 95)
K&G - Klein and Goldman (1958)
USGS - United States Geological Survey (1983 -1986)
HEC - Hydrologic Engineering Center (1987)
SLA - Simons, Li and Associates (1986)

Lithologic Origins of Cache Creek Gravel

The gravels of Cache Creek in the study reach can be classed into four major lithologic groups, based on the results from pebble counts by NHC and Klein and Goldman in 1958: (1) sandstone and metasandstone, (2) chert, (3) volcanic, metavolcanic, and ultramafic rocks, and (4) vein quartz. Minor constituents encountered in the study reach include limestone, granitic rocks (lumped in with the volcanics), pieces of concrete and brick, and large clasts of Tehama Formation (encountered after the 1995 flows and presumably freshly derived from outcrops in the bed and bank below Capay Dam). The distribution of the major geologic units and formations from which these lithologies derive are delineated in Figure 3.2-2 from Lustig and Busch.[18]

North Fork Cache Creek and Bear Creek are the two major tributaries to the main stem Cache Creek. They enter Cache Creek upstream from Rumsey, about 25 miles upstream from the present study reach, but supply almost 30 percent of the total suspended sediment load transported down Cache Creek.[19] The remaining 70 percent of the total suspended load is supplied by the main stem of Cache Creek. Lustig and Busch[20] also estimate that approximately seven percent of the total sediment load is transported as bedload.

Nine distinct soil types have been mapped in the Capay Valley and adjacent hills.[21] From Capay to Yolo, the dominant soil types adjacent to Cache Creek include: Yolo-Brentwood silt loams and silty clay loams and Rincon-Marvin-Tehama silty clay loams on the alluvial fan and floodplain surfaces.[22] Brentwood and Yolo soils are high fertility silt loams and silty-clay loams formed on alluvium under a dense oak forest in Capay Valley. Balcom and Sehorn soils, formed from alluvium and colluvium from the Tehama Formation, are moderate to high fertility soils overlying soft calcareous sandstone or siltstone in the uplands. Other soils bordering Cache Creek in Capay Valley have low to moderate fertility.

Geologic Structure and Tectonism

Southwestern Sacramento Valley and the adjacent Coast Ranges are extremely active geologically. Active tectonism in the region occurs along the coastal ranges which are actively being deformed by compression forces related to the movement of the Pacific plate relative to the North American plate. Major faults and folds in the Cache Creek basin have strikes oriented about N30° W.[23] The Coast Ranges began rising (uplifting) about 3.4 million years ago (Ma). Sediment eroded from these ancestral Coast Ranges was transported and deposited as the Tehama formation until about 1 Ma, when the uplift extended eastward under the Sacramento Valley and the sediments of the Tehama Formation itself were uplifted and underwent erosion. The patterns of micro-earthquakes under the Capay Valley-Lower Cache Creek area Rumsey Hills indicate that the crust down to about 8 miles is undergoing intense geologic compression accommodated by *thrust faults*,[24] in which large slabs of rock become detached at depth and slide past one another, something like a deck of cards being shuffled.

Capay Valley lies within an extensive zone of deformation associated with the San Andreas Fault System.[25] As shown in Figure 3.2-8, numerous faults and folds control the course and morphology of Cache Creek from Clear Lake to the Yolo Bypass. From Rumsey to Brooks, the

Capay Valley lies within an extensive zone of deformation associated with the San Andreas Fault System.[25] As shown in Figure 3.2-8, numerous faults and folds control the course and morphology of Cache Creek from Clear Lake to the Yolo Bypass. From Rumsey to Brooks, the Capay Valley is bounded by two major north-south trending thrust faults referred to as the East Valley Fault on the west and the Sweitzer fault to the east. Within the study reach from Capay to the Yolo Bypass, Cache Creek crosses the Madison Syncline, the Dunnigan Hills Anticline, the Zamora Syncline, and their associated thrust faults (see Figure 3.2-8).

A large thrust fault (the Sweitzer Fault) is exposed at the surface in the Rumsey Hills, as shown in Figures 3.2-8 and 3.2-9. Most of these thrusts in the upper basin are not exposed at the surface and are termed blind thrust faults. On the surface above these thrust faults, uplift and folding of the originally horizontal beds into synclines (downfolds) and anticlines (upfolds) is common. Examples of these occur at the Madison (Great Valley) syncline and the Dunnigan Hills anticline as shown in Figures 3.2-8 and 3.2-9.[26] Active upfolding and downfolding at the Dunnigan Hills Anticline and Madison Syncline have contributed to the historic channel profile adjustment of Cache Creek. Woodward-Clyde[27] and Wahler Associates[28] also imply that these active geologic structures affect the elevation and gradient of subsurface groundwater resources.

An interesting manifestation of the intense geologic compression of the Capay Valley formations is the occurrence of saline springs in the Rumsey Hills. As these springs occur near the tops of the range and show no variation in discharge related to wet or dry periods, it is inferred that this saline water is original fluid in the rock formation, now being squeezed out by compression of the beds.[29]

Uplift and Subsidence

It is widely accepted that the Coast Range is being actively uplifted, however there remains controversy as to the rate and amount of uplift.[30] Even though the Coast Range is seismically active, few movements along faults within the Cache Creek drainage basin have been recorded in recent history.

As reported by Borcalli and Associates during the Corps of Engineers Public Workshop for their Reconnaissance Study in March, 1995, approximately 2.25 feet of subsidence has been measured in the vicinity of Woodland during the period from 1942 to 1987 (see Figure 3.2-10). This amount of subsidence suggests not only pore pressure release and consolidation of subsurface materials, but also potential basin adjustment as a result of tectonic activity. Figure 3.2-11 shows the leveling route and bench mark locations used by the USGS to prepare the data shown in Figure 3.2-10. Water Engineering and Technology[31] presented a National Geodetic Survey line (Figure 3.2-12) showing the rates of ground movement between 1964 and 1967 from Davis to Madison along the same survey route shown in Figure 3.2-11.

Accordingly, in the vicinity of the Dunnigan Hills Anticline the approximate rate of uplift measured for the period 1964 to 1967 was 1.1 to 1.2 inches per year. At the downstream end of the present study reach near Yolo, there is approximately an equal and opposite trend of subsidence (-1.1 to -1.2 inches/year). As previously indicated, tectonic adjustment of the various geologic units occurring throughout the study area may affect channel morphology of Cache Creek in subtler ways.

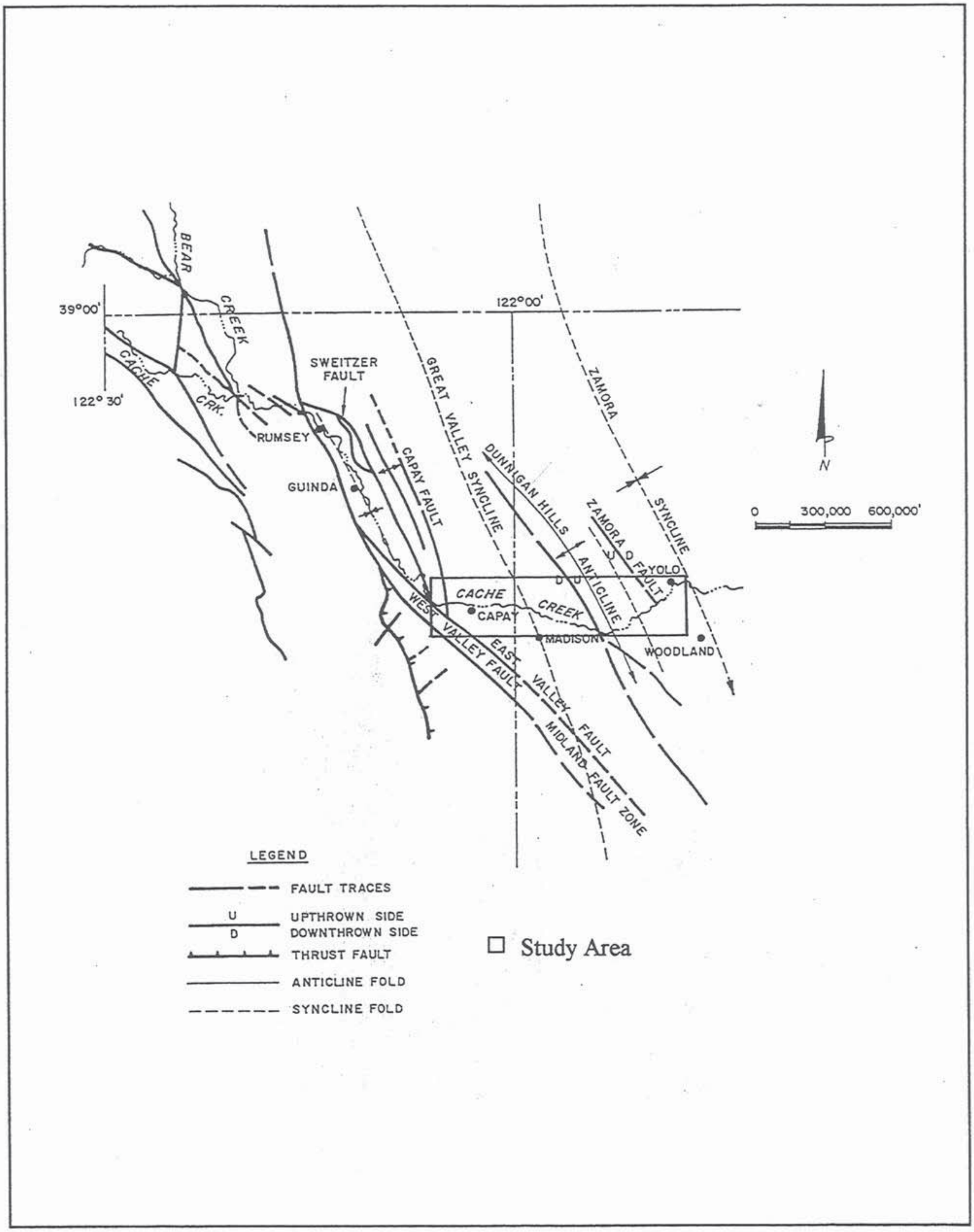


Figure 3.2-8 Generalized structure map of part of the Cache Creek Drainage Basin (Source: Helley and Harwood, 1985, and Jennings, 1977)

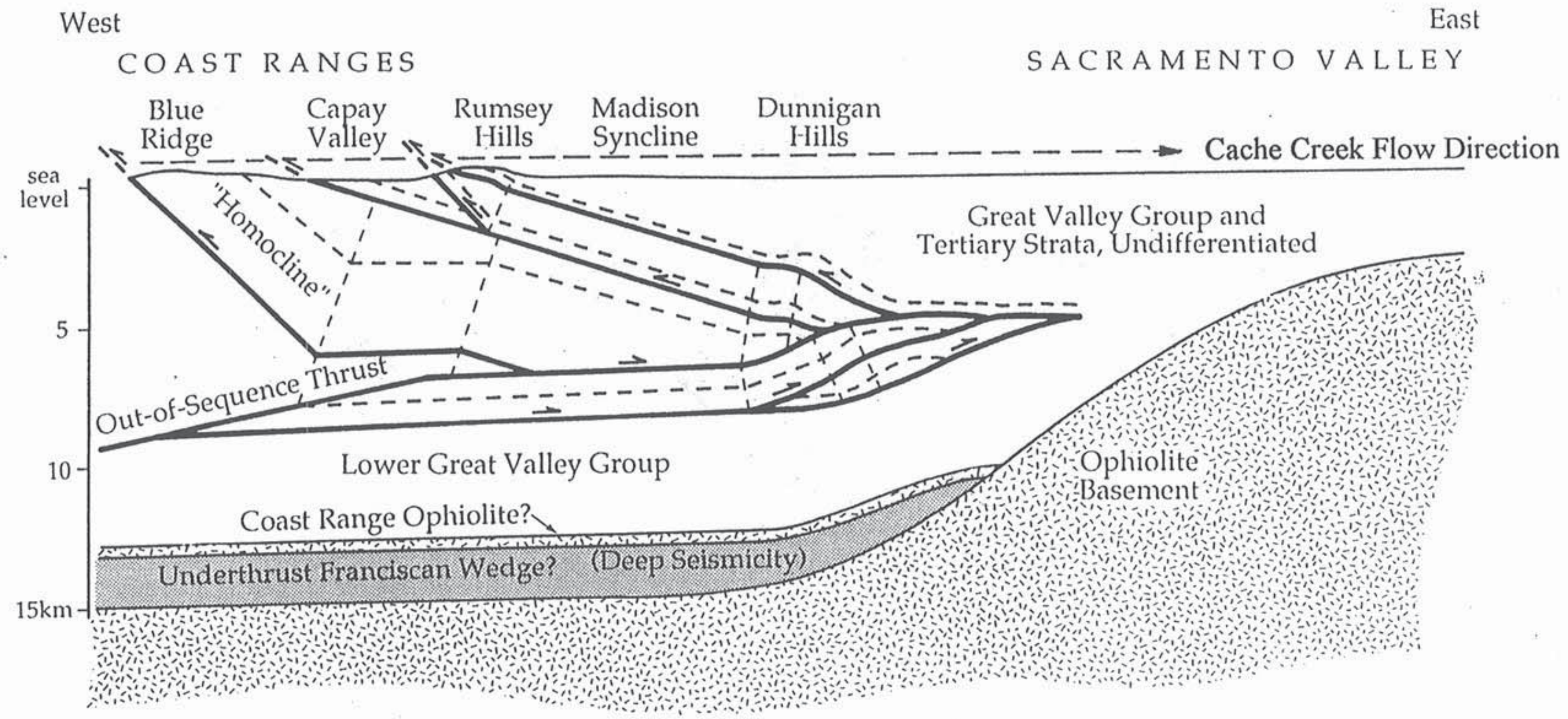


Figure 3.2-9 Schematic model for the blind thrust system beneath the southwestern Sacramento Valley based on tectonic-geomorphic development, patterns of microseismicity, and analysis of seismic reflection data (Source: Unruh and Moores, 1992).

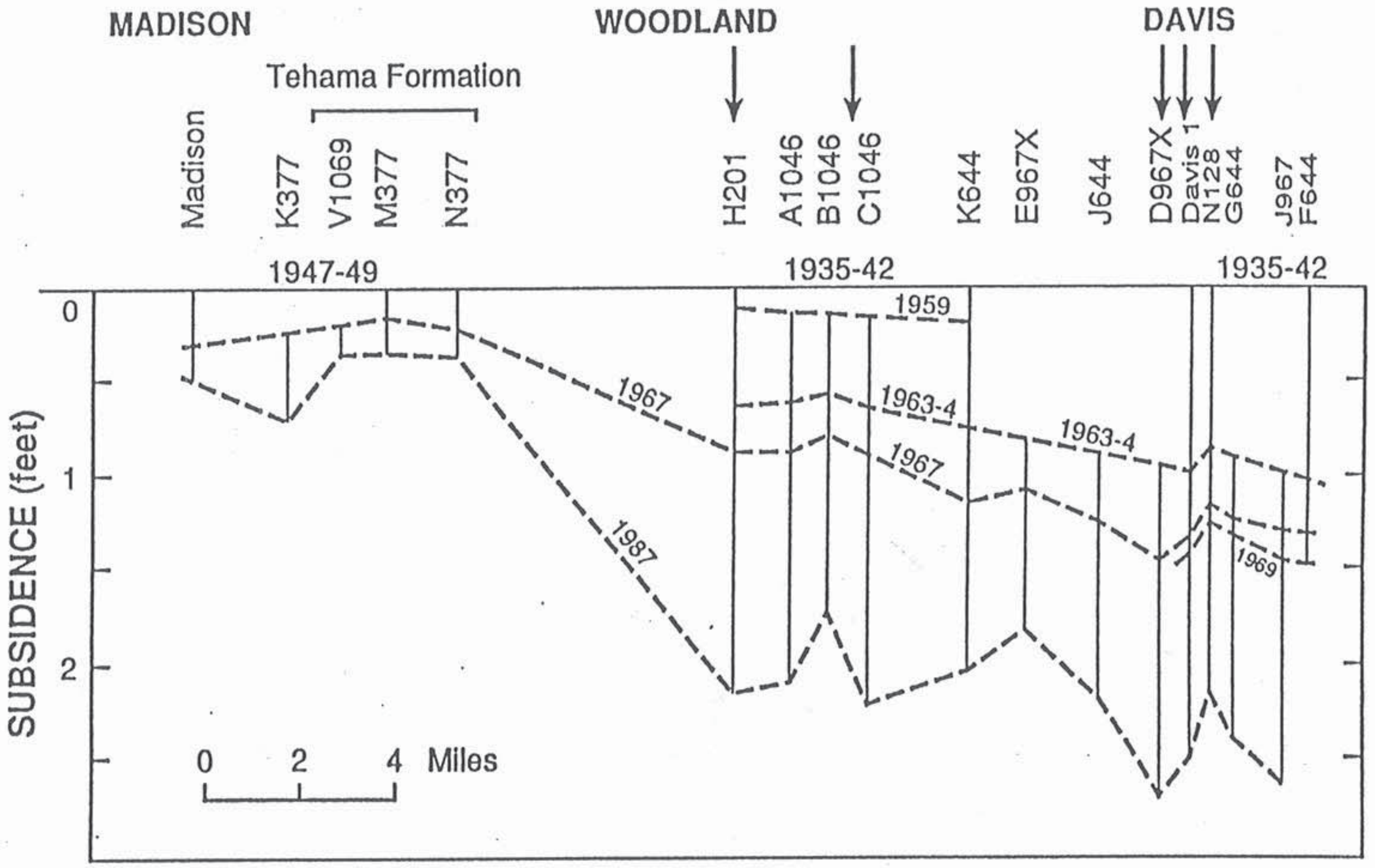


Figure 3.2-10 Diagram showing subsidence in feet from Madison to Davis along the Geodetic Survey route shown in Figure 3.2-11 (Source: Cache Creek Public Workshop).

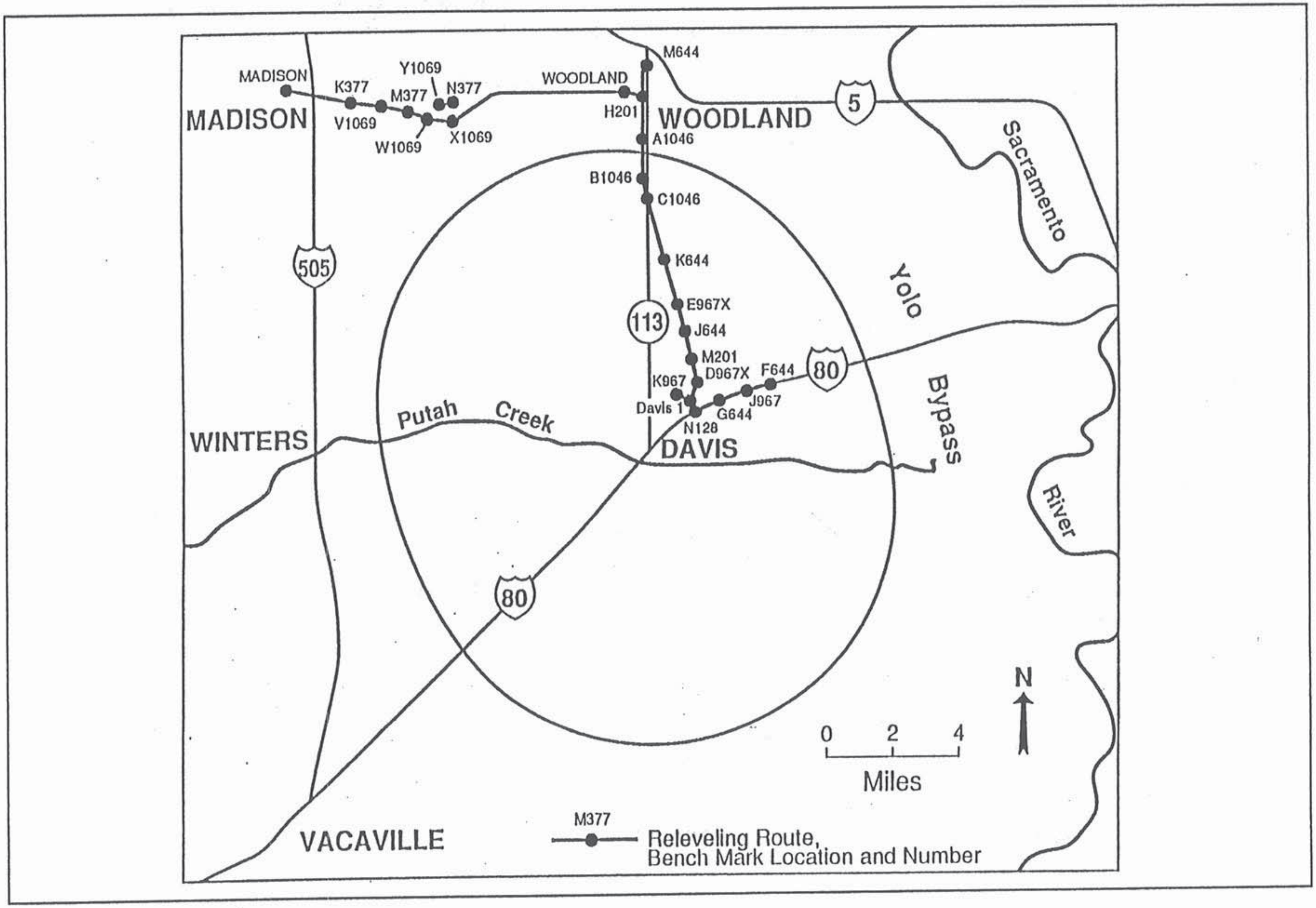


Figure 3.2-11 Map showing the location of the Geodetic Survey taken from Davis to Woodland (Source: Cache Creek Public Workshop).

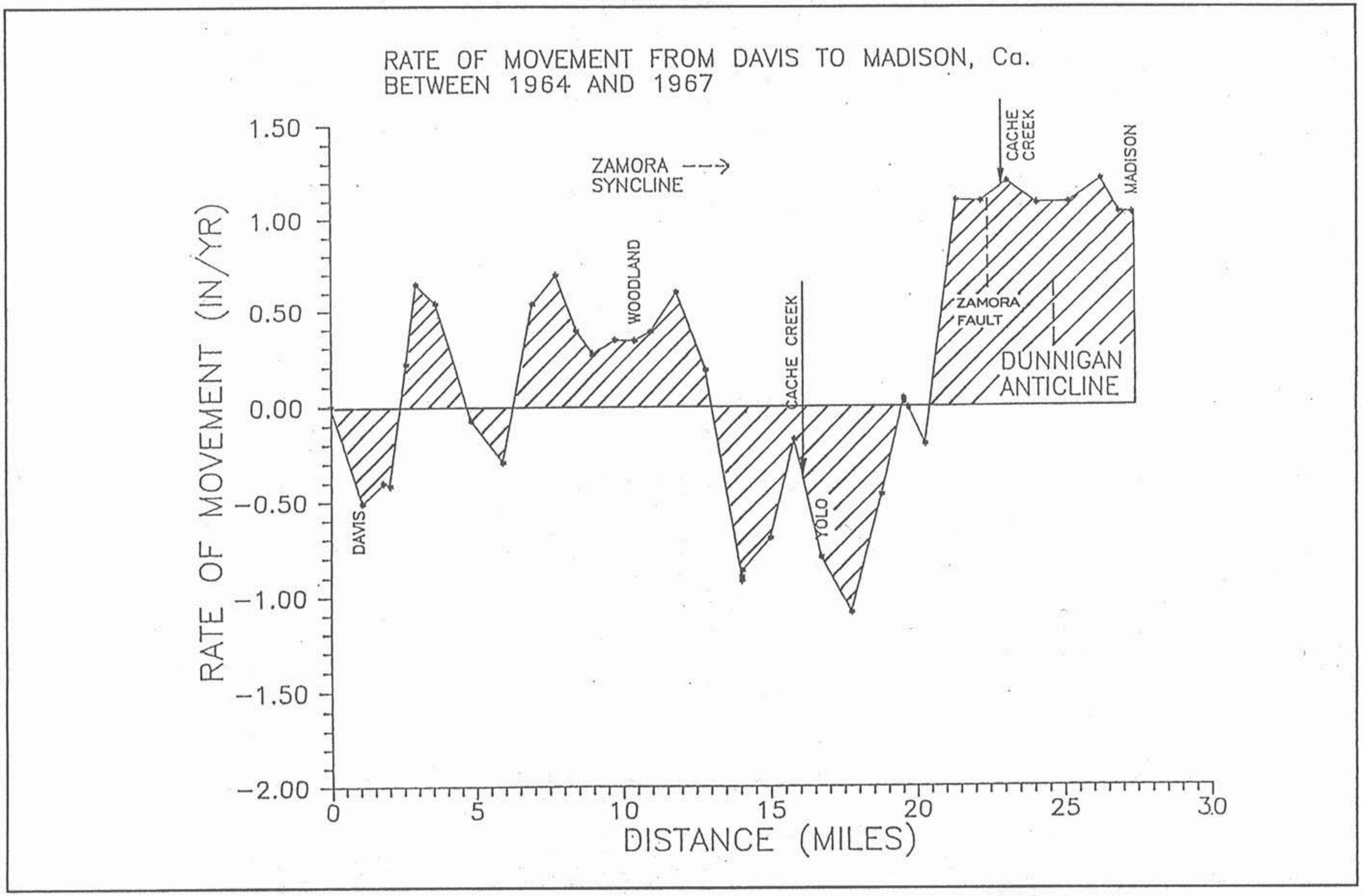


Figure 3.2-12 Rate of ground movement from Davis to Madison, California, between 1964 and 1967. Data obtained from National Geodetic Survey (Modified from WET, 1989).

Annual measurements of continuous, ongoing basin adjustments over time could be useful in assessing the impact of uplift and subsidence on river regime in the study area. Further monitoring of uplift and subsidence is necessary to quantify the effects more accurately.

Basin and Channel Geomorphology

Cache Creek flows alternately through bedrock canyons and alluvial reaches above Capay Valley. Capay Valley is oriented parallel to the strike (general orientation) of the geologic structure. The surrounding hills are composed of more resistant formations, while the weaker intervening units have eroded out to form Capay Valley. The flat valley floor is composed of Cache Creek alluvium deposited within the bedrock valley. Near Capay, Cache Creek turns to flow eastward through a low trough in the Rumsey Hills (transverse to the geologic grain) and debouches into the Sacramento Valley, where its deposits have built up an extensive alluvial fan.

Historical geomorphic characteristics of Cache Creek from Capay Dam downstream to the Cache Creek Settling Basin were considerably different from today. Through this 28-mile reach the pre-mining natural channel of Cache Creek underwent a transition in the downstream direction from a wide, relatively steep, braided channel on the upstream end of the alluvial fan (with active deposition of gravels and sands) to a narrow channel incised into fine-grained overbank deposits and Tule marsh areas downstream from Yolo. This trend was considerably complicated by the effect of the bedrock constriction where the channel passed between the Dunnigan Hills and the Plainfield Ridge. Here, the active channel narrowed and a bedrock sill forced groundwater to the surface, resulting in a shallow water table and encouraging proliferation of riparian vegetation. This resulted in an "hourglass" form to the active channel, with a wide active channel from Capay downstream to the vicinity of the old Moore Dam. Downstream from there, a narrower channel evolved down to about the present site of Stevens Bridge. This is the reach that crosses through the Dunnigan Hills Anticline. Beyond Road 94-B (Stevens Bridge), the channel widened again downstream nearly to Yolo where the bed slope decreases and the bed material gets much finer. From there the channel again narrows all the way to it terminus in the Yolo Bypass. The present day active channel (narrowed from 19th century widths) displays additional, smaller-scale variations in width associated with constrictions of the channel at bridges. It also displays considerable differences in depth and therefore channel conveyance (flow carrying capacity, or cross section area) resulting from the cumulative effects of aggregate extraction for the past 100 years.

From Capay Dam to the Capay Bridge, Cache Creek flows over moderately resistant sandstones and shales from the Great Valley Sequence, as well as occasional outcrops of Tehama Formation. Collins and Dunne[32] report that Great Valley Sequence rocks are exposed in the reach from the dam to the bridge due to about 15 feet of degradation that occurred between 1959 and 1980. Recent floods in March 1995 exposed additional outcrops of Tehama and Great Valley rock formations in the reach from the dam to the bridge, indicating that the river is continuing to degrade. Base level lowering of the main channel thalweg downstream from Capay (approximately 15 to 20 feet) may be contributing to channel steepening and the apparent channel incision in the reach upstream from the Capay Bridge.

Downstream from Capay Bridge the creek crosses a large Tertiary-Quaternary age alluvial fan. The fan is comprised primarily of coarse grained materials (sands and gravels) that deposited over time as outwash from Capay Valley. Collins and Dunne[33] estimate that gravel mining operations along this reach had extracted approximately 80 to 90 million tons of sand and gravel from 1905 to 1984.

Physiographic Provinces of Cache Creek

Moving from downstream to upstream, there are at least four major physiographic provinces (geomorphic units) with distinctly different morphologic, hydraulic, and sediment characteristics. Simply stated, the runoff and sediment delivery from the upper most basins near Clear Lake and Indian Valley are somewhat controlled by the lake and reservoir and the relatively flat valleys through which excess runoff travels. Just downstream from the upper province is a very steep, deeply incised river reach where high sediment production and very efficient sediment transport occurs. Below that province the river reach through Capay Valley has sufficient channel slope to move substantial material loads during high runoff periods, but during moderate to low flow periods the province may experience net aggradation and accumulation of sediment, especially those coarser bed materials moving through the system. Once deposited in the Capay Valley however, they may be remobilized by the next large event and move further downstream. Lateral inflows from tributary drainages and bank erosion processes serve to increase total sediment loads. Also, occasional landslide areas provide localized large pulses of material into the creek during short periods when the slides are activated.

Below the Capay Dam, the channel emerges out onto a broad, gently sloping alluvial fan characterized by dissected and often abandoned river terraces and previously avulsed channels. This physiographic province is characterized as a sediment deposition zone in the system and is the location where the most active aggregate extraction operations have occurred. In-channel gravel extraction through this reach has lowered the channel thalweg more than ten feet for several miles and narrowed the channel to more than 1,200 feet upstream and downstream from the Esparto and Stevens Bridges. The fourth province begins downstream from the active gravel extraction operations and continues to the Cache Creek Settling Basin. The channel through this reach is leveed and deeply incised in many locations. Channel capacity through the lower reach is much less than the reach immediately upstream because of its relatively narrow width. The Cache Creek Settling Basin has replaced the natural deposition zone, where the creek historically flowed into the tule marshes of the Yolo Basin.

Geomorphic Reaches Distinguished in this Study

For the purposes of the present Streamway Investigation, NHC identified nine geomorphically distinct subreaches in the 35 miles from upstream of the Capay Dam to the Settling Basin, as shown in Figure 3.2-13. From upstream to downstream the nine geomorphic subreaches are referred to as Capay Valley (Subreach 9), Capay (Subreach 8), Hungry Hollow (Subreach 7), Madison (Subreach 6), Guesisosi (Subreach 5), Dunnigan Hills (Subreach 4), Hoppin (Subreach 3), Rio Jesus Maria (Subreach 2), and the Settling Basin (Subreach 1). The specific study reach delineated in the scope of work for the Streamway Study extends from the Capay Dam, downstream to the Highway I-5 bridge near Yolo, a distance of approximately 14.5 miles.

Therefore, the primary study area falls within Subreaches 8, 7, 6, 5, 4, 3, and the upper-most portion of Subreach 2 (see Figure 3.2-13). A summary table of reach characteristics including mean width, mean depth, slope, reach length and stationing is given in Table 3.2-2.

Capay Reach

Capay Reach (Reach 8; Figure 3.2-14) extends approximately 2.1 miles from Capay Dam to the Capay Bridge (Station 1500+00 to 1390+00). It has an average bed slope of approximately 10.8 ft/mi and is characterized as relatively steep, confined and incised with several bed rock controls. Outcrops of Great Valley Sequence rocks are visible in the bed of the channel and in the toes of the banks, contributing to preferential bed scour and confinement of the channel into a narrow, incised reach. In addition, channel incision may have resulted from the cumulative effects of the following [not presented in any preferred order]: (1) more than 100 years of gravel extraction from the downstream end of the reach, (2) channel encroachment and river training works installed by local landowners adjacent to the creek (the training works have narrowed and straightened the channel), (3) construction and subsequent repair of the Capay Bridge in 1919 and 1947, respectively, and (4) the installation and operation of the Capay Diversion Dam that interrupts the flow of water and sediments through the reach. Note that in downstream sections of this reach, Cache Creek widens substantially, suggesting the absence of a bedrock control on alluvial channel width. Bed material overlying the bed rock in this reach is very coarse grained.

Hungry Hollow Reach

Hungry Hollow Reach (Reach 7; Figure 3.2-15) extends 2.8 miles from Capay Bridge to about one mile downstream of Esparto Bridge (station 1240+00) and has an approximate slope of 11.3 ft/mi. Below Capay Dam (a significant constriction), the channel widens and is braided. This channel planform is attributed not to natural conditions but to gravel extraction in the area which has resulted in significant degradation of the channel bed. A braided pattern was well developed historically; however, as well as after the 1995 flows but in general, the effects of sand and gravel extraction and training of the channel by dikes has reduced the degree of braiding and width of the band occupied by the actively migrating channel.

Madison Reach

Madison Reach (Reach 6; Figure 3.2-16) extends 2.5 miles from station 1240+00 downstream to the I-505 bridge (station 1110+00) and has an approximate slope of 12.4 ft/mi. Although not an active reach for gravel mining, this area was mined during the 1960s (in some cases more than 20 feet) to supply the aggregate needs for the construction of I-505. The reach is currently undisturbed by human activities and has a narrower width than upstream reaches. Grasses are the predominant form of vegetation. The old Madison Bridge, formerly along this reach, collapsed on August 1, 1978 as an empty tractor trailer flatbed drove rapidly across the bridge one Saturday morning, failing as the tractor trailer reached the other side.[34]

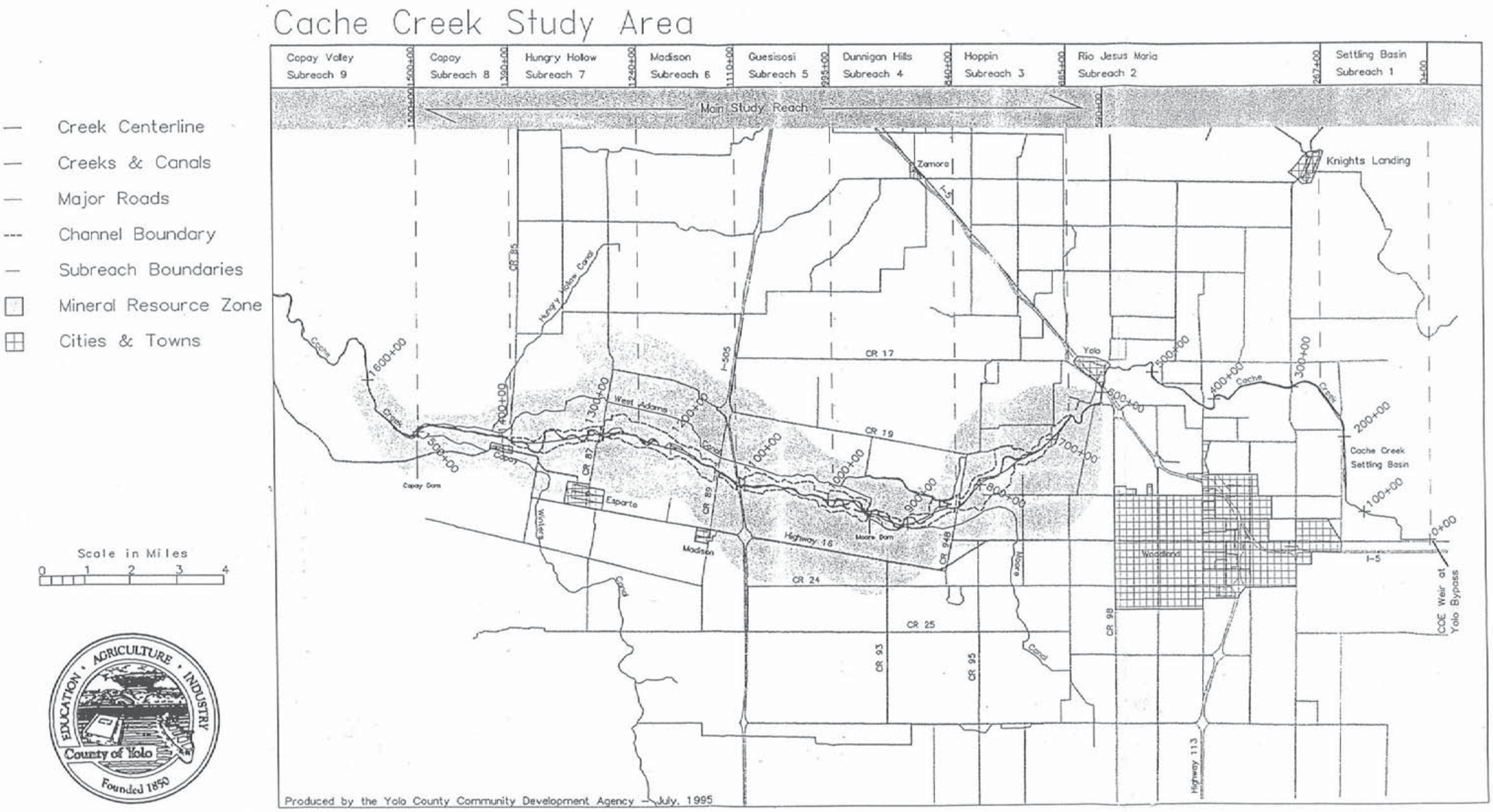
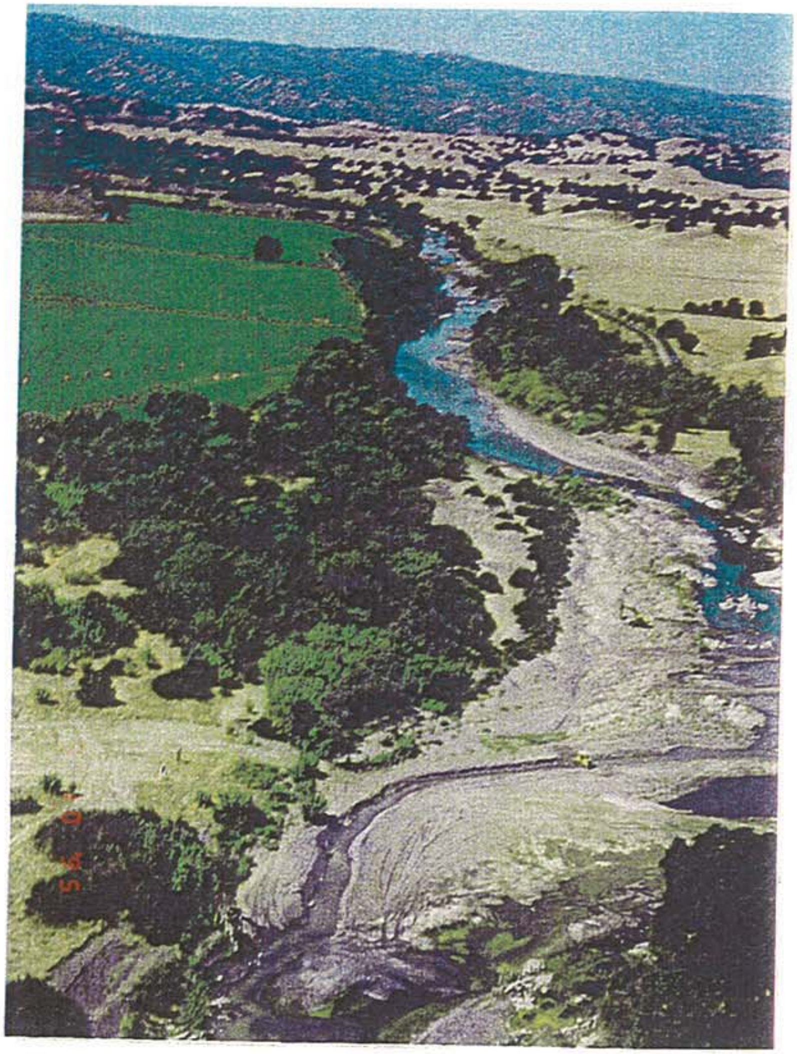
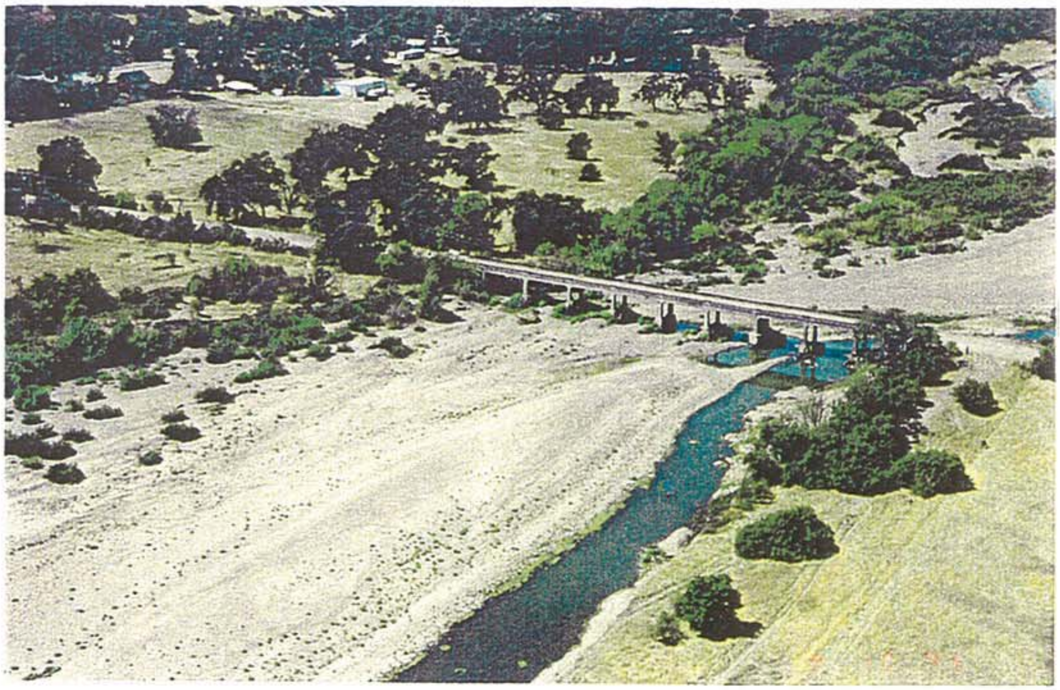


Figure 3.2-13 Cache Creek study area and geomorphic subreaches delineated by the streamway study.

Upstream of Capay Bridge
Looking Towards Capay Dam
(September 10, 1995)





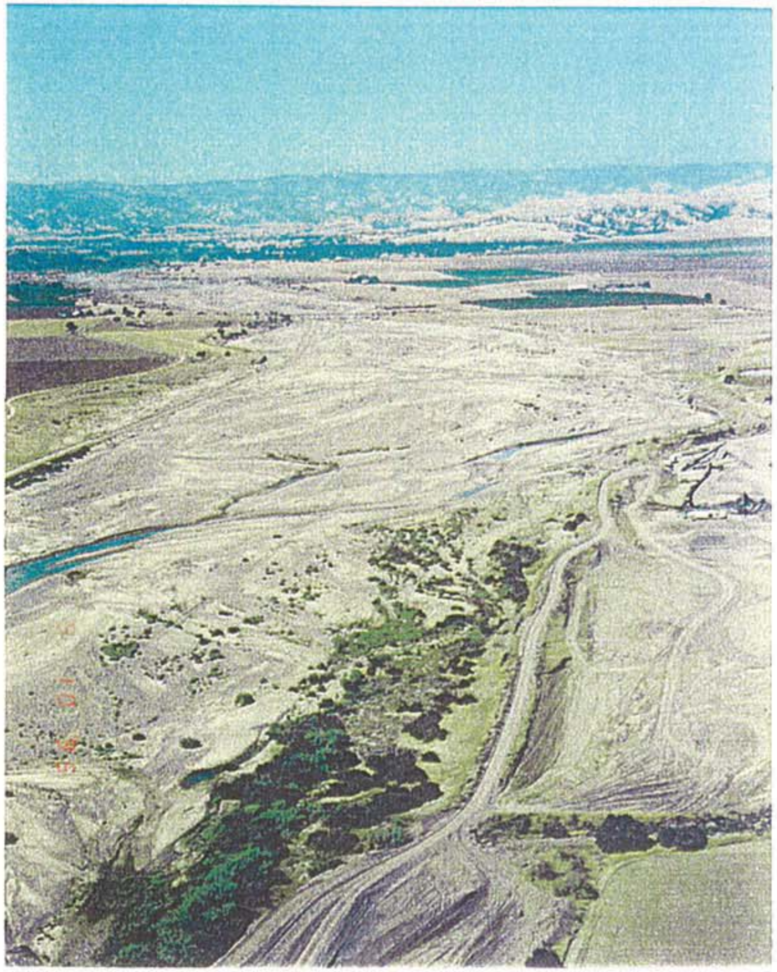
Capay Bridge Lookir
Upstream Towards
Capay Bridge
(September 10, 1995

Figure 3.2-14 Capay Subreach 8

Looking Upstream Towards Capay Bridge
(September 10, 1995)

Looking Upstream Towards Esparto Bridge
(September 10, 1995)

Figure 3.2-15 Hungry Hollow Subreach 7



Looking Upstream Towards Esparto Bridge
(September 10, 1995)

Looking Upstream Towards Esparto Bridge
(September 10, 1995)

Figure 3.2-16 Madison Subreach 6

Table 3.2-2 Summary of Reach Characteristics

Reach	Length (mi)	Stationing	Slope[1] (ft/mi)	Width[1] (ft)	Depth[1] (ft)	Comments
Capay	2.1	1500+00 - 1390+00	10.8	1759	19.7	steep, confined and incised with bedrock controls
Hungry Hollow	2.8	1390+00 - 1240+00	11.3	1548	11.5	channel widens; braided planform; active gravel mining
Madison	2.5	1240+00 - 1110+00	12.4	692	19.3	downstream portion of reach narrows and not actively mined
Geusisosi	2.3	1110+00 - 990+00	6.2	614	18.6	channel initially confined by levee, reasonably straight but meanders further downstream; some in-channel levees
Dunnigan Hills	2.8	990+00 - 840+00	9.9	879	16.1	well-developed low-flow meanders; significant riparian vegetation; site of former Moore diversion dam; bedrock controls along Dunnigan Hills; some in-channel levees; West Adams Canal drain and Goodenow Slough enter upstream from road 94B
Hoppin	3.3	840+00 - 665+00	7.4	1584	32.6	some meander development; bedrock controls upstream from Stevens Bridge; extensive gravel mining; dense vegetation downstream from Stevens Bridge; some in-channel levees
Rio Jesus Maria	7.5	665+00 - 590+00	7	384	41.6	upper 1.4 mi included in study area; channel considerably narrower and constricted with steep banks; some riparian vegetation; contains COE flood control levees; four bridge crossings near station 60000, at Yolo

[1] Reach-averaged values

Guesisosi Reach

Guesisosi Reach (Reach 5; Figure 3.2-17) extends 2.3 miles from I-505 bridge downstream to station 990+00, upstream of Moore Dam. The average gradient is approximately 6.2 ft/mi. In this reach, the water table shallows considerably as a result of the bedrock constriction and sill along the Dunnigan Hills-Plainfield Ridge lineament. For about one mile downstream of I-505, the channel has been constrained by levees and dikes into a straight course. Downstream of this, however, the low-flow channel begins to meander.

Dunnigan Hills Reach

Dunnigan Hills Reach (Reach 4; Figure 3.2-18) extends about 2.8 miles from Station 990+00 to Stevens Bridge (Station 840+00). The average gradient is approximately 9.9 ft/mi. The channel meanders in this reach at present, with well-developed wavelengths of about 1,000 ft and amplitudes of 500 ft mapped in 1978. The 1905 channel was much less sinuous (as it appears on the 1916 topographic map), with one clearly distinguished meander bend, for which the wavelength was about 1,000 ft and amplitude about 200 ft. The reach enjoys a high water table virtually year-round as a result of the near-surface presence of less permeable geologic formations along Plainfield Ridge. A likely additional source of water supply lies in return flow from the West Adams Canal. This has resulted in significant riparian vegetation along stream banks in this reach (USFWS, 1995).

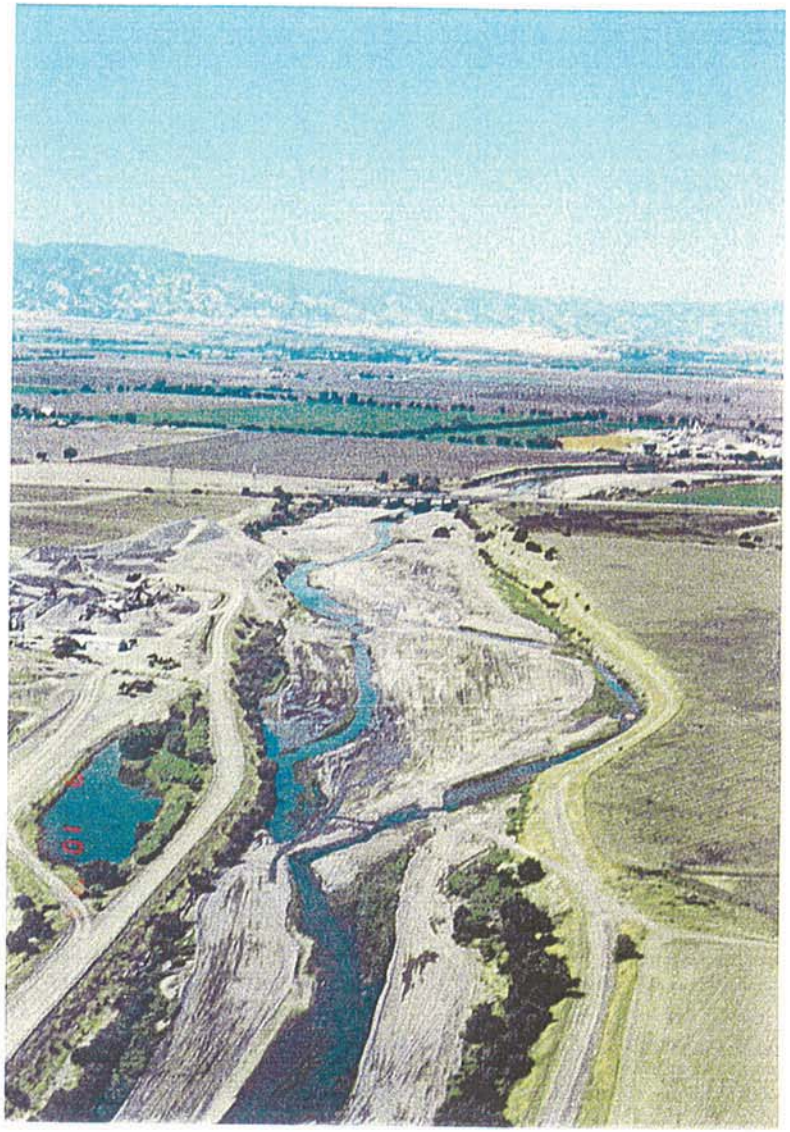
Hoppin Reach

Hoppin Reach (Reach 3; Figure 3.2-19) extends 3.3 miles from Stevens Bridge downstream to about one mile upstream of Yolo (stations 840+00 to 665+00). The average gradient is approximately 7.4 ft/mi. The channel has developed some meanders, with best meander development occurring in the downstream half of the reach in 1905 (based on USGS 15-minute topographic map of 1916), and in the upstream half of the reach in 1978 (based on a photo-revised USGS 7.5-minute topographic map of 1981). The meander amplitude was about 500 feet in both channels, although the wavelength appears to have increased from about 1,000-1,500 ft to about 2,000 ft. This reach is extensively mined, most notably on either side of the existing stream channel. Vegetation is most dense in a one to two mil section of the reach downstream from Stevens Bridge.

Rio Jesus Maria

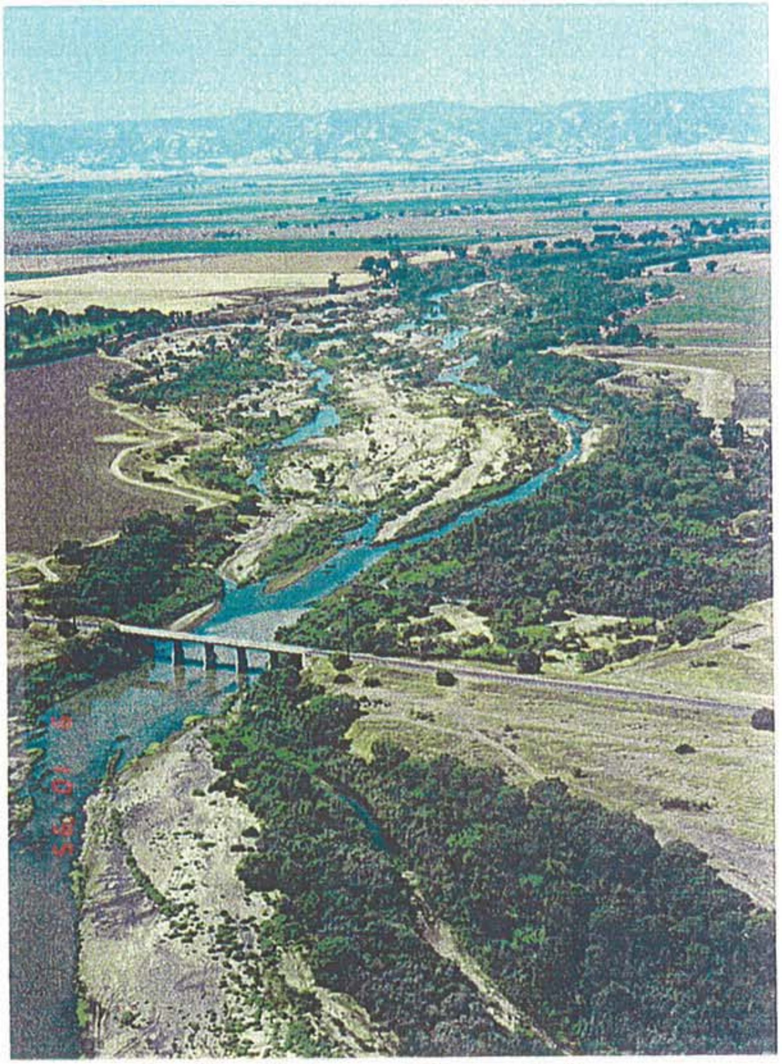
Rio Jesus Maria (Reach 2; Figure 3.2-20) extends 7.5 miles, of which the upper 1.4 miles (between 665+00 and 590+00) was studied. This portion of the reach has a slope of 7 ft/mi and is considerably narrower than upstream reaches. Vegetation consists of intermittent trees and shrubs, with some grasses.

View of Channel Skimming in
Guesisosi Subreach
(September 10, 1995)

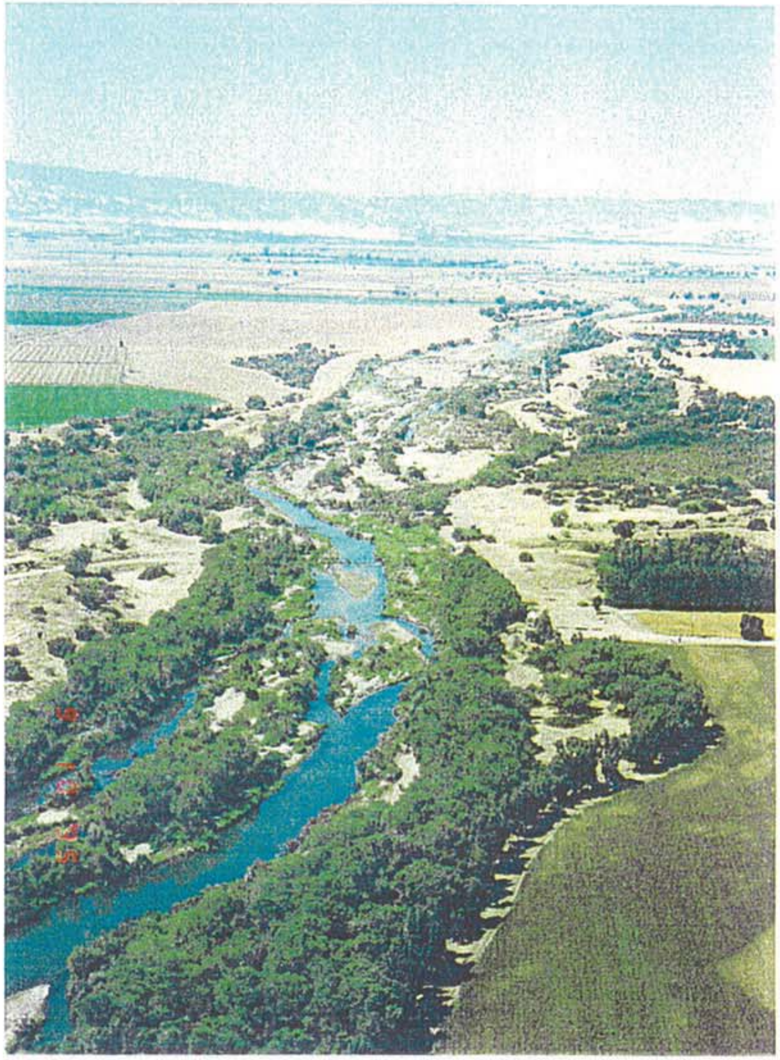


Looking Upstream Towards I-505
(September 10 1995)

Figure 3.2-17 Guesisosi Subreach 5



Looking Upstream at Stevens Bridge
(September 10, 1995)



Upstream of Stevens Bridge, Looking Towards I-505
(September 10, 1995)

Figure 3.2-18 Dunnigan Hills Subreach 4

Hoppin Reach Looking Upstream
(September 10, 1995)

Looking Upstream Towards Stevens Bridge
(September 10, 1995)

Figuire 3.2-19 Hoppin Subreach 3

View of Leveed Reach
Upstream of I-5
(September 10,1995)

View of Downstream End of the Study Boundary at S.P.R.R., Cacheville, and I-5 Bridges, Looking Upstream.
(September 10,1995)

Figure 3.2-20 Rio Jesus Maria Subreach 2

Temporal Variability and Channel Dynamics

As is typical of channels draining this part of the tectonically active, rapidly eroding Coast Ranges, Cache Creek experiences tremendous seasonal and year-to-year variability in flow and sediment discharge. Occurring in a Mediterranean climate, extreme seasonal variability is well known: portions of the Creek can be dry for months, only to become a powerful torrent of turbulent water, sediment and debris during a significant flood event. Perhaps less well-appreciated, except during wet years such as 1995, the stream may experience only modest flows for years (conditions which human inhabitants can come to regard as "normal") only to experience tremendous flooding (and resultant channel adjustments; flood scour and deposition) during an infrequent flood. If the period of time typically between such events is of the order of once every 10 to 20 years, it is highly possible that planning and management decisions regarding the welfare and utilization of various creek resources can overlook the dramatic episodic nature of the creek. Year-to-year variability in runoff and peak flows in Cache Creek is addressed in Section 3.3.

Sediment transport is a power function of river discharge. Sediment load and the grain size distribution of sediment materials associated with that load can vary greatly with changing river discharge. Periodic transport of sediment (especially the sand and gravel fractions) largely shapes the form and dimensions of the channel relating to the channels stability or instability. In environments such as this, the form of the channel will largely reflect the influence of these infrequent large floods through channel changes that occur during the floods: shifts in channel location, incision of the bed, deposition of new point bars and accumulation of floodplain sediments. In the years following a large flood, the channel will adjust or recover from some of the flood effects, often by narrowing from the flood-widened form through establishment of vegetation and trapping of sediment, or by cutting down through recent flood deposits to form a new low flow channel. An important implication of this is that it may require one or more large floods for the channel to adjust to human alterations in the system. Effects of activities such as gravel extraction or channel confinement (due to levee construction or bridge building) may not be evident for years during dry periods, only to manifest themselves during and following high flows. Thus, the history of floods on a river like Cache Creek must be known in order to interpret conditions observed at any one time. River systems of this nature have a very long memory of past modifications and perturbations previously imposed, and may continue to make adjustments to those perturbations (natural or man-induced) for many years. It is important to recognize the history and processes involved in the evolution of present day channel conditions in order to forecast possible future conditions. These issues are discussed in Sections 3.4 and 3.5, which present discussions of the History of Human Influences and Historical Channel Geomorphology, respectively.

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