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# Floodplain Restoration Potential on the Lower Mokelumne River, California


**by**
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LOWER MOKELUMNE RIVER, CALIFORNIA


## SUMMARY

Upstream of the Sacramento-San Joaquin River Delta, the pre-disturbance Mokelumne River, CA contained anastomosing channels that converged in the low elevation Sacramento flood basin. Prior to anthropogenic disturbances, geomorphic processes and sediment deposits in the avulsion-inundation dominated zone near the confluence with the Cosumnes River and Dry Creek formed heterogeneous topography and physical habitat that supported ecological diversity in the dynamic floodplain. Erosion, sedimentation, avulsion, and flood processes promoted riparian vegetation establishment and succession, input of woody debris, and diversity of habitat for aquatic and terrestrial species. Upstream of the flood basin, the lower Mokelumne River floodplain width was highly variable, containing multiple channels in the wide reaches, and a single incised meandering channel in narrower reaches. Land use disturbances during the past 150 years along the Mokelumne River included gold mining, woody debris removal, dredging, agriculture, logging, and urbanization. Today, large dams regulate flow and levees that concentrate flow into fewer channels and minimize overbank flow onto surrounding agricultural fields and residential areas. These changes prompted hydrogeomorphic responses in the floodplain system including reduction in the number of channel segments, leveling of topography, changes in floodplain hydrology, and minimization of floodplain sedimentation. The ecological response to the simplification of habitat associated with changing landuses combined with introduction of exotic species was the loss of floodplain function. This paper provides a summary of the physical changes to floodplain habitat resulting from these landuses and addresses the potential for floodplain restoration on the lower Mokelumne River.

# INTRODUCTION

The dynamic geomorphic processes that create floodplains are critical in sustaining the ecological integrity of lowland floodplain rivers (Petts, 1996). In natural rivers, seasonal floods create an assemblage of floodplain landforms through geomorphic processes such as overbank sediment accretion and channel migration or avulsion. Habitat biodiversity is dependent on the dynamic nature of these landform assemblages (Ward et al., 1999; Ward and Trockner, 2001) and the loss connectivity between rivers and their floodplains resulting from anthropogenic changes is a major factor in habitat loss (Naiman and Decamps, 1990).

The Mokelumne River drains portions of the west side of the Sierra, and flows through the lowland Central Valley, CA, upstream of the San Francisco Bay-Delta. Cumulative effects of land uses altered the flow and sediment regime and the hydrogeomorphic processes that sustained historic floodplain ecosystems. The goal of this study is to provide a preliminary assessment of floodplain restoration potential on the Lower Mokelumne River downstream of Camanche Dam. The scope of this work includes: 1) an evaluation of historical data that document changes in hydrogeomorphic processes in the lower Mokelumne channel-floodplain system; 2) identification of past land uses that control and influence floodplain processes and morphology in the Mokelumne River watershed; and 3) a preliminary assessment of floodplain restoration potential. This qualitative assessment is a critical first step in understanding the main constraints and opportunities in future floodplain restoration planning in the lower Mokelumne River. In this paper, the use of the term "restoration" is not meant to imply full recovery to the pre-disturbance condition. Rather, it is intended to imply a trajectory toward sustainable physical processes consistent with the term "rehabilitation" (Federal Interagency Stream Restoration Working Group; 1998). Restoration to pre-disturbance conditions is not possible on the Mokelumne system because the constraints that altered the ecosystem still dominate hydrogeomorphic processes.

## Physical Requirements of a Functioning Floodplain

Dynamic processes that maintain ecosystem integrity on floodplains are driven by floods (Junk et al., 1989; Sparks, 1995). In lowland floodplain rivers such as the Mokelumne, channel-floodplain interactions during floods create dynamic floodplain morphology. The dominant geomorphic processes required for a functioning lowland river-floodplain system include flooding, avulsion, levee breaching, and floodplain erosion and sedimentation. Floods are the catalyst for numerous physical floodplain processes that create and maintain biodiversity. For example floods initiate sediment erosion and deposition processes, provide shallow water habitat, increase soil moisture, and recharge the alluvial aquifer. Reestablishment of flood pulsing is recognized as an essential component of floodplain wetland restoration (Middleton, 2002).

During overbank floods, erosion and sedimentation on floodplains create topography and diversity of physical habitat. At the nearby levee breach restoration experiment at the Cosumnes River Preserve, relatively high areas result from sediment deposition while low areas result from channel incision and scour over previously level agricultural fields (Florsheim and Mount, 2002). The diversity of physical habitat and the re-creation of a flood pulse in the floodplain restoration area promote restoration of aquatic and terrestrial species in the floodplain ecotone. Connectivity between channels and their floodplains is needed to drive successional stages and promote biodiversity (Ward et al., 1999).

# STUDY AREA

The Mokelumne River originates in the Sierra Nevada and has a drainage area of 1,728 $km^2$ at Woodbridge, CA (Figure 1). The main tributaries to the lower Mokelumne River are Dry Creek and the Cosumnes River that join the Mokelumne in the Central Valley upstream of the Sacramento-San Joaquin River Delta (Figure 1). Downstream of Woodbridge Dam, the Mokelumne River channel is at an elevation below about ~8.0 m NGVD and has a gradient of 0.0003 (Figure 2). Mokelumne River flow is regulated by a series of upstream dams and is tidally influenced in the confluence area near the Delta margin. The extent of the historic floodplain in the Mokelumne River is illustrated on the geologic map shown on Figure 3.

## Overview of Pre-Disturbance Mokelumne River Floodplain System

About 2.8 km of the Mokelumne River system upstream of the Cosumnes River confluence is situated in the Sacramento Flood Basin (Figure 4), the southern-most flood basin along the Sacramento River extending from the City of Sacramento to the Delta margin (Gilbert, 1917). The flood basin is bordered on the west by natural and engineered levees along the east side of the Sacramento River (Bryan, 1923, Wagner et al., 1981) and on the east and northwest by late-Pleistocene fans (Riverbank Formation) that emanate from the Sierra Nevada (Atwater and Marchand, 1980). The flood basins were seasonally dry or were dry for longer periods during droughts. In contrast, during floods, the flood basins were inundated with only levee tops emergent (Bryan, 1923). Prior to construction of dams and levees and regulation of flows on the Mokelumne River, winter rainfall, spring storms, and snowmelt caused overbank floods that inundated the Mokelumne River-floodplain system (Figure 5). Bryan (1923) noted that overbank flows from the perennial Mokelumne, Cosumnes, and American Rivers, created floodplain lakes and seasonal marshes that slowly drained through multiple channels within the flood basins. Figure 6 shows an example of an anastomosing river pattern in a photo of Dry Creek taken in 1937. Relatively coarser sand transported in anastomosing channel networks was suspended in flow and deposited in the levees or crevasse splays close to channels, while finer clay and silt was carried in suspension farther into the flood basins. Thus, near the confluence with the Cosumnes River and Dry Creek, the pre-disturbance Mokelumne River floodplain system included hydrologically connected multiple channels of the anastomosing river system, the intervening islands and flood basin sediment deposits, and adjacent floodplain lakes. Tracy Lake is an example of a floodplain lake that was once hydrologically connected to the Mokelumne River floodplain system. Further upstream, floodplain width narrowed and the channel meandered (Figure 7). The complex hydrogeomorphic system supported thriving aquatic and terrestrial fauna and an extensive riparian forest prior to denudation from anthropogenic activities (Dawdy, 1989; TBI, 1998).

## Land Use Changes

The Mokelumne River floodplain system experienced significant land use changes in the past two centuries. Figure 8 summarizes some of the main changes affecting floodplain inundation, sedimentation and erosion, and ecology. Rapid changes after European settlement included riparian vegetation clearing for fuel and for agriculture (TBI, 1998). Ditches drained floodplain wetlands and levee construction was initiated to minimize overbank flooding. Subsequent land use disturbances included grazing, logging, woody debris removal, dredging for flood control, denudation of riparian forests, agricultural leveling, and urbanization. Constraints such as levees and controlled flow releases from dams currently dominate the hydrogeomorphic character of the lower Mokelumne River. In upstream meandering reaches, channel sinuosity compared on 1910 and 1982 USGS maps show slight variation with increases in some reaches and decreases in others (HSU, 2002). More significant changes included a reduction in the number of shallow anastomosing channel segments and edge habitat, loss of channel-floodplain connectivity, removal of large woody debris and dredging of shoals from channels, mining disturbance, and the conversion of the riparian forest to agriculture.

### Snagging-Woody Debris Removal

Figure 9 shows plans for an early "snagging" project intended to remove woody debris and shoals to deepen the lower Mokelumne River for navigation and flood control. Woody debris was one of the main components of structural complexity on pre-disturbance floodplains in other lowland river systems (MacNally et al., 2002). Removal of large pieces of wood that retained sediment, and removal of shallow channel bars may have caused headcutting and incision in upstream reaches of the Mokelumne River prior to dam construction. Loss of wood on floodplains reduced floodplain complexity while increased channel capacity is likely to have reduced floodplain inundation frequency.

### Gold Mining and Aggregate Extraction

Placer, dredge, and hydraulic gold mining followed the 1849 gold rush in California. Gilbert (1917) reported that hydraulic mining in the Mokelumne River basin was limited, and that sedimentation damage to downstream floodplain farms occurred but was less severe than in other mining areas of the Sacramento watershed. Nevertheless, numerous mines affected the headwaters of the Mokelumne River and Dry Creek (Turner, 1892). These included: points near the headwaters of Dry Creek in Amador County; two miles south east of Jackson; Chili Gulch; Northwest and west of Camp Seco; East and Southeast of San Andreas; Muletown (north of Ione); seven miles west of Plymoth; two miles southwest of Campo Seco; Camanche; Irish Hill four miles northwest of Ione; and three miles northwest of Ione. Additionally, hydraulic mining occurred in gold bearing gravel east of Lockwood affecting a tributary to the Middle Fork Mokelumne; southwest of Forth Mountain affecting a tributary to the South Fork Mokelumne (Turner and Ransome, 1898); and one mile west of Lancha Plana in an abandoned channel (followed by road from Lancha Plana to Camanche; Turner, 1892). These mining disturbances generally increased sediment supply, reduced channel capacity and led to more frequent and higher flood stages that breached or overtopped natural levees that in turn lead to more frequent floodplain inundation. Significant dredging for gold in Mokelumne channel alluvium continued through the 1950's (Figure 10). These mining activities and other land uses led to an accelerated floodplain sedimentation rate and are responsible for a coarser reddish "anthropogenic layer" of sediment deposited over the pre-disturbance fine grained blue-gray basin sediment deposit on the floodplain near the Mokelumne-Cosumnes River confluence (Atwater and Marchand, 1980; Florsheim and Mount, in press). Subsequent aggregate extraction in the Mokelumne River left numerous pits adjacent to the channel downstream of Camanche Dam (Figure 11).

## Levees

Levee construction on the Mokelumne system began in 1907 and fixed the multiple channels at the Harvey Tract in the area of the confluence of the Mokelumne River, Cosumnes River, and Dry Creek into their present positions (Figure 12). Progressive construction of levees following the turn of the century concentrated flow from multiple channels to a single channel and limited river-floodplain connectivity and floodplain sedimentation (Figure 13). Construction of levees generally prevented floodplain sedimentation except during floods that overtopped the levees or during accidental breaches. Completion of the levee system by the 1920's changed the hydrogeomorphology of the lowland flood basin by reducing floodplain flood stages and inundation duration. Levees limited transport of sediment, water and nutrients from the channel onto the adjacent floodplain, except during accidental breaches.

## Dams

Anthropogenic disturbances in the Mokelumne River and in its tributaries Dry Creek and the Cosumnes River, during the century following the 1849 gold rush in California, led to rapid alteration of the flood basin hydrosystem. Construction of dams on the Mokelumne River, including Pardee (1929), Salt Springs (1931), and Camanche (1963), altered downstream sediment supply and flow characteristics. The dams added to changes initiated by levee construction and further altered the hydrogeomorphology of the lowland flood basin by reducing floodplain inundation stage and duration.

Reductions in sediment supply downstream of dams commonly lead to channel incision and widening (Church, 1995; Ligon et al., 1995; Williams and Wolman, 1984; Petts, 1984). Dams on the Mokelumne system trap sediment from upstream reaches and limit supply downstream of Camanche Dam except from sources including: 1) channel bed incision; 2) channel bank erosion; and 3) fine sediment from adjacent land surface erosion. Sediment supply from these sources has not yet been quantified but influence the potential for floodplain restoration in the following ways. First, cycles of channel incision and widening, described on other systems by Schumm (1999), enlarges channel capacity and leads to reduced overbank flow onto floodplains. Second, adequate sediment supply is critical to both construct floodplain sediment assemblages and to create and modify floodplain topography, the physical structure of floodplain habitat.

The effects of dams usually diminish with distance downstream as tributary input augments sediment supply (Ward and Stanford, 1995; Stanford et al, 1996; Stanford and Ward, 2001). Downstream of Camanche Dam, the Murphy Creek and Dry Creek tributaries contribute flow and sediment to the Mokelumne River. However, Murphy Creek is likely to only supply fine-grained sediment because bedload is currently trapped behind multiple small dams on that system. The next downstream tributary of significant size to join the Mokelumne River is Dry Creek, however two culverts through the Mokelumne River levee currently control the confluence of Dry Creek and the Mokelumne River. High magnitude flows capable of transporting sediment on Dry Creek are diverted through Grizzly Slough to the Cosumnes River. Further work to determine the fate of sediment transported in Dry Creek through this infrastructure at the confluence of these systems is warranted. Flow and sediment contributed from the undammed Cosumnes River tributary influence the lower Mokelumne system (Simpson, 1972).

Geomorphic changes in the Mokelumne River related to altered sediment supply were compounded by development of the basin for water supply. Flow reduction in Mokelumne River began in 1800's in order to supply water to hydraulic mining operations (CALFED ERP, 2001). Construction of dams on the Mokelumne River, including Pardee (1929), Salt Springs (1931), and Camanche (1963), altered flow magnitude, frequency, duration, timing, and rates of change in channels and on the floodplain (Figure 14). In the regulated Mokelumne River, the hydrograph of flows upstream and downstream of Camanche Dam show alteration in magnitude of peak flows, however the downstream-most portion of the Mokelumne River is affected by a backwater effect caused by floods in the unregulated Cosumnes River as well as by high tides in the San Francisco Bay-Delta. The lower Mokelumne River flooded during storm events in 1950, 1955, and 1958 and while flooding has been greatly reduced since the construction of Camanche Dam in 1964, flooding still occurs downstream of the dam due to levee failure, poor levee maintenance, and the overall limitation in channel capacity (USCOE, comprehensive plan) in the downstream-most reaches. For example, some areas adjacent to the Mokelumne River flooded in 1986, 1995, and 1997. While flooding poses a hazard for some land uses, it presents a valuable opportunity for restoration planning.

## Floodplain Development: Agriculture and Urbanization

Agriculture is the dominant land use in the floodplain adjacent to the lowland Mokelumne River between Camanche Dam and the Cosumnes River confluence. However, urbanization on the floodplain creates the greatest constraint for floodplain restoration. For example, in Lodi, recent residential development on the floodplain on the south side of the river prevents release of overbank flows from Camanche Dam, as overbank flow on the floodplain would inundate the developed floodplain (Figure 15). The discharge associated with flooding in this residential area is under169.8m$^3$/s (6,000 ft$^3$/s; EBMUD, Personal Communication, 2000). Thus, in the short-term, the current design release flow from Camanche Dam (141.5m$^3$/s; 5,000 ft$^3$/s) is not likely to be increased to restore higher flow magnitudes that inundate the floodplain, at least in the short term.

# PRELIMINARY ASSESSMENT OF FLOODPLAIN RESTORATION POTENTIAL

## Intentional Levee Breaches or Setbacks

During the first decade after Camanche Dam was constructed, USGS surveyed 112 cross sections in the lower Mokelumne River and modeled water surface elevations for a series of small floods using a one-dimensional, steady flow model (Simpson, 1972). Results of the USGS study illustrated areas of potential overbank flow during releases ranging from 169.8 m$^3$/s (6,000 ft$^3$/s) to 84.9 m$^3$/s (3,000 ft$^3$/s) (Figure 16). Although the channel geometry data utilized in this study were surveyed in 1970, results illustrate one method to determine areas with floodplain restoration potential. For example, data illustrated in Figure 16 may be used conceptually to illustrate flows required for floodplain inundation as greater than 84.9 m$^3$/s (3,000 ft$^3$/s). When water surface elevations are higher than the elevation of the top of bank, overbank flow occurs—one of the requirements for floodplain restoration. As bank height decreases relative to the thalweg elevation in the downstream direction, varying areas of floodplain apparently would be inundated by flows less than 69.8 m$^3$/s (6,000 ft$^3$/s), if levees were intentionally breached or set back.

These data suggest that there is the potential for a range of relatively small floods to inundate portions of the historical floodplain if levees were modified, as on the adjacent Cosumnes River. This evaluation of data from the 1970's should be considered qualitative, as updated channel cross section surveys, and an unsteady hydraulic model that incorporates sediment supply and transport is needed.

The ability of the Mokelumne River to create and maintain a restored floodplain would depend on the range of flood magnitudes, frequency, duration, rate of change and timing of flows released from upstream dams as described by Poff et al. (1997). However, sediment supply necessary to erode and deposit sediment outside the active channel may be a limiting factor on the Mokelumne due to the presence of large dams that trap sediment from the upstream basin. Re-surveys of the USGS cross sections could help evaluate these changes, however, no subsequent surveys have re-occupied the cross sections surveyed in the 1970's (although many of the sections could be re-located; Simpson, personal communication, 2001). Additionally, available surveys at gaging stations (EBMUD, USGS) have not been analyzed to assess hydrogeomorphic change. Analyses of these data are critical in assessment of historic changes and trends needed to develop floodplain management or restoration plans for the lower Mokelumne River.

The greatest potential for floodplain restoration in the lower Mokelumne River exists in the downstream-most reach of the system, between the confluence of the Mokelumne River with its tributaries the Cosumnes River and Dry Creek upstream to Tracy Lake. This area includes Grizzly and Bear Sloughs and the intervening former floodplain. In many locations along this reach, it appears that breaching or setting back engineered levees would result in overbank flow under the current regulated hydrologic regime. However, floodplain restoration designs in this lowland reach of the Mokelumne River system will be dependent on acquisition and analysis of updated floodplain topography and channel bathymetry data needed to quantify historical changes and to construct an accurate flood inundation model.

## Other Opportunities to Rehabilitate Floodplains

Other opportunities to rehabilitate floodplain processes in the lower Mokelumne include: 1) reconnecting Tracy Lake to the Mokelumne system; 2) obtaining "erosion easements" that accommodate lateral migration of the channel downstream of Camanche Dam; and 3) re-configuring streamside areas such as excavation of side channels in existing low benches, or filling of gravel pits that could create areas with elevations in quasi-equilibrium with the post-dam hydrologic regime floodplain. Future work is warranted to understand the relation of such created features to the elevations of small new inset floodplains forming in some locations downstream of Camanche Dam.

# CONCLUSIONS

Understanding the coupled geomorphic and ecological response to land use disturbance is critical in developing management strategies for restoring or rehabilitating floodplain habitat. Prior to anthropogenic disturbances, geomorphic processes and sediment deposits in the avulsion-inundation dominated confluence zone formed heterogeneous topography and physical habitat that supported ecological diversity in the dynamic floodplain ecotone. Erosion, sedimentation, avulsion, and flood processes promoted riparian vegetation establishment and succession, input of woody debris, and diversity of habitat for aquatic biota in this pre-disturbance system. Anthropogenic disturbances prompted geomorphic responses including reduction in the number of channel segments, changes in hydrology, leveling of topography, and minimization of floodplain sedimentation and inundation. The ecological response to this simplification of habitat combined with introduction of exotic species was the loss of ecosystem function in the Mokelumne River Floodplain.

Floodplain restoration potential on the lower Mokelumne River is highest in the downstream-most reach of the river near its confluence with the Cosumnes River and Dry Creek. In this area, floodplain elevations appear to be low relative to flood inundation levels during potential releases from Camanche Dam. However this must be verified by updated surveys and analyses that quantify the relationship between flood inundation stage, bank height and floodplain topography, and the sediment budget. Several factors are essential in order to develop a floodplain restoration and monitoring design for the lowland Mokelumne River. First, a systematic approach to repetitively collected cross section data is necessary to evaluate historical changes and assess trends in channel geometry. Second, quantification of the current sediment supply is necessary to evaluate the potential for restoration of floodplain processes such as deposition and erosion. Finally, updated flow modeling that considers the importance of the flood pulse and hydrologic characteristics such as magnitude, frequency, duration, rate of change and timing in floodplain restoration areas should be developed over a range of flow magnitudes to design sustainable floodplain habitat.

Other opportunities to rehabilitate or improve floodplain habitat include hydrologically re-connecting Tracy Lake to the Mokelumne River, obtaining stream side erosion easements that allow some lateral migration of the river channel and connectivity with the channel, and re-configuration of stream side areas (e.g. dredged or excavated areas) to elevations inundated by the post-dam hydrologic regime. These options could maximize habitat but would not restore or sustain floodplain function on the regulated Mokelumne River system.

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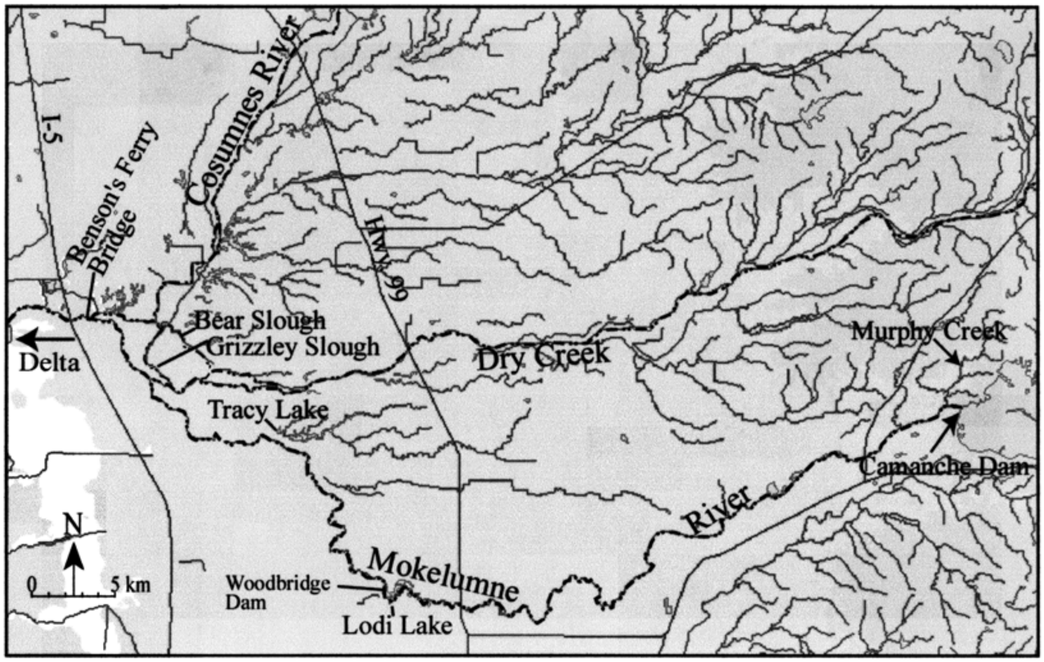


Figure 1. Location of lower Mokelumne River.

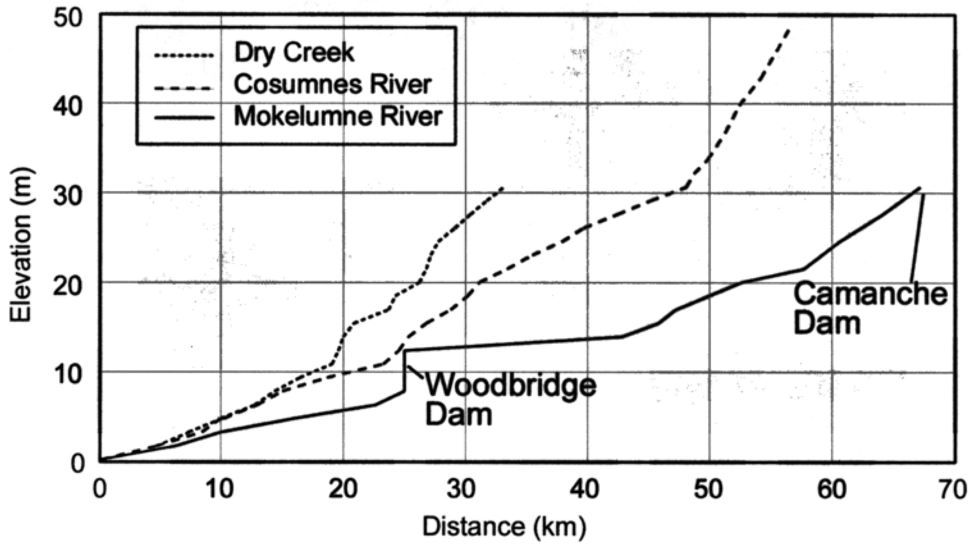


Figure 2. Longitudinal profile of the lower Mokelumne River and its tributaries Dry Creek and the Cosumnes River.

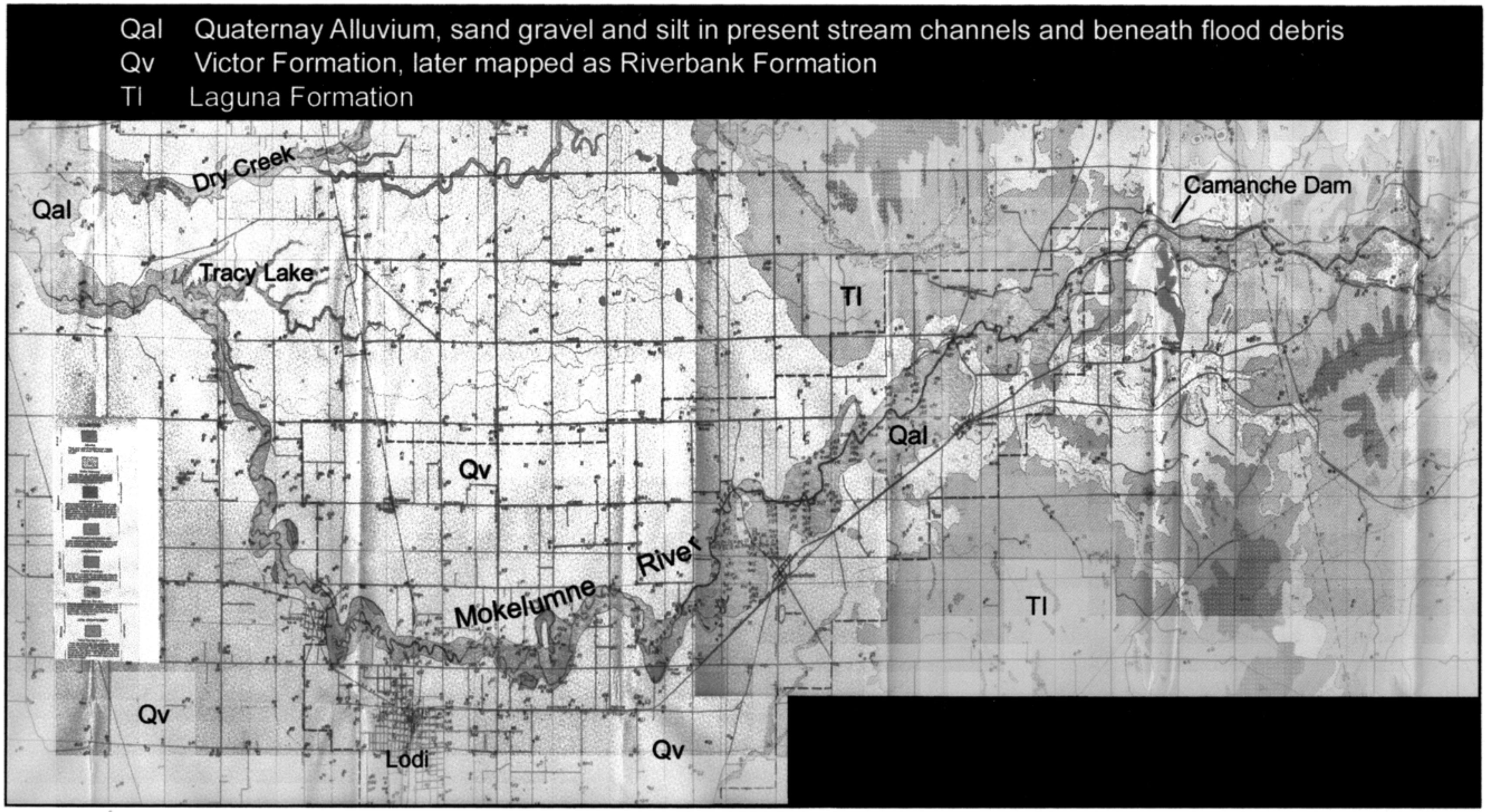


Figure 3. 1939 Geologic Map Illustrating Mokelumne River Floodplain (source: HSU, 2002).

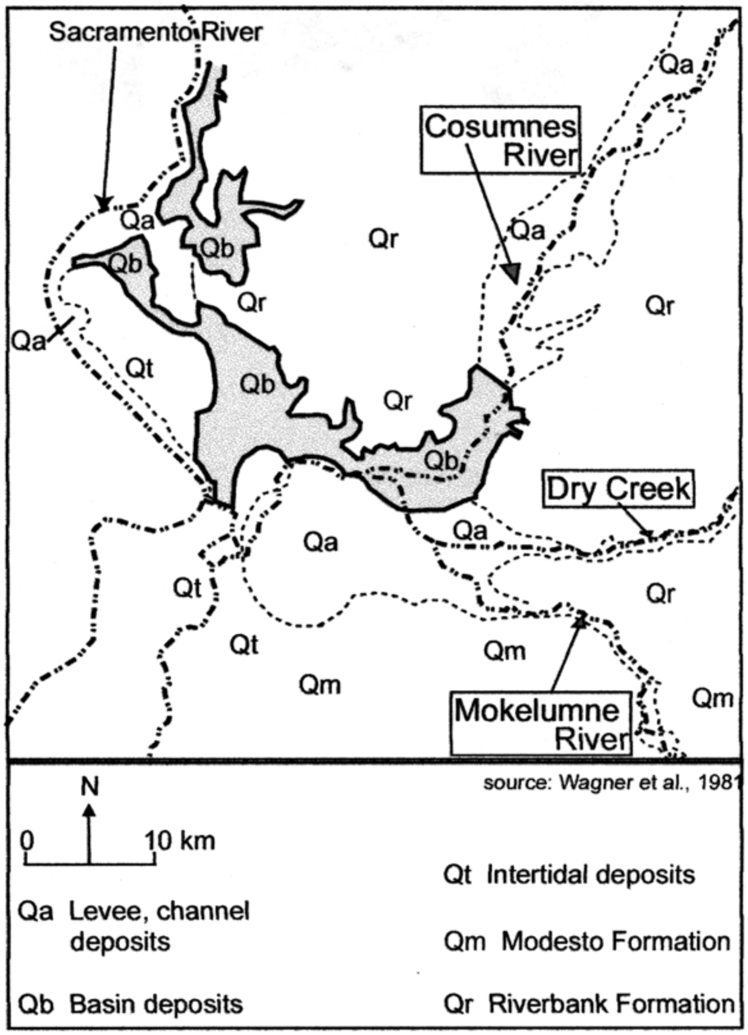


Figure 4. Geologic map showing the basin deposit.

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LOOKING SOUTH TOWARD THE POINT OF CONFLUENCE OF DRY CREEK AND THE COSUMNES AND MOKELUMNE RIVERS SHOWING THE FLOODED AREA NORTH OF THE MOKELUMNE RIVER AND EAST OF THE WESTERN PACIFIC RAILROAD GRADE. THE COMBINED FLOWS OF THE THREE STREAMS TOTALED 41,000 SECOND FEET AT THE BENSON FERRY BRIDGE WHERE THE GAGE READING WAS 15.5 FEET THE HIGHEST EVER RECORDED. THE CONTROL EFFECTED AT PARDEE RESERVOIR DURING THIS EXCESSIVE RUN-OFF PERIOD SAVED THOUSANDS OF ACRES OF RECLAIMED DELTA LANDS FROM BEING FLOODED.

April 1,1940

Figure 5. Flooded Mokelumne River-Dry Creek-Cosumnes River confluence in 1940.

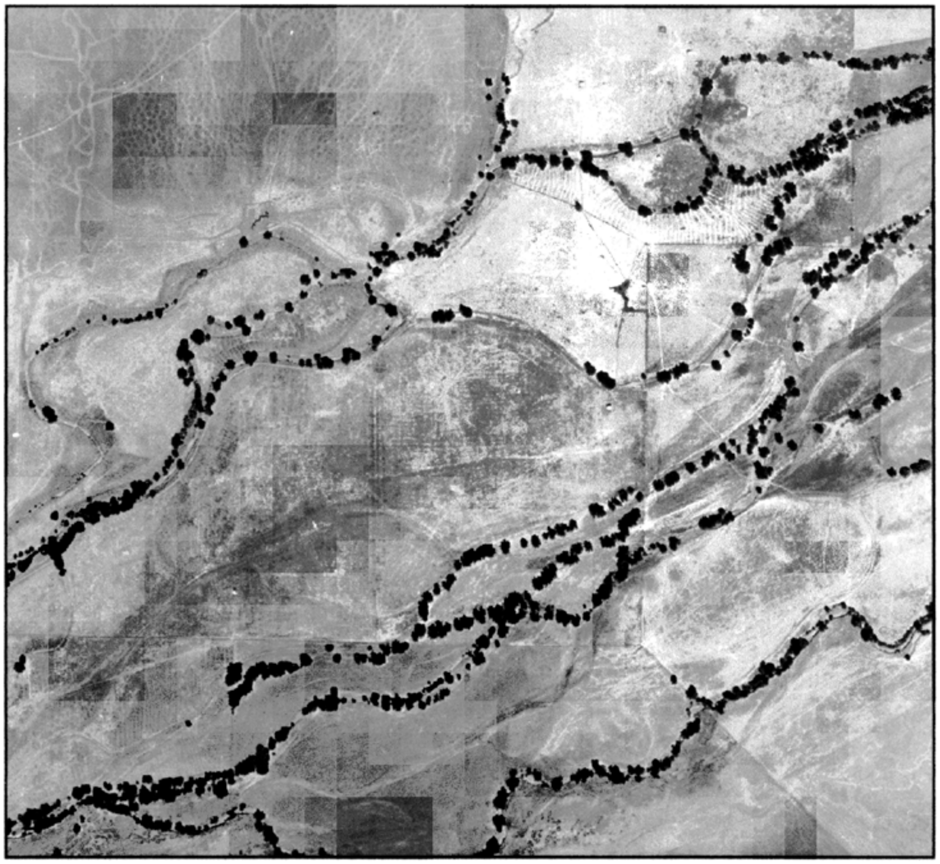

Figure 6. Anastomosing channel segments, Dry Creek 1937.

Figure 7. Meandering channel, Mokelumne River 1935.

| Date | Land Use Change | Effect on Floodplain Sedimentation |
|---|---|---|
| 1849 | Use of wood for fuel, initiation of agricultural clearing | Loss of riparian forests |
| 1850 | Arkansas Act--land reclamation from floodplain marshes and riparian forests to agricultural fields | Draining wetlands, filling secondary and abandoned channels and sloughs, leveling floodplain topography |
| 1849<br>1853 to 1884<br><br><br>1950's | Placer mining for gold began<br>Hydraulic mining continued until declared illegal by Sawyer decision<br>Dredging alluvial deposits | Excessive sedimentation raised bed elevation in Sacramento system; caused backwater and increased inundation duration in flood basins |
| 1907, 1908 | Initiation of levee construction and channelization | Concentration of flow from multiple channels into fewer channels; limitation of river-floodplain connectivity and reduced floodplain sedimentation |
| 1908 to present | Continued levee construction and land conversion to agriculture | Progressive limitation of river-floodplain connectivity; reduced floodplain sedimentation except during accidental levee breaches |
| 1929, 1931, 1963 | Construction of Salt Springs, Pardee, and Camanche Dams on the Mokelumne River | Alteration of flow magnitude, frequency, duration, timing, and rates of change in channels and floodplain |

Figure 8. Land use changes and effects on floodplain sedimentation.

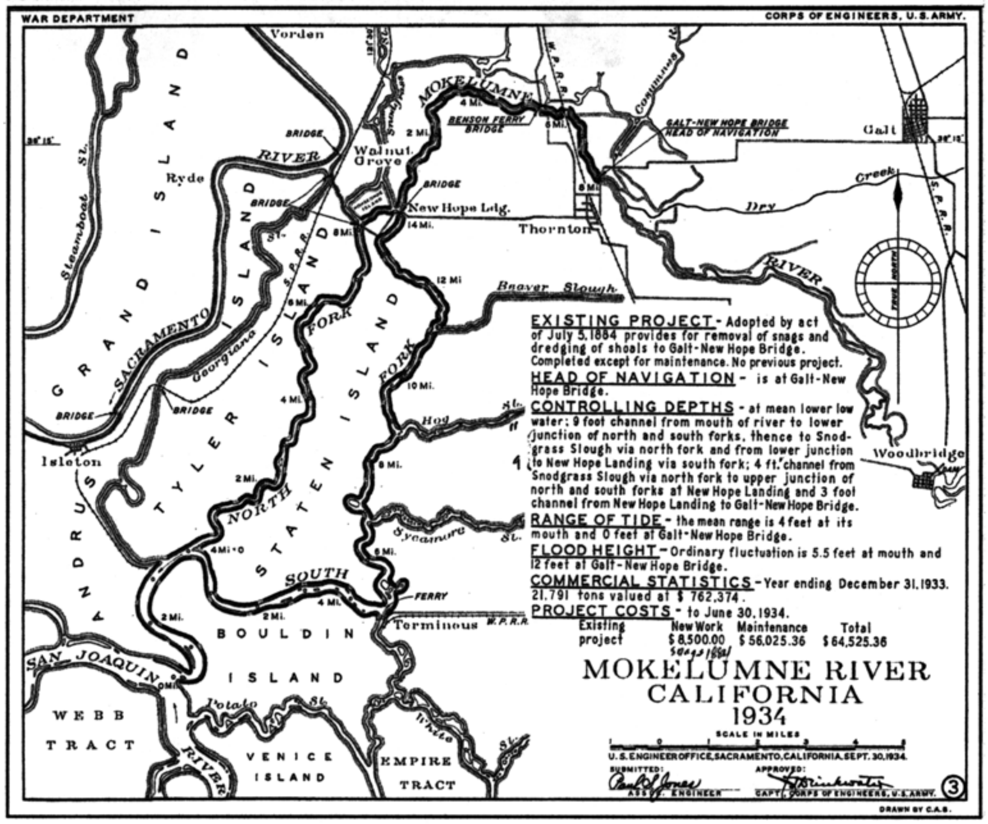


Figure 9. 1934 Engineering project plan to remove woody debris and shoals.

Figure 10. Dredging in the Mokelumne River Channel prior to construction of Camanche Dam.

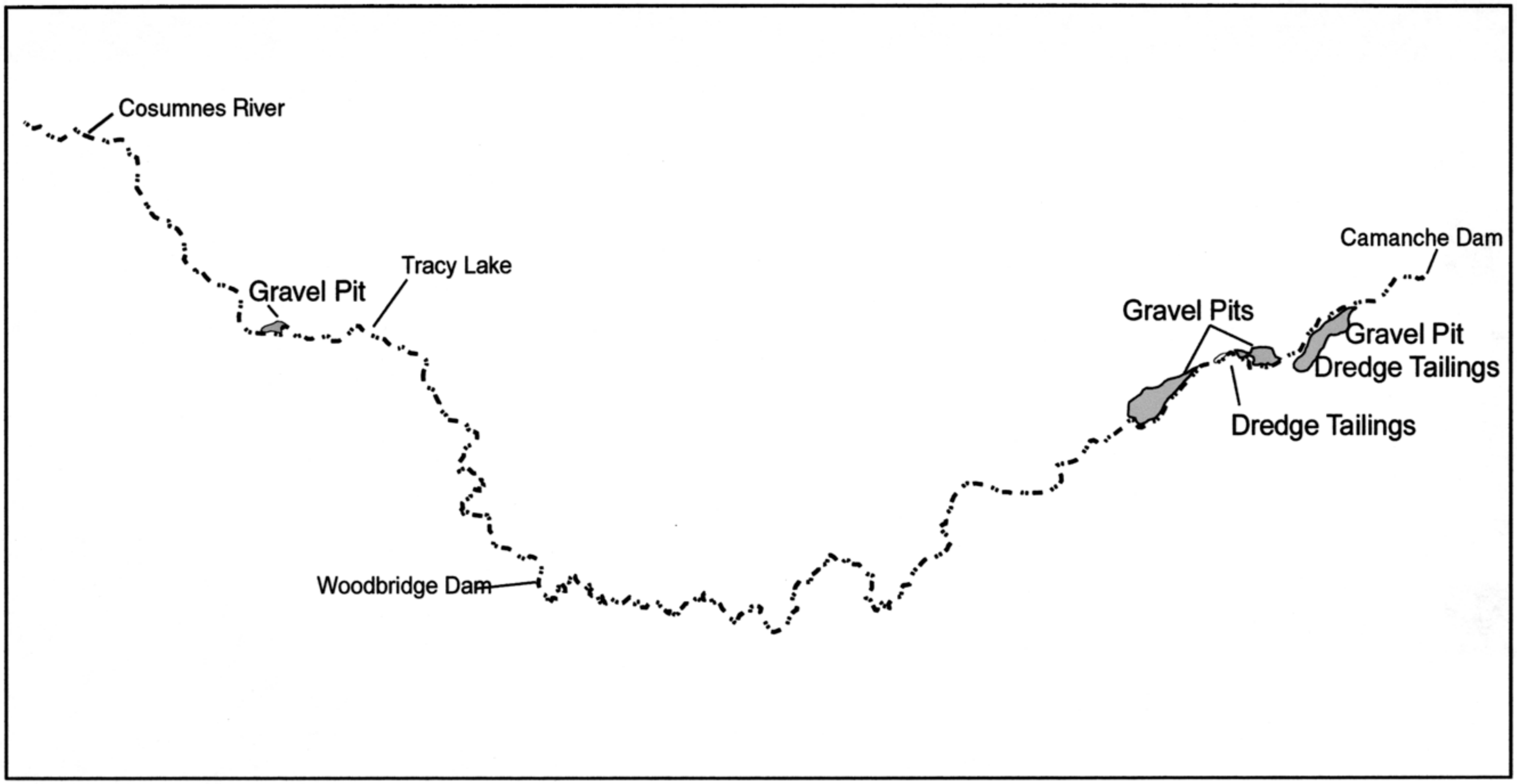


Figure 11. Location of gravel pits and dredge tailing areas adjacent to Lower Mokelumne River.

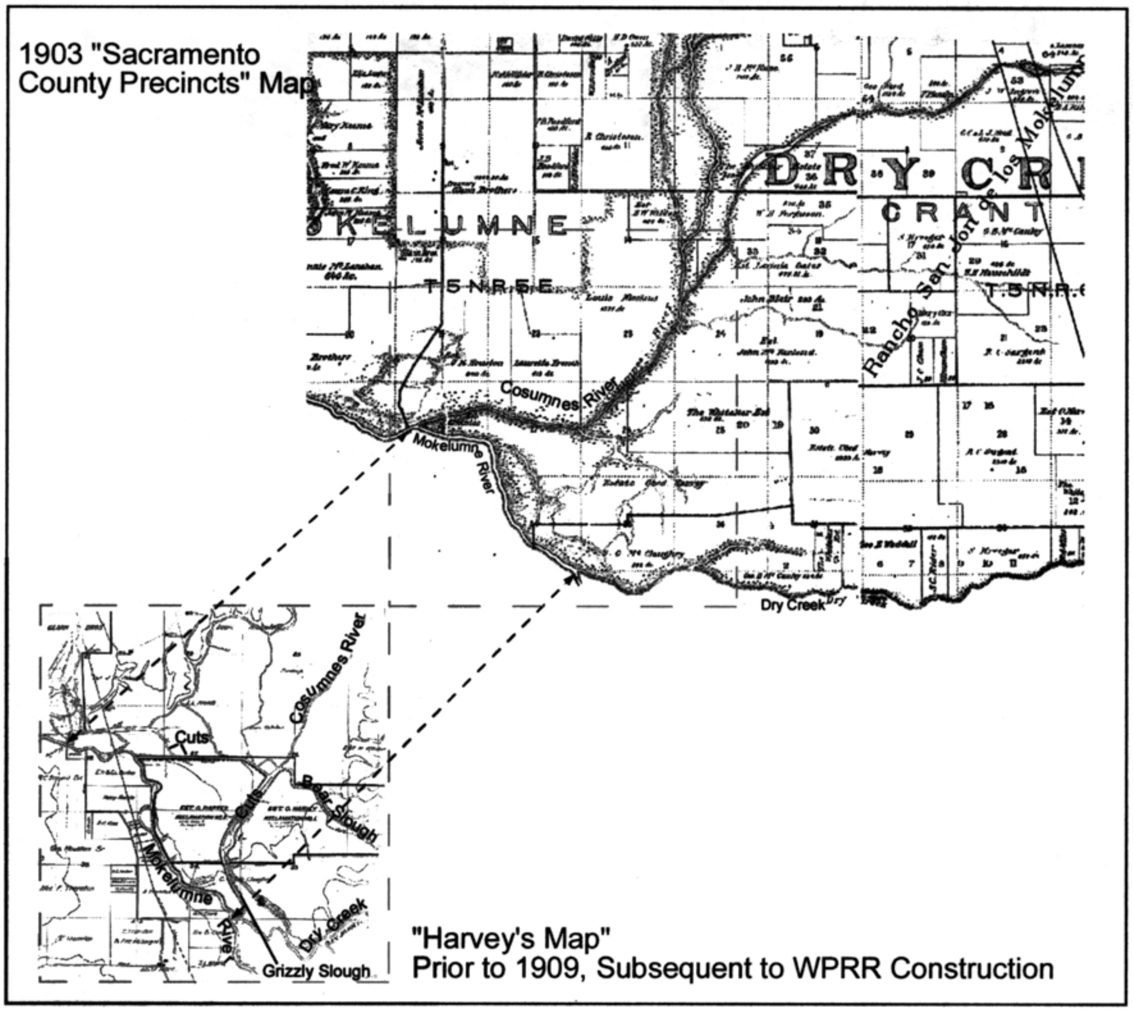


Figure 12. Levee construction at the Harvey Tract near the confluence of the Mokelumne River, Dry Creek, and the Cosumnes River.

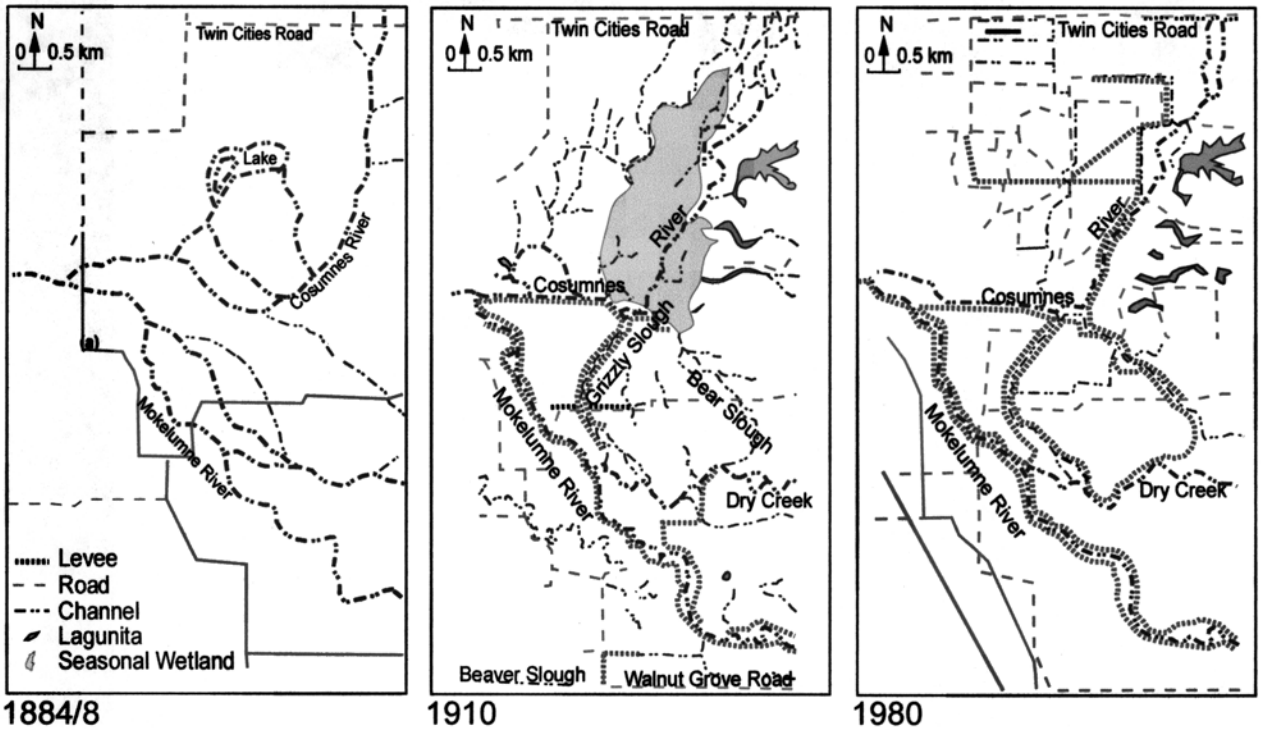


Figure 13. Maps showing changes in river channel planform at the confluence of the Mokelumne River, Dry Creek, and the Cosumnes River.

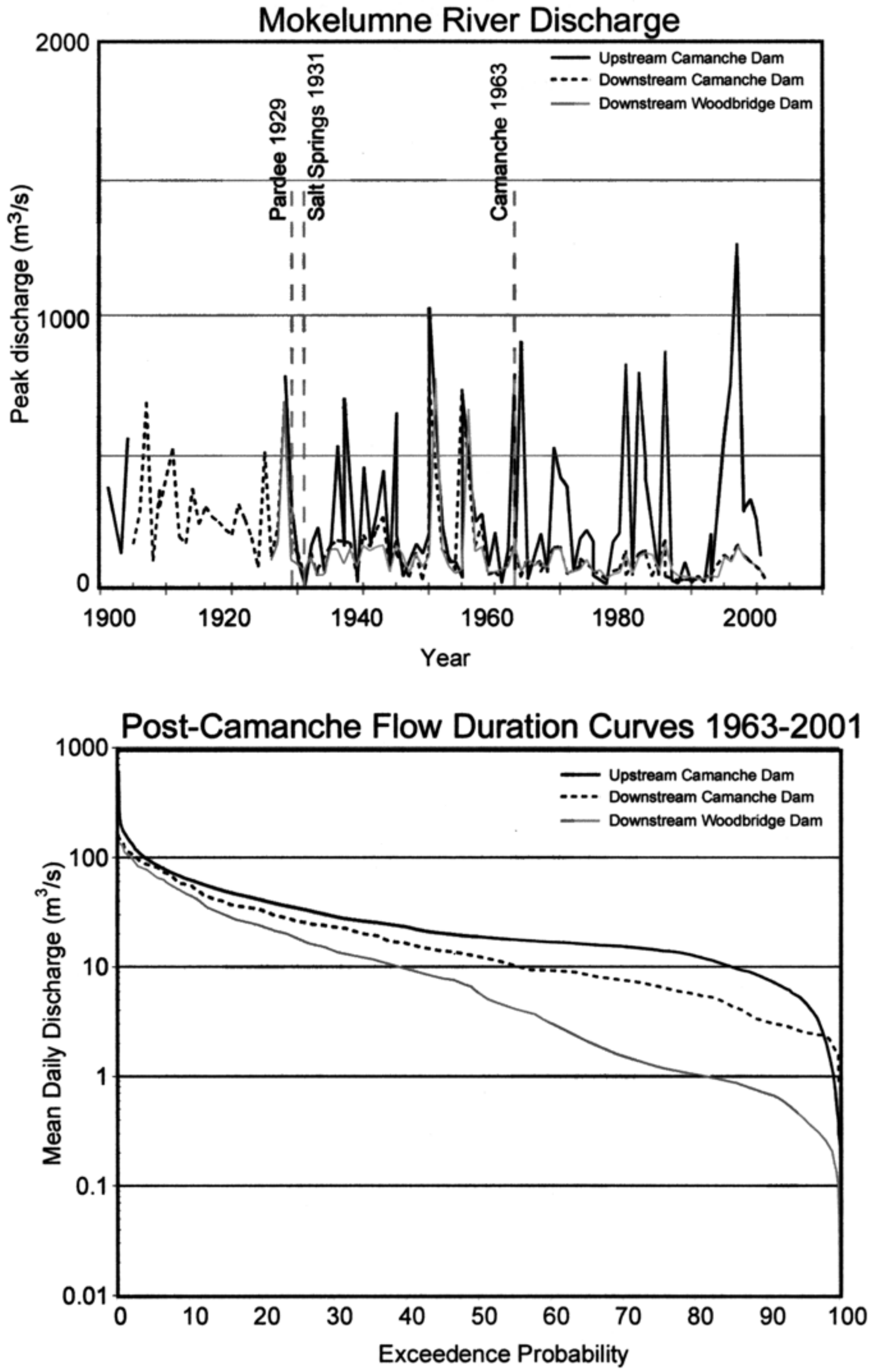


Figure 14. Mokelumne River discharge from 1905 to the present and post-Camanche Dam flow duration curves.

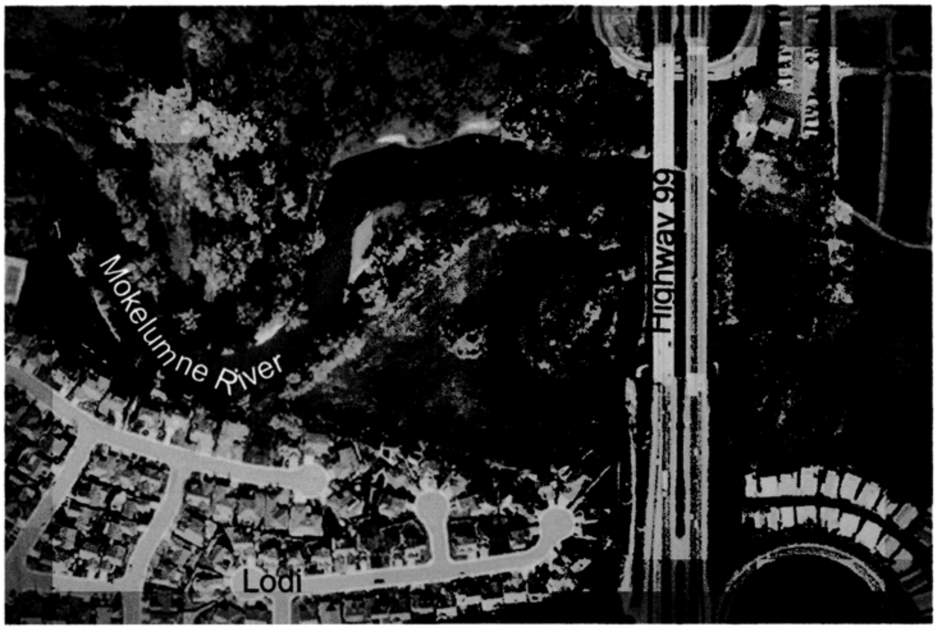


Figure 15. Aerial photograph Lodi, 1995.

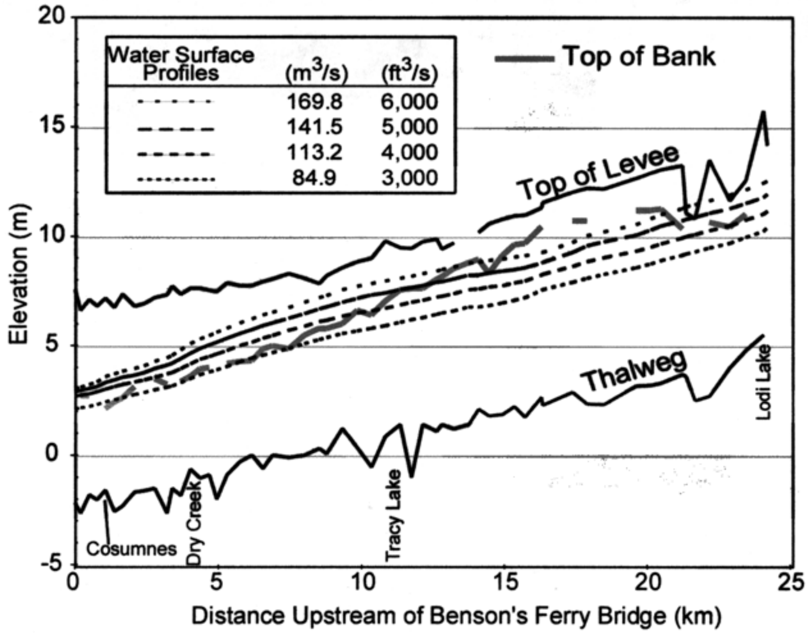


Figure 16. Relation of modeled flood water surface elevations to top of bank--an indication of floodplain inundation.