Tulare Lake Basin
Hydrology and Hydrography:
A Summary of the Movement of Water and Aquatic Species

12 April 2007

Prepared for:
U.S. Environmental Protection Agency
Document Number 909R07002

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

CONTENTS

Tulare Lake Basin Hydrology and Hydrography: A Summary of the Movement of Water and Aquatic Species

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

LIST OF APPENDICES

1.0 INTRODUCTION

This report provides a summary of the historic and current hydrology of the Tulare Lake Basin (Basin) and describes past, present and potential future movement of water out of the Basin, and potential movement of biological organisms and toxicants within and outside of the Basin. This study was initiated at the request of the U.S. Environmental Protection Agency (USEPA).

The first part of the report describes the natural and man-made hydrography and hydrology in the Tulare Lake Basin. The geographic focus is on the lowland portion of the Basin (the lowlands) below the low elevation reservoirs or approximately the 500-ft (152-m) elevation contour. Detailed maps were prepared to help illustrate the surface water pathways within the lowland part of the Basin as well as the movement of water into and out of the Basin. Daily and annual hydrological information is also presented, but flow analyses are limited due to time, budget, and constraints obtaining hydrological data. A table of primary hydrologic connections is also provided as a summary.

The second portion of the report describes the fish populations and aquatic habitats in the Tulare Lake Basin, and the potential for movement of organisms (both swimming and non-swimming) to move within the Basin and to move outside of the Basin. The evaluation of white bass during and after the high runoff of 1983 is described since it appears to represent a "worst case scenario" for the movement of aquatic species within the Basin and potential transport outside the Basin. Potential movement pathways for both swimming and non-swimming organisms to move outside of the Basin are identified for a range of hydrologic conditions.

Information presented in this report is derived from many published and unpublished (archival, gray literature, and internet) reports, maps, and data compilations. Primary references, including hydrological data, were prepared by the U.S. Army Corps of Engineers (USACOE), the U.S. Bureau of Reclamation (USBR), California Department of Water Resources (CDWR), California Department of Fish and Game (CDFG), Friant Water Users Association (FWUA), Kern County Water Agency (KCWA), Tulare Lake Basin Water Storage District (TLBWSD), and the individual river watermasters. A field visit was conducted on June 29 (accompanied by USBR and FWUA personnel) and June 30 (accompanied by CDFG personnel), 2006 to evaluate some of the hydrographic features and potential pathways for aquatic organisms to move within and outside the Basin. Potential pathways and hydrographic connections evaluated during this field visit are provided in Appendix 1. Agency personnel provided information on water movement and aquatic species issues and were helpful in developing some of the scenarios described in this document. Several attempts were made to obtain information and conduct a site visit with knowledgeable persons in the Kings River, Kaweah River, Tule River, Kern River and the Tulare Lakebed regions including the watermasters offices of the four rivers. However, these attempts were unsuccessful.

2.0 TULARE LAKE BASIN GEOGRAPHY

The Tulare Lake Basin encompasses about 16,400 square miles – about 10% of California's land area – and is one of 10 hydrologic regions recognized by the State for water planning purposes (see Map 1: *Site and Vicinity*).[1] The Basin is part of the Great Central Valley geographic province and the lowland area is included as part of the San Joaquin Valley, usually referred to as the southern San Joaquin Valley.[2] The lowland area encompasses about 8,400 square miles and is defined for this report as the region below 500 ft in elevation. The Kings River watershed and service area is included in the Tulare Lake Basin hydrologic unit because the majority of its runoff flows south toward Tulare Lake, though some Kings River water periodically flows into the San Joaquin River. Panoche Creek is not included in this report's definition of Tulare Lake Basin since most of its runoff is directed northeasterly into the San Joaquin River.[3]

---

[1] The basin boundary used in this report is the USGS HUC boundary and does not include the Panoche Creek drainage. The area encompassed by the basin listed here was measured using GIS technology. The DWR Water Plan (Bulletin 160) March 2004 draft states the area is 17,033 sq. miles but includes the Panoche Creek drainage; Bulletin160-93 states the area as 16,520 sq miles; the USACOE office report (Johnson, W., 2004.) states it is 14,000 square miles.

[2] Bookman-Edmonston Engineering, 1972.

[3] In this report the northern boundary of the Basin is defined by the San Joaquin River, Mendota Pool and the southern boundary of the Panoche Creek watershed. The Regional Water Quality Control Board Basin Plans include the Little Panoche Creek watershed (north of Panoche Creek) within the Tulare Lake Basin although recent staff reports note the error of including the Little Panoche drainage within the basin boundary, as Little Panoche Creek drains to the San Joaquin River (Regional Water Quality Control Board, Central Valley Region, September 2004.)

Elevations in the Basin range from a low of about 175 ft (53 m) above mean sea level (MSL)[4] in the Tulare Lake bottom to the 14,496-ft (4,418 m) summit of Mt. Whitney, the highest point in California. Lake and stream deposits cover much of the Lowlands, and create a flat, smooth land surface with very low gradients. In the Tulare Lakebed, minimal gradients allow bi-directional movement of canal water. Peripheral lowland areas are highly dissected by small drainages, although these drainages seldom carry water.[5] Along the east side of the Basin, the Sierra Nevada mountains rise steeply, with the highest peaks over 14,000 ft (4,267 m), and in the south, the Tehachapi Mountains rise to over 8,000 ft (2,438 m). The Coast Range flanks the west side of the Basin, with the highest peaks rising to about 5,000 ft (1,524 m).

3.0 HISTORICAL HYDROGRAPHY AND HYDROLOGY

Prior to European settlement, river-floodplain systems occupied large portions of the Sacramento, San Joaquin and Tulare Lake Basins (see Map 2: *San Joaquin Valley Historical Surface Hydrography*). Seasonal inundations from the rivers created vast areas of tule-dominated marshes and wooded wetlands that early surveyors mapped as overflow land. These marshes and wooded wetlands covered approximately 1.4 million acres including more than half a million acres in the tidally influenced Sacramento-San Joaquin Delta[6] and over 400,000 acres in the Tulare Lake Basin.[7]

Historically, river runoff in the Tulare Lake Basin collected in terminal lakes on the basin floor. The interior drainage was created primarily by tectonic sinking and to a lesser extent by the damming effect of valley-crossing alluvial fans.[8] The terminal lakes complex fluctuated in size from a few square miles during extended dry periods, to over 800 square miles in wet years, and supported an extensive, fringing tule marsh.[9]

---

[4] All of the elevations provided in this document are referenced to the current mean sea level (MSL) unless otherwise noted.
[5] Hydrographic maps convey the impression that these peripheral lowland areas have a dense drainage network but they carry water only during rare high volume rainfall events.
[6] The Bay Institute, 1998. Hall, W. H., 1887.
[7] Map 2 does not depict the riparian forestland and oak woodland that encompassed another one million acres along the main-stems and tributaries.
[8] Davis, 1998a.
Davis, G. H., J. H. Green, F. H. Olmsted and D.W. Brown, 1959. Many writers mention only the alluvial dam theory, which is not consistent with the sedimentary record.
[9] Grunsky, C. E. 1898a. Hall, W. H., 1886b., Sheet 4.

3.1 Tulare Lake Basin Terminal Lakes

3.1.1 Historical Hydrography

Tulare Lake, by far the largest of the Basin's terminal lakes, received runoff from several rivers, including the South Fork Kings, Kaweah, Tule and Kern Rivers.[10] Smaller east-side streams such as Deer and Poso Creeks and the White River likely reached the lake only in wet periods. Surface runoff from the Coast Range reaching the lake was rare, and usually occurred only after heavy winter rains. Tulare Lake was the largest freshwater lake west of the Mississippi River[11] and the second largest freshwater lake in the United States based on surface area.[12] Tulare Lake was estimated to encompass 790 square miles at its highest overflow level of 216 ft (66 m), recorded in 1862 and 1868. The area of Tulare Lake as shown on Map 2 is about 700 square miles, its area when the water level was at an elevation of about 212.5 ft (65 m).[13] The lake was very shallow and annual fluctuations, typically 3 or 4 ft (0.9 to 1.2 m) in normal years or 5 to 10 ft (1.5 to 3 m) in wet years, could expose or submerge 100 square miles of land or more.[14] The boundaries of Tulare Lake were ill defined and changeable due to the low gradients in the Basin; strong winds could move the lake boundary several miles.[15]

Tulare Lake had no natural outlet when the lake level was below 207 ft (63 m). At lake levels above 207 ft, water in Tulare Lake could flow northward into the San Joaquin River Basin. At this elevation, water flowed into Summit Lake and over the lowest point in the ridge created by the alluvial fans of the Kings River and Los Gatos Creek. The lowest point in this ridge was at least 30 ft (9 m) above the low point of the Tulare Lake Basin.[16] A dense tule marsh complex

---

[10] Under natural conditions the Tule River and the Kaweah River distributaries may not have flowed year-round all the way to down to Tulare Lake in drier years. Early flow measurements and descriptions (see pages 14) suggest perennial flow but these were made upstream of where the rivers entered Tulare Lake. The Kern River inflow to Tulare Lake was likely a wetter year phenomena either from one of its distributaries or when Buena Vista Lake overflowed.
[11] San Joaquin Valley Drainage Program (SJVDP), 1990.
[12] Warner, R. F. and K. Hendrix, 1985. San Joaquin Valley Drainage Program (SJVDP), 1990.
[13] Area-elevation table compiled by Harding 1949 and reported in United States Bureau of Reclamation, 1970.
[14] USBR 1970 reproduces the lake level fluctuations from 1850 to 1969.
[15] Mayfield, Thomas Jefferson, 1993.
[16] San Joaquin Valley Drainage Program (SJVDP), 1990. USBR 1970. The elevations given in the literature about Tulare Lake levels and its overflow must be treated carefully and do not necessarily represent what the elevations would be today with current sea level reference datum and given the land subsidence that has occurred in the area. Some of the elevations are derived from surveys done 100 or more years ago and the sea level datum is usually not

impeded substantial northward outflow to the San Joaquin Basin until the elevation was close to 210 ft (64 m).[17]

The San Joaquin and Tulare Lake Basins periodically exchanged surface waters through a complex of slough channels. Some of the channels branching off the main stem of the San Joaquin River near Firebaugh extended southward, and eventually formed a single, deep channel about 40 mi (64 km) long and 250 ft (76 m) wide, called Fresno Slough. Fresno Slough then branched into intricately connected smaller channels 8 to 10 mi (13 to 16 km) from the river before entering Tulare Lake.[18]

Flow in the Fresno Slough system was generally believed to be from south to north, bringing seasonally high water from a Kings River distributary,[19] groundwater,[20] and periodic overflows from Tulare Lake into the San Joaquin Basin. Eyewitness reports describe flows in this slough system at different times as both southward from the San Joaquin Basin toward the Tulare Lake Basin,[21] and northward from the Tulare Lake Basin into the San Joaquin Basin.[22] George Derby, an early explorer and mapmaker in the area during the 1840s and 1850s, was one of those who noted southward flow from the San Joaquin system. However, Grunsky, a well-known civil engineer who first examined this region in the 1870s, believed Derby had crossed the delta of the Kings River and that the water in the Fresno Slough was flowing from the Kings River delta north toward the San Joaquin River and that part of the Kings River was flowing south to Tulare Lake.[23]

---

specified. The elevations that are used in this report are consistent with USBR 1970 which reproduced Harding's 1949 reconstruction of Tulare Lake levels. Harding notes the elevations presented by Hall (1886) and used by Grunsky (1898) in his graph of Tulare Lake levels should be reduced by 4.2 feet to conform to the USGS datum in 1949 (USBR 1970). An example of the confusion created by not noting the datum is that the recent literature still generally reports the high stand in 1862 and 1868 as 220 feet (Preston, W. L., 1981. Schroeder, R. A. et al., 1988. Moore et al 1990). Grunsky's graph labels 210 ft as "level of outlet of lake" and Harding labels 207 ft as the "overflow line".

[17] Reported by C.H. Lee 1907, cited in USBR 1970. It is not clear which sea level datum C.H. Lee's report referenced and whether it was the same as that used by Hall and Grunsky.

[18] Williamson, Lieutenant R. S., 1853.

[19] California Department of Public Works, 1931.

[20] Anonymous, 1873.

[21] Derby in Farquhar, F. P., ed., 1932.

[22] Coulter, T, 1835. Fremont, J.C., 1848.

[23] Farquhar, F. P., ed., 1932.

The other three large terminal lakes in the Basin were Kern, Buena Vista, and Goose Lakes (see Map 2). The Kern River alluvial fan ridge forced the Kern River to discharge most its flow into Kern and Buena Vista Lakes, which then overflowed into Buena Vista Slough towards Tulare Lake during periods of higher flow in years of above average runoff. Buena Vista Lake overflow and a Kern River distributary fed Goose Lake, the smallest of the Basin's terminal lakes. Collectively the lakes covered about 44 square miles in the middle of the 19th century, contracting in drier periods and expanding to over 100 square miles during particularly wet years when the waters of Kern and Buena Vista Lakes coalesced.[24]

3.1.2 General Tulare Lake Hydrology

Prior to intensive European settlement and the significant alteration of the Basin hydrology, the balance between runoff and evaporation volumes determined Tulare Lake levels and the frequency and volume of overflow into the San Joaquin River. Tulare Lake levels from the 1850s to the early 1900s were reconstructed using precipitation records, estimates of evaporation, and eyewitness observations by Dr. S. T. Harding, a Professor of Irrigation at the University of California Berkeley and long-time consultant to the Tulare Lake Basin Water Storage District (TLBWSD).[25] According to Harding's reconstruction, Tulare Lake water flowed out of the Tulare Lake Basin in 19 of the 29 years from 1850 to 1878.[26] The total outflow during that period is estimated to be 1.055 million acre-feet (MAF) with the highest annual outflow estimated at 180 thousand acre-feet (TAF) in 1862. Although the lake was just above its overflow elevation for a short period in 1878, no outflow is assumed to have occurred in that year and thus the last natural outflow from Tulare Lake is assumed to have been in 1877.[27]

In addition to the hydroclimatic balance between runoff and evaporation, Tulare Lake levels were also influenced by shifts in the Kings River distributaries and the division of its flows between the Tulare Lake Basin and the San Joaquin Basin. The north side distributaries of the Kings River, including Cole and Murphy Sloughs, could carry water to Fresno Slough and the

---

[24] Alexander et al 1874 cited in San Joaquin Valley Drainage Program (SJVDP), 1990., and Fredrickson, David A., 1983. The 44 square mile area was based on 1850s and 1860s surveys, as reported to the Irrigation Congress.
[25] The USGS began publishing Tulare Lake levels in 1906. Prior to 1850, no reconstructions of the Tulare Lake levels and overflow were found in the literature.
[26] USBR 1970.
[27] USBR 1970.

San Joaquin River during high flows.[28] By the 1860's, settlers had begun to divert Kings River water for irrigation, often using natural slough channels. By 1872, reports indicate that settlers intentionally directed Kings River water into channels that took the flow north into the Fresno Slough and the San Joaquin River.[29] The diversion of flow to the north and increasing diversions of water for irrigation from all Tulare Lake tributaries led to the eventual drying of the lake by 1899.[30] Despite the disappearance of the perennial lake, the lake bottom still periodically flooded during the wet periods of the 20th century.

A rough estimate of the unimpaired (i.e. assuming no alteration of the Tulare Lake Basin hydrology) overflow recurrence interval after 1878 can be estimated by comparing precipitation and estimated runoff records from the 1850-1878 period with modern records. These comparisons and the measured and calculated fluctuations of terminal lakes that also receive Sierran runoff (such as Mono Lake) can be used to establish when conditions would have been similar to the times of recorded Tulare Lake overflow. Analysis of those records performed for this report indicates that with pre-development conditions, Tulare Lake would likely have overflowed in the early and mid-1880's, early and mid-1890's, and at times during the following wetter periods of the 20th century: 1906-1917, 1936-46, 1965-69, 1978-86, and 1995-98. Overflow could have continued for one or more years beyond the end of these periods.[31]

From this reconstruction and comparison with other lakes it is conjectured that Tulare Lake levels would have been relatively high and the lake could have overflowed into the San Joaquin River in nearly 40% of the years during the 20th century.

Long-term climate reconstructions for the Sierra also indicate a general increase in precipitation and temperature since the mid-19th century, and that the past century is the third wettest in the last thousand years.[32] Prior to the 19th and 20th centuries, Tulare Lake may have dried up or was very low during what paeloclimatologist Scott Stine describes as century-scale "epic"

[28] Grunsky, C. E. 1898a. Davis et. al., 1959. On page D-89, the document states that under natural and regulated condition the Kings River is peculiar because it splits: "during low and normal stages, most of the water flows to Tulare Lake Bed; during high stages much spills north to the San Joaquin."
[29] Grunsky, C. E. 1898a.
[30] USBR 1970.
[31] Overflow could have also occurred in individual wet years such as 1952 and 2006
[32] Stine, S., 1990., Stine, S., 1996., and Graumlich, L. J., 1987.

drought periods, one that occurred from about AD 892 to 1112 and the other from about AD 1209 to 1350.[33] Shifts in the Kings River distributaries could also have sent more water toward the north and reduced the volume of inflow to the lake, resulting in much lower lake levels. Without citation, Preston 1981 states that "estimates from recent lacustrine deposits and from early observations indicate that the average area of the lake over the past several thousand years is probably delimited by the 210-ft elevation contour."

According to anecdotal evidence, groundwater outflow from the Tulare Lake Basin may have been an important contributor to the base flow of the San Joaquin River. The Irrigation Congress, reporting on fieldwork for canals in the San Joaquin and Tulare Lake Basins, stated that "the San Joaquin receives an important accession of volume from underground drainage - probably from the Tulare Lake drainage."[34] However, most accounts of groundwater in this area indicate that it was "stagnant" – not flowing northward along the trough of the valley toward the San Joaquin River.[35] Additionally, though some northward movement of groundwater may have occurred, groundwater contours of the Valley indicate that this water primarily moved toward the valley trough, rather than along the axis of the valley.[36]

3.2 Rivers

3.2.1 Historical Hydrography

The Kings, Kaweah, Tule and Kern Rivers formed broad deltaic fans as they emerged from the foothills and channel bottoms and flowed toward the Basin's terminal lakes. Flows were distributed in multiple channels and sloughs that shifted periodically. These shifts were precipitated by major floods of water and sediment that overwhelmed the natural channel capacity, like the floods of 1861-62.

---

[33] Stine, S., 1990., Stine, S., 1996..
[34] Anonymous, 1873., p. 8.
[35] Mendenhall, W.C., R.B. Dole, and H. Stabler, 1916.
[36] e.g., Ingerson, I. M., 1941. Mendenhall et. al., 1916.

The Kings River flowed southwesterly out of the foothills into numerous channels, and into a bottomlands area that is incised slightly below the surrounding land. It then coalesced into a single channel and flowed southwest. Most of the Kings River water flowed south toward Tulare Lake. Near Kingsburg, water began to flow out of the mainstem Kings River into numerous sloughs that later facilitated the distribution of irrigation water. High flows distributed water into these sloughs over a large, marshy area that merged with Tulare Lake. The northernmost two of these sloughs, now called Cole and Murphy Sloughs, periodically carried water north into Fresno Slough and the San Joaquin River.[37] The head of Cole Slough was cut by the floods of 1861-62.[38]

The Kaweah River branched into 8 or 10 shallow channels that easily overflowed during high flows, creating marshland and fertile alluvial deposits with abundant oak trees. These shallow channels were later integrated into irrigation delivery systems. Four of the channels (Elbow, Mill, Packwood, and Deep creeks) gave the name "four creek country" to the area around Visalia. The flood of 1861-62 created the St. John's River, the largest distributary of the Kaweah River.[39] Downstream of where the St. John's River turned south, it was called Cross Creek, which also received water from Cottonwood Creek and Sand Creek. Further downstream Cross Creek was joined by the two branches of Mill Creek and then flowed into Tulare Lake, merging its water and sediment with those of the old high-water delta channels of the Kings River.[40]

The Kaweah distributaries of Packwood Creek, Deep Creek, and Deep Creek's distributary Cameron Creek also flowed into Tulare Lake. Outside Creek flowed along the eastern margin of the Kaweah delta into Elk Bayou, which joined with a channel of the Tule River before flowing into Tulare Lake.

The Tule River split into several channels near Porterville. Porter Slough was formed by the 1861-62 floods, and was briefly the main channel of the Tule River. Further downstream, the river separated into a network of channels having a generally westerly course into Tulare Lake.

---

[37] Grunsky, C. E. 1898b.
[38] Grunsky, C. E. 1898b.
[39] Grunsky, C. E. 1898b
[40] Grunsky, C. E. 1898b.

The river channels could not hold bigger flows and commonly overflowed, inundating areas of considerable extent and facilitating the diversion of water for irrigation.[41]

Deer Creek and the White River flowed across the lowlands in poorly defined channels and had no water for many of the months of the year. During high flow events both streams could flow all the way to Tulare Lake.[42]

The Kern River entered the valley floor flowing in a well-defined flood plain incised below the general upland surface. Near Bakersfield, the river split into several distributaries and sloughs with poorly defined channels, and discharged most of its flow into Kern and Buena Vista Lakes. Like the channels of the other river systems, the Kern River distributaries later facilitated the delivery of irrigation water.

3.2.2 Hydrology Overview

The Tulare Lake Basin has a Mediterranean-type climate with a pronounced cool, moist season in the late fall and winter, and a warm, dry season from late spring through early fall. On average, approximately 80% of the annual precipitation occurs from November through March. Compared to areas further north in the Central Valley, a greater portion of the Basin's annual precipitation falls later in the season, during February and March. The primary sources of precipitation are the low-pressure disturbances that move in from the northwest off the Pacific Ocean. Storms from the southwest containing abundant sub-tropical moisture can generate heavy localized precipitation and high runoff from the surrounding mountains. During the summer months, the lowland portion of the watershed often receives no precipitation and the Sierra Nevada and Tehachapi mountain ranges receive intermittent, localized thunderstorms.

Precipitation over the Basin varies tremendously, increasing with elevation and with movement to the north and east. The Basin-wide average annual precipitation is 15.2 in; in the lowlands the annual average ranges from 5 to 12 inches per year with the higher amounts in the north and east. Because the western lowlands are in the rain shadow of the Coast Range,

---

[41] Grunsky, C. E. 1898b.
[42] Preston, W. L., 1981.

precipitation is higher on the east side of the lowlands than on the west side. In the Coast Range and Tehachapi Mountains, the average annual precipitation varies from 10 to 25 inches. In the Sierra Nevada, the average annual precipitation varies from 20 to 50 inches, generally increasing toward the north. Above about 6,000 ft (1,829 m) in elevation, snowfall provides the majority of the annual precipitation. Precipitation from year to year can vary greatly, ranging from about 35% to 250% of the long-term average.

In an average year, more than 13.5 Million Acre-Feet (MAF) of precipitation falls in the Basin. Evaporative demand in the Basin is very high, ranging from 6 ft annually in the Basin lowlands to less than 3 ft annually in the High Sierra. Because of the large amount of evaporation, only a little over 25% of the precipitation, or about 3.6 MAF, becomes runoff. The majority of the runoff comes from precipitation generated in the Basin uplands as snow and rain, though intense winter storm events can also generate significant amounts of runoff from rain in the lowlands. Aside from these storm events, little runoff is generated in the lowlands. Over 98% of the Basin's Mean Annual Runoff (MAR) from the upland area comes from the Sierra Nevada and most of that, about 3.223 MAF/YR, is collected in the Basin's four principal river systems: the Kern, Tule, Kaweah, and Kings. About 50% of the Basin runoff is derived from Kings River (MAR = 1.791 MAF), the Kern River is the next highest producer (MAR = 0.802 MAF), followed by the Kaweah River (MAR = 0.474 MAF) and the Tule River (MAR = 0.156 MAF) (see Tables 1 and 2).[43]

About 0.325 MAF of runoff on average comes from drainages other than the four principal rivers.[44] Much of this runoff is collected by streams draining the Greenhorn Mountains between the Kern and Tule Rivers and the Sierra Nevada foothills between the Tule and Kings Rivers. These include the White River, and Deer, Poso, Yokul, Cottonwood, Dry, and Mill Creeks. The Caliente Creek system has the highest runoff of the streams draining the Tehachapi Mountains.

[43] The 1962-2006 mean annual runoff (MAR) amounts for the Kings, Kaweah, Tule, are derived from monthly full natural runoff (FNF) or unimpaired runoff amounts given in URS 2003 and DWR. (http://cdec.water.ca.gov/cgi-progs/previous/FNFSUM). FNF is calculated by DWR and/or USACOE as the full natural runoff at the terminal reservoirs, which are near the lowland-upland boundary. Kern River natural runoff figures are from KCWA, 2003 and DWR. (http://cdec.water.ca.gov/cgi-progs/previous/FNFSUM). Although the period of record (POR) for FNF for all four streams extends back to 1894, the 1962-2006 period is used so the FNF record on all four rivers is comparable to the reservoir outflow. 1962 was the first water year that reservoir outflow was measured on all four rivers. The natural MAR for the 1894-2006 period is 2.985 million acre-feet, or about 7% less than the 1962-2001 average.
[44] Minor stream runoff from the uplands is from Bookman-Edmonston Engineering, 1972., adjusted upwards by 3% to be more comparable to the 1962-2006 period of record.

The Arroyo Pasajero system, which includes Los Gatos Creek, has the highest runoff of the streams draining the Coast Range. These two mountain ranges contribute only 2% of the mean annual runoff from the uplands.[45] The drainages other than the four principal rivers are collectively referred to as the minor streams of the Tulare Lake Basin. Table 3 (Minor Stream Runoff) shows annual runoff for these minor streams in 1977, 1978, 1979, and 1983, which includes an extremely dry year (1977), a wet year (1978), a close-to-average year (1979), and an extremely wet year (1983). For most of the streams, 1977 and 1983 represent the extremes on record for a 12-month (annual) period.[46]

Table 2 (4-river runoff) displays the annual natural runoff for the four principal rivers for the 1894-2006 period. The total annual runoff volume, as measured by the sum of the flows for the four major rivers, varies from a low of 0.692 MAF or 23% of average in 1977 to a high of 8.793 MAF or 295% of average in 1983. Annual runoff volumes for individual streams vary even more, especially those that are primarily rain-fed. For example, the annual runoff for the Tule River ranges from 11% (1977) to 443% (1983). In a majority of years, there is a pronounced north to south gradient of decreasing percentage of average runoff, as occurred in 2000 and 1993. However, in some years, there is a trend of increasing percentage of average runoff from north to south, as occurred in 1969 and 1998.

The two years of highest total annual runoff in the Basin's 108-year record are 1983 (8.8 MAF) and 1969 (8.4 MAF), which exceed the next highest total of 7.4 MAF in 1906 by about 14%. Five out of the 10 highest years of runoff have occurred since 1978.[47] Although 1983 and 1969 stand out as the wettest years in the modern record, estimates by the USBR show the runoff may have been greater in 1862 (9.9 MAF), 1868 (9.1 MAF), and 1853 (8.9 MAF).[48] Historical

---

[45] The Arroyo Pasajro along with Cantua and Salt creeks, which also drain the Coast Range, can occasionally deliver significant amounts of rainfall runoff into the California Aqueduct and into the lowlands. Over the long term, however, these systems contribute only minor amounts of runoff.

[46] The effect of antecedent soil moisture conditions in small, lower elevation watersheds (with little exposed bedrock and mostly rain fed) is illustrated by the values in the table. The runoff in 1983, which followed a wet year, was two to three times greater than the 1978 runoff, which followed a record dry year. The precipitation totals for the two years were fairly similar, and the four-river runoff did not differ by nearly as much as the minor stream runoff totals.

[47] Eight out the 11 years with the largest amount of runoff have occurred since the flood control reservoirs were all completed in 1962.

[48] The USBR (1970) estimated the 19th century four-river runoff by correlating it with the estimated runoff into Tulare Lake that was calculated by Harding in 1949. Harding used water balance methods and estimated lake level rises to calculate the runoff.

accounts from 1862 and 1868 indicate very large flows and a dramatic rise in the Tulare Lake level occurred in those years. The 1862 floods caused channel avulsion on all four major rivers in the Basin, and the December 1867 flood is considered the greatest in the Tulare Lake Basin since European settlement began.[49] In 1970, the USBR did a frequency analysis using 19th century runoff volumes, and estimated the return interval for the 1969 runoff volume of 8.4 MAF at 55 years.[50] No additional frequency analysis of the 1969 or 1983 runoff volumes was done for this report.

The annual pattern of runoff for the major rivers reflects the fact that the Kings, Kern and Kaweah watersheds all receive a major portion of their precipitation as snow, and thus delay the bulk of the runoff to the April-July snowmelt period (see unimpaired inflows in Figures 1, 3, 4, and 6). In the Kings River watershed, 71% of the Basin is above 5,000 ft and 71% of its average annual unimpaired runoff volume occurs from April to July. In the Kaweah River watershed, 61% of the watershed is above 5,000 ft and 63% of its average annual unimpaired runoff occurs from April to July.[51] These three watersheds experience high flows in two distinct seasons. In winter, short-duration peak flows lasting several days are due to rainfall. During spring and early summer, long-duration higher flows lasting 2 to 4 months come from snowmelt. The Tule River drains a lower elevation watershed and its peak flows usually occur in the winter. Only 34% of the Tule River watershed is above 5,000 ft and only 43% of the average annual runoff volume occurs from April to July, while 51% occurs from December to March.

The mean daily peak flows in the spring, which usually occur in the mid-May to late June period, generally exceed the winter peak mean daily flow. Prolonged winter rainstorms, especially those with high snowlines, such as occurred in January 1997 and December 1966, produce peak flows substantially higher than the snowmelt peaks and can result in extraordinary runoff volumes. In 1997, two large rainstorms occurred in January, and the month's runoff accounted for 31% of the annual runoff volume on the Kaweah and 42% on the

[49] United States Army Corps of Engineers, Sacramento District, 1972.
[50] USBR 1970.
[51] 72% of the Kern River watershed is above 5,000 ft. The Kern's monthly unimpaired runoff for the period of record was not available. In 1993, a slightly wetter than average water year (105%), 70% of the average annual unimpaired runoff occurred from April to July.

Tule. In 1966, the mean daily flow on December 6 was 40,000 cubic feet per second (cfs), and that single day contributed 21% of the annual discharge of the Tule River in water year 1966-67.

The watersheds draining the uplands do not store significant amounts of groundwater, and stream base flows are very low in summer and fall after the snow pack is depleted. The calculated and measured unimpaired inflows since 1962 indicate that the Kings and Kern rivers appear to maintain base flows of at least 100-200 cfs; Kaweah River low flows can drop below 50 cfs and the Tule River can show no flow.[52] No pre-development "natural" daily flow records were found for the streams downstream of the present reservoirs, but William Hammond Hall estimates mean monthly flow records from 1879-84 at points near the present reservoirs; his records are based on occasional measurements and rod records.[53] Mid-19th century descriptions of the lowland Kings River described it as perennial;[54] Hall's records indicate that November had the lowest average flow, at 313 cfs, and the lowest flow in any single month was 220 cfs.

The Kaweah River and its distributaries on the valley floor were described as being "abundantly watered" in August[55] and Grunsky in 1898, using Hall data, stated the "river has a perennial flow, but its flow is comparatively small at low stages, ordinarily around 30 cfs".[56] The lower Tule River was described by William Brewer in mid-April of 1863, a very dry year, as "a small river, easily forded, with wide stretches of barren sand on either side."[57] Hall's records indicate mean flow in the low flow months generally ranged from 44 cfs to 87 cfs.[58] Even before irrigation, the Tule River's porous bed and tree-lined banks absorbed much of the downstream flow.[59] Lieutenant R. S. Williamson described the Kern and Kings rivers as "large streams" that

[52] When unimpaired or full natural flow is a calculated number, low flow values must be interpreted with great caution. Small errors in observed storage change or diversion can lead to absurd results, such as negative flows.
[53] Hall, W. H., 1886a.
[54] Williamson, Lieutenant R. S., 1853.
[55] Williamson, Lieutenant R. S., 1853.
[56] Hall's records for the Kaweah indicate that the mean monthly flow for the driest months in a dry year (1879) was 31 cfs; in the wetter years the low flow months ranged from 50 to 100 cfs. The Kaweah measurements were made at Wutchumna Hill and at times near Three Rivers.
[57] Farquhar, F. P., ed., 1974.
[58] Hall, W. H., 1886a. Hall's measurements were made on the Tule River near Porterville.
[59] Cook 1960 in Preston 1981. Base flow in the mid-19th century was likely higher than current observations. During the 19th century, minimum temperatures in the mountains in the summer were noticeably cooler than during the late 20th century. Early observers make note of what appears to be a greater extent of late season snow covered area in

"do not become exhausted in the driest seasons".[60] Hall's records indicate that the mean flow in the Kern River in the driest months ranged from about 200 to 400 cfs.[61]

4.0 MODERN HYDROGRAPHY AND HYDROLOGY

The natural hydrography and hydrology of the Tulare Lake Basin have been extensively modified over the last 150 years. The 19th century modifications were mainly for irrigation supply, flood control, and land reclamation. Natural sloughs and river channels as well as constructed ditches were used to supply water to the irrigated land; by the 1870's, numerous canals had been constructed to divert water from each of the major rivers. By 1872, Kings River water was intentionally directed north into the Fresno Slough and the San Joaquin River for flood control purposes and by 1880 some conversion of the Tulare Lake bottom for agricultural use is reported.[62]

In the early 20th century, reclamation of the Tulare Lake bottom continued as levees were built to divide the lake bottom into cells and confine floodwaters to smaller areas. Development of local river and groundwater supplies allowed expansion of the Basin's irrigated areas. Dwindling water supplies led to the development of long-distance water import systems first outlined in the State Water Plan of 1931 and implemented by the Federal Central Valley Project (CVP) and the State Water Project (SWP) (see Map 2). Dams and large reservoirs were built on each of the four major rivers for flood control and water supply purposes in the middle of the 20th century (see Table 4, Reservoir Information). Additional dams have been built on the Kings River further upstream for hydroelectric generation.

In the 20th century, channelization of the rivers and streams for flood control and the creation of numerous percolation ponds for groundwater recharge have further modified the Basin's hydrography. In the latter part of the 20th century, additional conveyance facilities were built to

---

the Sierra, which helped sustain base flow. Climatologists now recognize that the mid-19th century climate was the tail end of the cooler Little Ice Age in California.

[60] Williamson, Lieutenant R. S., 1853.

[61] Hall's measurements were made near Rio Bravo Ranch near the foothills. In May of 1863, a very dry year but presumably still receiving snowmelt, Brewer (Farquhar, F. P., ed., 1974.) described the lower Kern as a wide, swift stream over a hundred yards wide and treacherous to cross.

[62] USBR 1970; Tulare Lake Basin Water Storage District, 1981.

facilitate water transfers and exchanges, both within the Basin and as exports out of the Basin via the California Aqueduct. Map 3 (*San Joaquin Valley Current Hydrography*) shows the major natural and man-made hydrographic features of the Tulare Lake and San Joaquin River Basins. Map 4 (*Hydrography of the Lowland Tulare Lake Basin*) is a more detailed view of the hydrography of the Basin.

4.1 Kings River

4.1.1 Hydrography

Kings River has the largest runoff volume and the second-largest drainage basin of the four rivers (see Table 1, Drainage Areas and Mean Annual Runoff). Pine Flat Dam, which was completed in 1954, separates the upper and lower reaches of the river. The drainage area above the dam is 1,545 sq. mi. The dam is 95 river miles upstream of where the Kings River South Fork joins the Tulare Lakebed, and 113 miles upstream of the North Fork Kings River confluence with the San Joaquin River. Mill Creek and Hughes Creek contribute primarily winter runoff to the Kings River within the three miles immediately downstream of the Pine Flat Dam. The Friant-Kern Canal crosses the Kings River approximately 10 miles west of Pine Flat Dam, where water can be turned out into the Kings River through the Kings River wasteway.

Below the dam, the river follows its natural course southwesterly out into the lowlands and splits into numerous channels in the Centerville Bottoms. These channels then re-join to form a single channel, which follows a more southerly course toward Kingsburg. This section of the river is slightly incised below the main valley floor and is flanked by small, intermittent levees. Near Kingsburg, the river emerges onto its delta and must be continuously leveed to contain high flows. Numerous permanent weirs cross the river and the resulting pools are used to facilitate diversion of water into large canals. Some of the larger canals like Lemoore Canal, Last Chance Ditch, and Peoples Canal, distribute water south into the historic Kings River delta area. Lakeland Canal transports water into the Lower Kaweah Delta service area and Cross

Creek.[63] Alta Canal, also a large canal, distributes water into lands that drain their tailwater into Cottonwood Creek and Cross Creek.[64]

Major canals diverting water to the north side of the Kings River include the Gould, Fresno, and Consolidated Canals, which are diverted just downstream of the Friant-Kern Canal. The Fresno and Gould Canals serve Fresno Irrigation District (FID) lands that extend north and west to the San Joaquin River. Irrigation tailwater from the FID lands and distribution system is occasionally discharged into the San Joaquin River at one or more points.[65]

The Lower Kings River flow is separated into the North and South forks at Army Weir (Map 4). North Fork flow can be routed back to Kings River South Fork using Crescent Weir and Crescent Bypass. Flow in excess of the downstream water supply needs in the Kings River is normally first diverted into the North Fork which then flows into Fresno Slough, Fish Slough, and James Bypass, which together constitute the Kings River North channel system.[66] The Kings River North system discharges into Mendota Pool, which also receives flow from the San Joaquin River. The Mendota Pool releases water into the San Joaquin River channel at Mendota Dam. The published capacity of the Kings River North system is 4,750 cfs although flows up to 6,000 cfs have passed through this reach.[67] When the Kings River North capacity is reached, floodwater is sent into the Kings River South system up to its published channel capacity of 3,200 cfs. Flow in excess of the 7,950 cfs combined capacity of the Kings River South and North systems is supposed to be divided equally between the two systems. In practice, during large floods, the stage of the San Joaquin River may affect how water is divided between the two channels.

---

[63] Lakeland Canal below Cross Creek is also called Highlands Canal and is the principal conveyance facility for the Corcoran Irrigation District. Fugro West, Inc., 2003.
[64] Alta Canal serves the Alta Irrigation District. District tailwater is also directed through a wasteway into Cross Creek.
[65] Jerry Pretzer, USBR, personal communication May 2005. The "Biola spill" is one of the largest discharge points of FID water into the San Joaquin River; USBR hydrographers have visually estimated discharge up to 300 cfs. Spills are more typically in the 25 cfs to 50 cfs range when they occur. Discharge into the river can also occur above Donny Bridge, around Skaggs Bridge, and upstream of Gravelly Ford. Stormwater from the Fresno metropolitan area can also be routed into the FID canals and discharged into the San Joaquin River east of Highway 99. The water supply for the FID lands that discharge into the San Joaquin may be from the Kings River, the Friant-Kern Canal, or local sources such as Dry Creek. The FID canal system provides a hydrographic pathway from these sources to the San Joaquin River.
[66] Johnson, W., 2004.
[67] McBain and Trush, eds., 2002.

The South Fork of the Kings River is known as Clark's Fork before it turns south and is used to convey irrigation water to canals that divert from Empire Weir No. 1 and Empire Weir No. 2 (Map 4). At Empire Weir No. 1 water can be diverted into the Stratford, Westlake, and Empire Westside Canals. At Empire Weir No. 2, water can be diverted into the Blakely Canal and the Tulare Lake Canal, or continue over the weir to the South Fork Canal, all of which serve lands on the Lakebed. The Lateral A Canal also delivers water from the California Aqueduct to the Kings River system at or above Empire Weir No. 2. Below the weir, the South Fork Canal flows another 10 mi (16 km) to the lowest point in the Tulare Lakebed where it intersects the Tule River Canal.[68] Most flood-flows entering the Lakebed come in via the South Fork Kings River and thus can be measured at Empire Weir No. 2. Some flood-flows can also come into the Lakebed from canals in the system. During the 1969 flood, for example, about 28 TAF of Kings River floodwaters reached Tulare Lakebed from Peoples Canal, Lakeland Canal, Last Chance Canal, and Lemoore Canal.[69]

4.1.2 Hydrology

Pine Flat Reservoir stores 1 MAF of water at capacity and is operated to minimize floodwaters into the Tulare Lakebed and provide water to the 28 member organizations of the Kings River Water Association (KRWA). Figure 1 displays daily inflow and outflow hydrographs for the Kings River for recent median (2000), wet (1998), and dry (1988), years.[70] Because of its relatively large storage, Pine Flat releases in winter can normally be kept at minimum levels for fishery and other needs (50 cfs to 200 cfs). Larger releases are necessary when high inflow causes the reservoir to encroach on the flood control storage reserve.[71] Uncontrolled winter runoff from Mill Creek, which enters the Kings River below Pine Flat Dam, can result in higher flow in the lower Kings, including flow into the James Bypass, even when Pine Flat releases are low. Pine Flat outflow increases in the spring and summer as it is metered out for irrigation water supply. The summertime peak demand downstream is in the range of 6000 cfs to 7000

[68] KRCD and KRWA 1994
[69] USBR 1970.
[70] Appendix 1 explains why those years were chosen.
[71] Another 252 TAF of storage exist upstream of Pine Flat in Courtwright and Wishon Reservoirs. The ratio of watershed reservoir storage to the mean annual runoff is about 70%.

cfs. Flood control releases up to 17,000 cfs occur in the late winter, spring and summer in years of heavy snow pack to prevent uncontrolled spills from Pine Flat.[72]

Dam and reservoir control is sufficient to handle the river runoff in most years, though in over a third of the years, or 20 of the 53 years since Pine Flat Dam was completed, surplus runoff was routed via the North Fork into the San Joaquin River.[73] In 8 of the 20 wet years (1958, 1967, 1969, 1980, 1983, 1997, 1998, and 2006), surplus Kings River flow was also routed into the Tulare Lakebed. Flow into the San Joaquin River occurs most commonly in the March-June period as a result of snowmelt flood control releases while flow into the Tulare Lakebed is more common in the May-July snowmelt period.[74] The largest flows to the San Joaquin River occurred in 1969 and 1983 with 1.6 MAF and 2.3 MAF of flow measured in the James Bypass, respectively; and in 14 out of the 20 years the flow was greater than 100 TAF.[75] The largest Lakebed inflows also occurred in 1983 and 1969 with 224 TAF and 196 TAF of inflow, respectively. Comparatively small amounts of surplus Kings River flow was also pumped into the Friant-Kern Canal in 1982, 1995, 1998, and 2006 (the highest amount was 12.7 TAF in 1995).[76]

Table 5 (Kings River Water Distribution) shows the annual volume, peak magnitude, and duration of flow in most of the major canals that distribute Kings River water in an average (1979), dry (1988), and wet (1995) year using the data compiled and published by the Kings River watermaster.[77] The period of time that water is distributed in these canal systems varies with the year type, the irrigated cropland that they serve, and the water rights priority of the

---

[72] The highest 50 daily release amounts all occurred in the snowmelt months in the heavy snow pack years of 1969, 1983, and 1967. Most of those releases occurred in June.

[73] Appendix A, URS, 2002, for data through 2000. Data for 2005 and 2006, obtained from California Data Exchange Center, James Bypass station; http://cdec2.water.ca.gov/cgi-progs/queryFx?JBP. Water year 1973 was not included because only 139 acre-ft of water was recorded in the James Bypass for the year (all of it in June 1973), and that water may not have reached the San Joaquin River. The next smallest flows occurred in 1979, when 11,752 acre-ft were routed toward the San Joaquin River.

[74] Excess flow into the lakebed, in the eight years it did occur, was most common in the May-July snowmelt period. Only 1980 and 1997 did not have a Tulare Lakebed inflow in the snowmelt period.

[75] In 1995, 1998 and 2006 a relatively small amount of Kings River inflow into Mendota Pool (e.g. 4 TAF in April 2006) was pumped up to the California Aqueduct through Lateral 7L of the Westlands Water District. The water is transported south in the joint use Aqueduct to users within Westlands Water District although it is co-mingled with California Aqueduct water that is exported to Southern California.

[76] The amounts of water pumped into Friant-Kern Canal into the Kings River are also relatively small compared to the pump-ins of Kaweah (St. John's) and Tule River. See page 41 for a discussion of the pump-ins.

[77]. Kings River Water Association, 1980, 1989 and 1996. The watermaster records were not available for 1998 and 2000, therefore different years were chosen to represent the range of hydrologic conditions than were used in Figure 1 (see Appendix 1).

diversion. Generally, water is supplied to the canals for the longest duration possible each year. The annual diversion volume is highest in years of average and above average runoff. In the very wet years the duration and volume of water deliveries can be less than average, since precipitation and local runoff reduce demand. In drier years, the duration and volume of irrigation water deliveries will also be reduced due to limited water supply. When water supply is not restricted, water is diverted into the canals in at least the spring and summer months. Water is also diverted into most of the canals listed in Table 5, with the exception of Alta and Lakeland Canals, in at least some of the winter months. In the case of Peoples, Last Chance, Westlake, Empire Westside, Blakely, Tulare Lake, Fresno, Gould, and Consolidated Canals, water is diverted into the canals nearly every month of the year. Dry years can restrict flows to mainly the summer months.

Gould, Fresno, and Consolidated Canals distribute water to the north of the river. All other canals except Alta Canal distribute water south in the historic Kings River delta area and Tulare Lake bottom. Alta Canal distributes water up-slope of the historic deltaic alluvial fan to land that can drain into St. John's/Cross Creek system of the lower Kaweah Delta system. Lakeland Canal distributes water to areas that are also served by the lower Kaweah Delta system. All of these canals that distribute water to the south are noted because they or their subsidiary distribution canals were identified by the California Department of Fish and Game (CDFG) to have contained white bass that came from the Kaweah River system.[78] Many of these canals had barriers constructed on them to prevent white bass migration into the Kings River.[79]

The presence of water in these Kings River canals and other water bodies in the Tulare Lake Basin was evaluated by the CDFG in the mid-1980's for the White Bass Management Program Final Environmental Impact Report (FEIR).[80] Table 18 in the FEIR (Table 6 in this report) assigns a "dewatering code" to each waterway where white bass were found. The codes suggest a relative ranking of the duration of water in the water bodies. In many cases the dewatering code information in the FEIR is consistent with the flow duration indicated in Table 5 and in other cases (e.g. Blakely, Tulare Lake, Empire Westside, Lakeland Canal) the

[78] California Department of Fish and Game, 1987.
[79] Sampling conducted by CDFG indicated that white bass were found within these canals (see Table 18 of the FEIR) at locations downstream of the fish barriers
[80] California Department of Fish and Game, 1987.

dewatering code suggest a longer duration of water. Table 6 provides supplemental duration information but should not be compared to the flow duration information for the canals listed in Table 5, which is based on diversions into the headgates for specific years.

4.2 Kaweah River

4.2.1 Hydrography

Terminus Dam, which was completed in 1962, separates the upper and lower watersheds of the Kaweah River. The dam is located approximately 60 river miles above the Tulare Lakebed with a contributing drainage area of 561 sq mi. Within a mile downstream of the dam, Dry Creek (aka Limekiln Creek), flows into the Kaweah from the north. Dry Creek drains an 80 sq. mi drainage basin and is the largest source of runoff below the dam, mainly during the winter season. Yokul, Mehrten, Antelope and Cottonwood creeks are also tributary to the Lower Kaweah distribution system, supplying highly seasonal rain runoff (see Figure 2, Kaweah River Schematic).

The Kaweah River water supply distribution system begins immediately downstream of the dam, where three ditches (Hawkeye, Lemoncove, and Foothill) divert relatively small amounts of water from the river (less than 10 TAF per year total). About 1.5 mi (2.4 km) below the dam, Wutchumna Ditch diverts water year-round to the north into Bravo Lake, a 4,000 acre-foot regulating reservoir. The ditch flows out of the reservoir and crosses the Friant-Kern Canal; water is occasionally pumped out of the ditch into the canal for transfer down-canal to the Lindsay-Strathmore Irrigation District.[81] The main river flow is divided into two branches about 3 mi (4.8 km) downstream of the dam at McKays Point weir. The northern branch becomes the St. John's River, carved in the 1862 flood, and the southern branch becomes the Lower Kaweah River. The Friant-Kern Canal crosses the two branches approximately 2 mi (3.2 km) downstream of their split and can divert water into both branches. The Tulare Irrigation District imports additional Friant-Kern Canal water to the Kaweah River distribution system from

[81] The frequency of the pump-in is described on p. 27 at the end of the Kaweah River section.

a turnout located up-canal from the St. John's River crossing. The St. John's River can also be pumped into the Friant-Kern Canal to reduce downstream flooding during high runoff years.[82]

The St. John's River flows roughly parallel with the Lower Kaweah system until near Visalia, where the channel turns to the northwest. Water is then distributed into a series of ditches and canals that divert off both sides of the river. Longs Canal, Sweeney Ditch, Ketchum Ditch, Packwood Canal, Tulare Irrigation District Main Canal, Jennings Ditch, Modoc Ditch, St. John's Ditch, and Goshen Ditch begin on the south bank and flow west or southwest. Diversions that originate on the north side of the river include Mathews Ditch, Uphill Ditch, and the Harrell Ranch diversion; these diversions flow northwest towards Elbow Creek, which was one of the original Kaweah distributaries, and Cottonwood Creek. The St. John's River becomes Cross Creek about 2 miles east of Highway 99 where it turns to the southwest and is joined by Cottonwood Creek. Cross Creek diverts flow into Lakeside Ditch and Lakeland Canal No. 2, which distribute water to Tulare Lake and Kings River Delta water users.[83] Cross Creek flow can also be diverted into the Corcoran Reservoir. Once it reaches the historic Tulare Lakebed, Cross Creek splits into three branches. The west branch terminates at the Tulare Lake Canal, and the middle and east branches terminate at the Tule River Canal.

In addition to carrying Kaweah River runoff, Cross Creek and its tributary Cottonwood Creek can receive outflow from the Alta Irrigation District system via the Cross Creek Wasteway, Sand Creek, and potentially other irrigation ditches. After the high flows of 1983, CDFG constructed barriers on Banks Ditch, Kennedy Schoolhouse Ditch, Button Ditch, Williams Ditch, and Sand Creek to prevent the upstream migration of white bass into the Alta Irrigation District system and potentially into the Kings River system (see the Table on Map 4 and discussion in Section 5.4.1).[84] Barriers were also constructed on Lakeland Canal and Settlers Ditch, which carry Kings River water, since their systems can potentially join with Cross Creek and by extension

[82] Floodwater pump-ins to the Friant-Kern Canal since 1978 are documented in United States Bureau of Reclamation, 2004. Pump-ins from the St. John's River into the canal occurred in 1978, 1982, 1983, 1986, 1997, and 1998.
[83] Lakeside Ditch serves Lakeside Irrigation District and Lakeside Ditch Company; Lakeland Canal serves Corcoran Irrigation District and other Tulare Lakebed users. From Lakeside Ditch, Cross Creek flows can be diverted into the Melga Canal, which flows into the Tulare Lakebed.
[84] Water may move through other pathways from the Alta Irrigation District into Cross Creek and Cottonwood Creek but that cannot be determined without a site visit.

the rest of the Kaweah River system.[85] The connectivity of the St. John's River and Cross Creek system with Alta Irrigation District is further evaluated in the discussion of aquatic pathways in section 5.6.1.1 and 5.6.2, below.

The Lower Kaweah River below McKays Point conveys water to a series of natural distributary channels and constructed ditches, canals, and percolation basins. The principal diversions from the Lower Kaweah and its extension, Mill Creek, in downstream order below McKays Point are: Hamilton Ditch, Consolidated Peoples Ditch, Deep Creek, Crocker Cut, Tulare Irrigation Company Ditch, Fleming Ditch, Packwood Creek, Oakes Ditch, Evans Ditch, Persian and Watson Ditch.[86] Outflow from the Lower Kaweah system occurs via a number of waterways including Mill Creek, which joins Cross Creek, Elk Bayou, which joins the Tule River, and spill from the Tulare Irrigation District into the Tule River.[87]

The Lower Kaweah and St. John's distribution system also intentionally allows water to percolate into the ground using unlined channels and off-stream percolation basins. Currently the Kaweah Delta Water Conservation District operates 40 basins with a combined area of 2,100 acres.[88] In 1972, 36 percolation basins were identified as covering an aggregate area of 4,640 acres within the District.[89]

Channel capacities in the Kaweah River system are occasionally exceeded in high runoff periods resulting in overland flood flows. High winter runoff from Cottonwood and Sand creeks combined with excess flow in the St. John's River cause extensive flooding around their confluence and also back water up into Cottonwood Creek.[90] The Lower Kaweah distributaries including Deep, Cameron, and Outside Creeks occasionally flood nearby farmland because of

---

[85] A barrier was constructed on Clough Ditch since it appears to join with Lakeland Canal. The maps suggest this but cannot be confirmed without a site visit.
[86] Bookman-Edmonston Engineering, 1972.
[87] Fugro West, Inc., 2003. Bookman-Edmonston Engineering, 1972. The document also indicates outflow through Cameron Creek, which flows southwest toward Corcoran and the Tulare Lakebed, but it is not clear which channel it joins with. Topographic maps also suggest outflow could occur through Deep Creek and Bates Slough to the Tule River.
[88] Fugro West, Inc., 2003.
[89] Bookman-Edmonston Engineering, 1972.
[90] United States Army Corps of Engineers, Sacramento District, 1972.

their limited capacity for large amounts of winter runoff. Flooding also occurs where Elk Bayou joins the Tule River.

4.2.2 Hydrology

Lake Kaweah can store up to 185,630 acre-ft of water. The recent addition of spillway gates added 21 vertical feet and 42,600 acre-ft of storage capability. The dam is operated to minimize downstream flooding of the Kaweah River and Tulare Lakebed, and to regulate irrigation water supply for downstream water right holders.

Figure 3 displays daily inflow and outflow hydrographs for the Kaweah River for recent median (2000), wet (1998), and dry (1988) years.[91] Flood control requires that most of the reservoir space be reserved for high rainfall and snowmelt runoff and only a small amount of water can be retained in storage from late fall through early spring, usually between 1 TAF and 10 TAF. As a result, there can be very low reservoir outflow in winter (10 cfs or less) punctuated by rapid increases for flood control purposes for periods of days to weeks, depending on rainfall and snow pack accumulation. In drier years, storage for water supply begins in late winter and releases are increased later in the spring and early summer to meet downstream demands. In wetter years, storage must be reserved through the spring for snowmelt runoff and releases may remain high (above 2,000 cfs) through the spring and early summer.[92]

The Kaweah River flow is split between the St. John's and Lower Kaweah River in accordance with water rights entitlements. Fugro-West (2003) describes this split thusly:

> *The entitlement flow of Kaweah River at McKays Point is divided equally between the Lower Kaweah River and St. John's River until the flow has once receded to 80 second-feet in the late summer months. Thereafter, the entire flow, regardless of the amount, is diverted into the Lower Kaweah River until such time as it first exceeds 80 second-feet after October 1. In 1945, the Wutchumna*

[91] Appendix 1 explains why those years were chosen.

[92] The ratio of Kaweah Reservoir storage to the mean annual river runoff is 39%, which is the lowest ratio of the four Tulare Lake Basin rivers. The Tule River ratio is normally about 51% but it is temporarily at about 18% while Success Reservoir is being managed at lower storages due to seismic concerns.

Water Company entitlement on the St. John's River at Barton Cut (below Mathews Ditch Diversion) was transferred to the head of Wutchumna Ditch on Kaweah River above McKays Point. Thus an additional flow, in an amount equal to the transferred Barton Cut entitlement, is diverted to the Lower Kaweah River.

It is not known how strictly this split was adhered to in the past or whether it is today. The only daily records that were available to evaluate for the two rivers are for the 1976-80 period.[93] In general there was more flow in the Lower Kaweah, especially in the very dry years of 1976 and 1977. The St. John's River recorded zero flow for one or more months in the fall, while the Lower Kaweah had water year round except at the end of 1977.

Using a combination of natural distributaries and constructed unlined ditches, the two branches of the Kaweah River system distribute most of the Kaweah River runoff onto irrigated fields or allow it to percolate into the ground. However, in at least 11 years with large runoff volumes since the completion of Terminus Dam, including 1967, 1969, 1973, 1978, 1980, 1982, 1983, 1986, 1995, 1997, 1998, 2006 excess water was sent to the Tulare Lakebed or pumped into the Friant-Kern Canal (records for pump-in begin in 1978).[94] In 1970 and 1984, excess Kaweah River water was sent to the Tulare Lakebed even though they were not considered high runoff years.[95] Those two years followed the extremely wet water years of 1969 and 1983, respectively, and their early season runoff was considerably above average.[96] In about 30% of the years since 1962, excess Kaweah River water has reached the Tulare Lakebed.[97] In 1983, a record 550 TAF of Kaweah River is estimated to have reached the lakebed. The second-largest contribution to the lake (430 TAF) occurred in 1969. The third-highest volume (194 TAF)

---

[93] California Department of Water Resources, 1983. More recent daily data maintained from the Watermaster was not available.

[94] For the purpose of this report, high water year runoff is defined as any year the Kaweah River runoff exceeded 130% of the 1962-2006 average or 143% of the 1894-2006 average.

[95] Johnson, W., 2004.

[96] The USACOE's Johnson (2004) does not include 1995 in the years of excess Kaweah River runoff while a compilation by Dan Steiner for URS (2003) includes 1995 but not 1970 or 1984.

[97] Johnson (2004) states that "Based on the Kaweah River Basin, California, Hydrology Office Report, August 1990, there is a 33% chance that 1,000 acre-feet of Kaweah River floodwater will reach Tulare Lakebed during any particular year." Bookman-Edmonston Engineering, 1972., estimated Tulare Lakebed flood flows from the Kaweah River in about 23% of the years using correlations of modern lakebed flooding with unimpaired runoff; the wet years in the 1980's and 1990's increased the likelihood of Kaweah River floodwater reaching the Lakebed. The Kaweah Reservoir storage enlargement should reduce the frequency and volume of the smaller flood events but not the volume of the large floods.

occurred in 1997, and the fourth largest (181 TAF) in 1998.[98] The high flow to the lakebed in 1969, 1983 and 1998 were due to both winter rain and spring snowmelt events, while the 1997 flow occurred only in the winter.

Recent analysis by Fugro-West 2003 for the period 1981-99 indicate that about 144 TAF per year on average are diverted from the St. John's River and about 215 TAF per year on average are diverted from the Lower Kaweah system. About 35% of these diversions on average or about 128 TAF per year are estimated to be lost in transit from headgate to fields and another 66 TAF per year occur as seepage losses in the Kaweah and St. John's River. Most of these "losses" end up in groundwater storage.[99] There are wide variations in these values depending on the amount of runoff in the Kaweah River.

Table 6 (Kaweah River Water Distribution) shows the annual volume, peak magnitude, and duration of flow in selected channels of the Lower Kaweah and St. John's River distribution system in a very dry (1977), wet (1978), and average (1979), year using the data compiled by the Kaweah and St. John's River Associations and published by the Department of Water Resources.[100] The duration of flow in the distribution system is related to the magnitude of the runoff, ranging from no or little flow in the very dry year to practically year round flow in a wet year. In an average year, water is made available in the spring and summer irrigation months. Table 6 (reproduced from Table 18 in CDFG 1987) indicates most of the Kaweah system has water in it seasonally for irrigation and some water bodies such as Elbow Creek and Bates Slough have water in them for longer periods.[101]

The Kaweah and St. John's Rivers received the most water from the Friant-Kern Canal in the near-average year (1979), since in wet years the river runoff is used to satisfy more of the demand and the canal diversions into the rivers occur later in the summer when snowmelt runoff has subsided. Evaluation of more recent records of Friant-Kern canal releases into the St. John's and Kaweah Rivers, from October 1994 through July 2004, indicates an average of

---

[98] URS, 2002, for 1983 and 1997; and USBR 1970, for 1969.
[99] An estimated 71 TAF per year on average is artificially recharged into the ground at the percolation basins.
[100] The watermaster records were not available for 1988, 1998 and 2000 and therefore different years were chosen to represent the range of hydrologic conditions.
[101] Elbow Creek and Bates Slough may receive tailwater or shallow groundwater and have standing water but that cannot be confirmed without a site visit.

about 8 TAF per year was released into each river.[102] No releases were made in some of the very wet and dry years. Releases were sporadic, and generally lasted for one to three weeks. The highest annual releases occurred in years that were neither dry nor very wet, such as 1996 and 2000.[103]

The Wutchumna Ditch pump-in to the Friant-Kern canal has averaged 1,655 acre-feet in the last decade, with a maximum annual amount of 4,262 acre-feet in 2003. The pump-in events are sporadic occurring for a few days to a few weeks in the winter and spring. In recent years the pump-in has occurred most often in May.[104]

4.3 Tule River

4.3.1 Hydrography

Success Dam, which was completed in 1961, separates the upper and lower watersheds of the Tule River. The dam is located approximately 40 mi (64 km) upstream of the Tulare Lakebed with a contributing drainage area of 391 sq mi.

The Tule River water supply distribution system, like the Kaweah River system, uses natural channels, sloughs, and constructed ditches to supply water for irrigation and allow it to percolate into groundwater storage. The Tule River alluvial fan is steeper and smaller than the Kaweah system's alluvial fan, and flows are not distributed among as many channels or across as wide an area. The Tule River distribution system also begins immediately downstream of Success Dam. Pioneer ditch begins on the north side of the river, followed shortly by Porter Slough, the largest of the diversions on the north side. The rest of the major ditches begin on the south side of the River and include Campbell-Moreland, Poplar, and Woods-Central

[102] Obtained from Friant Water Users Authority data on diversions into the rivers, and provided in response to a request by the USACOE in May 2004.
[103] It appears that less water may have been released into the St. John's and Kaweah River systems from the Friant-Kern canal in the last decade than in the 1976-80 time period because Tulare Irrigation District was taking less water into their system from the rivers and instead diverting it directly from the Friant-Canal into their canal system.
[104] It is not known if this pump-in was generally greater in previous decades but the amount transferred in 1977, 12.7 TAF, is much higher than in the past decade.

Ditches.[105] The Friant-Kern Canal crosses under the Tule River and Porter Slough about 10 mi downstream from the Dam; water can be released from the Canal into both waterways. Downstream of the last major ditch diversion, the river channel is used to "sink" water, or hold excess water and allow it to percolate.

The Tule River splits into two, then three branches downstream of Oettle Bridge, which is considered the dividing point between upper and lower river users. Further downstream, water flowing out from the Lower Kaweah River system through Elk Bayou and Deep Creek join the Tule River. The Tule River crosses Lakeland Canal at Turnbull Weir, the last point of flow measurement before entering the Tulare Lakebed. The river crosses under Highway 43 and eventually becomes a straightened canal on the Lakebed. Cross Creek flows into it at a right angle, and the canal then joins the Kings River South Fork Canal at the lowest point of the Lake bottom.

4.3.2 Hydrology

Success Reservoir can store up to 82,300 acre-ft, but recently imposed restrictions on storage due to seismic concerns limit the maximum storage to 29,200 acre-ft.[106] The reservoir is operated to minimize downstream flooding of the Tule River and the Tulare Lakebed, and to regulate irrigation water supply for downstream water right holders.

Figure 4 displays daily inflow and outflow hydrographs for the Tule River for recent median (2000), wet (1998), and dry (1988) years.[107] There are no minimum release requirements, so winter reservoir outflow can be less than 1 cfs at times. Similar to the Kaweah River, flood control requires that most of the reservoir space be reserved for sudden high inflows, and only a small amount can be retained in storage in the late fall and winter (usually less than 10 TAF). As a result, most winters have higher flows for varying periods of time, from days to weeks, separated by periods of very low outflows. In all but the wettest years, higher, longer duration outflow is metered out in the spring and summer for water supply purposes; the drier the year,

[105] Hubbs-Minor Ditch is a relatively small ditch on the north side downstream of Porterville.
[106] During high runoff periods the USACOE temporarily allows higher storage.
[107] Appendix 1 explains why those years were chosen.

the shorter the duration of higher flow. In wet years like 1998, higher flows (> 500 cfs) persist for much of the winter, spring and summer.

Because the Tule River watershed accumulates less snow pack than the Kaweah, under normal operations, storage for water supply can begin earlier in the winter season. The newly imposed storage restrictions for Success Reservoir will change the spring and summer outflow pattern to more closely resemble the inflow pattern. Instead of using the storage to meter outflow to more closely match downstream demand requirements, the restricted storage will create higher outflow in the winter and spring and lower outflow later in spring and summer than under previous reservoir operations.

The Tule River system has been able to distribute all of the runoff in at least two-thirds of the years since 1961, either through delivery to irrigated land or by allowing it to percolate into the ground. Since the completion of Success Dam, excess flow has reached the Tulare Lakebed and/or been pumped into the Friant-Kern Canal in 1967, 1969, 1970, 1978, 1980, 1982, 1983, 1984, 1986, 1995, 1997, 1998, and 2006.[108] The largest annual volume of excess flow occurred in 1983 when about 295 TAF of Tule River water is estimated to have reached the Tulare Lakebed. The next highest in volume is 1969 with 215 TAF and the third highest is 1998 with 189 TAF of flow reaching Tulare Lake.[109]

Table 7 (Tule River Water Distribution) shows the annual volume, the range of magnitude, and duration of flow in the Tule River and the major ditches of the Tule River distribution system in very wet (1998), below average (2000), and above average (1996) years using the data compiled and published by the Tule River Association.[110] The Tule River downstream of the Porterville gage is below the last major ditch diversion. The duration of flow in the distribution

[108] Johnson, W., 2004., states that "Based on the Tule River Basin, California, Hydrology Office Report, August 1990, there is also a 33% chance that 1,000 acre-feet of Tule River floodwater will reach Tulare Lakebed during any particular year." The 13 years of excess flow since 1962 represent 29% of the years.
[109] 1983 and 1998 values from URS, 2002. 1969 value from USBR 1970.
[110] Appendix 1 explains why those years were chosen.

system is related to the magnitude of runoff each year; sporadic flows occur in the drier years, while flows are practically year-round in wet years.[111]

The Friant-Kern Canal diverts water into the Tule River system in all but the wettest years, such as 1998, when about 100 TAF of water was pumped into the Canal to reduce the amount flowing to the Tulare Lakebed.[112] An evaluation of records from October 1994 through July 2004 indicates an average of approximately 8 TAF of Friant-Kern Canal water was released into the Tule River per year. No releases were made during some of the drier years. Releases were sporadic in most years, generally lasting from one to three weeks. The Lower Tule River Irrigation District (LTRID) and Porterville Irrigation District take delivery of their Friant-Kern Canal water supply at other turnouts. LTRID can take delivery of Canal water through a Deer Creek release.

4.4 Kern River

4.4.1 Hydrography

The Kern River is the southern-most of the four major rivers in the Tulare Lake Basin. It has the largest drainage basin area and carries the second-largest amount of runoff in the Basin. Unlike the other three terminal dams that are located near the foothill-valley boundary, Isabella Dam is located approximately 33 mi (53 km) east of the foothill boundary in a valley formed by the junction of the mainstem and south fork of the Kern River.

Downstream from the Dam, the Kern River flows southwesterly through a deep canyon, emerging at the canyon mouth northeast of Bakersfield. From there, the Kern River flows about 12 mi (19 km), distributing water into relatively small diversions, to a point where the

[111] Table 18 of CDFG 1987 indicates that the Tule River has water year round or can only be dewatered by pumping. Without further information it is not possible to say why the Table 18 dewatering codes appear to be inconsistent with flow information from the Watermaster reports. One possible explanation is that the Tule River may have water in stretches even if there is little or no flow.

[112] The records from the Friant Water Authority show that in July 2001, a dry year, about 600 acre-feet of Tule River water were pumped into the Friant-Kern Canal. This may have been done as part of a water transfer and was not done for flood control purposes.

river's flow is measured (the "first point of measurement").[113] Beyond this point the river flows through the Bakersfield-Oildale area to a series of three weirs where much of the water is diverted into canals. At Beardsley Weir, water is diverted north into the Beardsley-Lerdo canal system; at Rocky Point Weir water is diverted south into the Kern Island Canal system. At Calloway Weir water is diverted north into the Calloway Canal and south into a series of canals that distribute water in the historic Kern River fan area and Buena Vista Lake bottom.[114]

Downstream of the major weirs, flows are present during wetter conditions when high river flow exceeds the canal demands. Water is released to the channel downstream of the weirs mainly for groundwater recharge operations. Flow also occurs through Bakersfield in the May-September period for recreation purposes and groundwater recharge.[115] The river also receives water from the Friant-Kern Canal, which terminates at the river, when excess flow in the San Joaquin, Kings, Kaweah, and/or Tule rivers is put into the canal. Friant-Kern Canal water is also discharged into the Kern River for groundwater recharge operations and is also diverted into the Arvin-Edison Canal for distribution into the Arvin-Edison Water Storage District to the southeast. The Arvin-Edison Canal can receive Cross Valley Canal water, which transfers flow from the California Aqueduct. Figure 5 shows the junction of the Kern River with the Friant-Kern, Arvin-Edison, and Cross Valley canals.

High Kern River flow that is not used for groundwater recharge will flow either into the Buena Vista Lakebed, into the Kern River Intertie and the California Aqueduct, or north toward Tulare Lake via the Kern River Flood Canals. The Buena Vista Lakebed is normally dry and intensely farmed. Kern River water can be diverted into the Buena Vista Lakebed through the Alejandro Canal and the Kern River inlet canal; up to 30,000 acre-ft of floodwater can be stored in cells per agreements between the landowners and Buena Vista Water Storage District.[116] Excess

[113] The flow at this first point of measurement is used to determine the water allocations to the major canal systems downstream.
[114] City of Bakersfield Water Resources Department, 2003a. At the Calloway Weir water can be diverted on the south side to join up with the Kern Island system and redistributed at the Four Weirs. Water can also be diverted into the Carrier and Kern River Canal system, which roughly parallels the river.
[115] City of Bakersfield Water Resources Department, 2003a., and City of Bakersfield. 2003. An agreement was signed in November 1999 allowing flow in the summer months in most years through Bakersfield to Stockdale Highway for recreational purposes.
[116] Johnson, W., 2004.

water in the Buena Vista Lakebed is occasionally sent north toward Tulare Lake through the Kern River/Buena Vista Outlet Canal.

Extensive groundwater recharge occurs in and along the river and off-stream spreading basins throughout the lower Kern River alluvial fan area. As noted above the Friant-Kern Canal and Kern River supply recharge water. The Kern County Water Agency identifies 34 groundwater recharge sites in the Southern San Joaquin Valley portion of Kern County.[117] The California Aqueduct also supplies water for recharge through the Kern Water Bank Canal and the Cross Valley Canal. The latter two canals can also "reverse" flow and bring water from groundwater banks back into the California Aqueduct.

4.4.2 Hydrology

Lake Isabella Reservoir can store up to 568 TAF. Unlike the reservoirs on the Tule and Kaweah Rivers, Isabella usually can hold water in conservation storage through the late fall and winter and does not have to make flood control releases except in years of very high runoff.[118] Other than the years of high runoff volume, all of the Kern River water is used for irrigation, groundwater recharge, or stored in Isabella Reservoir.

In years when potentially damaging flow to the Tulare Lakebed may occur, all or a portion of the excess flow is diverted to the California Aqueduct via the Kern River Intertie. The excess flow in the Kern River is from both Kern River runoff and from excess Friant-Kern Canal flow discharged into the Kern River that is derived from the San Joaquin River and the Tulare Lake Basin rivers that are pumped into the Canal. Since the Intertie was built in 1977, excess flow has been sent to the California Aqueduct during 10 of the years: 1978, 1980, 1982, 1983, 1984, 1986, 1997, 1998, 2005, and 2006.[119] 1983 had by far the largest volume with over 750 TAF of inflow. Other large flows into the Intertie (>139 TAF) occurred in 1978, 1980, and 1998 when

[117] Kern County Water Agency, 2003
[118] Isabella storage has rarely dropped below 100 TAF in the last 10 years.
[119] KWCA 2003 and Mike Nolasco, DWR, personal communication, Oct. 27, 2006. In March 1995 a major flood in the Arroyo Pasajero north of Kern County caused the Intertie to be used in reverse and accept water from the California Aqueduct. In 2006 the flow into the Intertie was mainly from excess Friant-Kern Canal water.

Kern River exceeded 200% of average runoff.[120] In 1969, prior to the construction of the Intertie, it is estimated about 227 TAF of Kern River flow reached the Tulare Lakebed.[121]

Figure 6 displays daily inflow and outflow hydrographs for the Kern River for recent median (2000), wet (1998), and dry (1988)) years.[122] While watermaster data for the other rivers was available, Kern River Watermaster records will not available to evaluate the magnitude and duration of the diversion. However, records of the annual Kern River diversions were evaluated for 1998 (a very wet year) and 1999 (a moderately dry year on the Kern River and above average year for the SWP).[123] In 1999 the Kern River unimpaired runoff was about 434 TAF, or 62% of the 1894-2001 average, and the total Kern River diversions below the first point of measurement were about 462 TAF.[124] Most of the river runoff went to water districts that could divert river flow at one of first three weirs; a somewhat greater portion was diverted to districts south of the river (e.g. Kern-Delta WD, Arvin-Edison WSD, Buena Vista WD) than north of the river (e.g. Cawelo WD, North Kern WSD, Rosedale-Rio Bravo WSD). The Kern River supplied water for groundwater recharge mainly in off-stream recharge areas (at least 232 TAF) but a much greater amount of the recharge water was derived from the SWP (at least 660 TAF).[125] In 1998 the unimpaired runoff was about 1,718 TAF, or 234% of the 1894-2001 average, and the total Kern River diversions below the first point of measurement were about 1,663 TAF including about 188 TAF that went into the California Aqueduct via the Kern River Intertie.[126] In 1998, much greater amounts of Kern River water and far less SWP water were used for groundwater recharge than in 1999.

---

[120] In the very wet years, the California Aqueduct cannot accommodate all of the excess flow and so the remainder is routed to the Tulare Lakebed.
[121] Johnson, W., 2004. Additional Kern River floodwater in 1969 was stored and percolated in the Jerry Slough and pumped northward in the incomplete California Aqueduct.
[122] See Appendix 1 for data sources and rationale for selected years.
[123] Kern County Water Agency, 2002, and Kern County Water Agency, 2003.
[124] About 2.5 TAF were diverted above the first point of measurement.
[125] Kern County Water Agency (2002) separates some of the recharge water by source (SWP, Kern River, Friant-Kern Canal) but about 88 TAF was combined in 1999 so a full breakdown between sources cannot be compiled.
[126] The diversions above the first point of measurement were 2.9 TAF.

4.5 Tulare Lake

4.5.1 Tulare Lakebed Development

As irrigation infrastructure was built, the historical Tulare Lake was gradually cut off from its sources of inflow and the lake shrank. The Tulare Lakebed was first reported to be dry in 1899. The Lakebed has been farmed to a greater or lesser extent since the late 19^{th} century. Conversion of the Lakebed proceeded rapidly with formation of reclamation districts and construction of levees in the first three decades of the 20^{th} century.[127] Following the 1906-1917 wet period when portions of the lakebed were under water, a long dry period from 1918-1935 allowed nearly full development of the historic lakebed.[128]

Prior to the construction of Pine Flat, Terminus, Success, and Isabella Dams, runoff during years of average to wet water years flooded portions of the Tulare Lakebed. The lake had water from 1937 to 1946 and again from November 1950 to June 1953.[129] The Lake was usually confined to cells located in T22S R20E, toward the west side of the lake, which were designated for water impoundment earlier in the 20^{th} century. Generally, Lakebed flooding has occurred when the runoff volume contained by the lakebed canals exceeded about 5,000 acre-ft. The innermost leveed cells failed frequently, spilling the contained flood flows into adjacent cells. There was no regular sequence of flooding since levee failure depended on the lake stage, which was affected by the prevailing wind direction.[130] Because the Lakebed has subsided substantially over the course of the 20^{th} century, it is difficult to compare water surface elevations from floods in the earlier parts of the 20^{th} century with those in the later 20^{th} century.

---

[127] Over 20 reclamation districts were formed between about 1896 and 1925. By 1940 there were 35 reclamation districts. USBR 1970; Preston, W. L., 1981.
[128] The Lakebed was dry from April 1919 through February 1937 (USBR 1970). During this period, excess runoff was evaporated, absorbed by the soil or used for irrigation.
[129] USBR 1970.
[130] United States Army Corps of Engineers, Sacramento District, 1996., and Preston, W. L., 1981.

4.5.2 Modern Flow Management and Flood Events

The dams on the Kings, Kaweah, Tule, and Kern Rivers have reduced the volume and frequency of minor and moderate floods into the lakebed.[131] Under existing conditions, the Tulare Lakebed area has an extensive levee and diversion system designed to manage irrigation flows and flood flows from the four regulated watershed areas and the surrounding uncontrolled drainage area. Floodwaters flow into the lakebed from the South Fork Kings River over Empire Weir No. 2. During very large floods, such as the one in 1969, relatively small amounts of Kings River floodwater come in from Peoples, Lakeland, Last Chance, and Lemoore Canals.[132] Floodwaters from the Kaweah River system enter the Lakebed via Cross Creek, Melga Canal, Lakeland Canal, and Turnbull Weir (via Elk Bayou). Floodwaters from the Tule are delivered to the Lakebed via Lakeland Canal and Turnbull Weir. Additional floodwaters can come in from the southwest via Deer Creek and from the Kern River south of the lakebed via the Kern River Flood Canal and Goose Lake Canal (Map 5: *Tulare Lake Bottom Hydrography*).

During the 20th century, a series of named storage cells on the lakebed were developed to handle floodwaters, using a network of levees to separate the cells (see Figure 7). Under current conditions floodwaters are managed using two different procedures, either using the methods alone or in conjunction. One method is routing water through canals to specific storage areas; the other method is to breach specific levees to flood certain cells and thus prevent a larger area from flooding.[133] When possible, floodwaters are pumped into the south-end flood detention areas (the Wilbur cell and the three Hacienda cells) that encompass about 20,000 acres and store about 100,000 acre-ft.[134] These four cells are dedicated flood detention areas and are no longer used as agricultural land. Additionally, the cells can also be used to store State Water Project supplies during non-flood periods.

When runoff volumes are high, such as the volumes that occurred in 1969, 1983, and 1997 (which had the third largest runoff volume), levees are breached and agricultural land in the

131 The two largest recorded water years and eight of the eleven largest water years since 1894 have occurred since the projects were developed.
132 USBR 1970 estimates that 28,000 acre-ft of floodwaters came in from these canals.
133 Johnson, W., 2004.
134 United States Army Corps of Engineers, Sacramento District, 1996.

center of the Lakebed is flooded. Land is usually flooded starting with what is called the Basin cell (7,550 acres) near the center of the lakebed where the Kings and Tule River meet. The adjoining Brown (11,580 acres) and Cousins (13,260 acres) cells are usually flooded next, and filled up to an elevation of 189 ft (58 m) above mean sea level.[135] When high runoff is distributed over a long period of time such as occurred in 1969 and 1983, the following cells will also flood: RD 749 (27,500 acres), Lovelace (7,650 acres), Progressive and Stevens (together comprising 5,890 acres), and Helm (6,530 acres). Up to 80,680 acres can be flooded in the main Lakebed storage cells, which can store up to 931,100 acre-ft of floodwater (Figure 7).[136] In all, up to 100,360 acres can be flooded in the main Lakebed and south area, holding as much as 1,030,926 acre-ft of floodwater.[137]

The largest floods since the dams were completed, by both volume of water and surface area flooded, occurred in 1969 and 1983. In 1969, 960 TAF of water was impounded, inundating 88,700 acres of land. On June 24, 1969, the lake reached its highest modern level at 192.5 ft. [138] The total estimated Lakebed inflow in 1969 was about 1.155 MAF, which includes measured inflow from the Kings, Kaweah, Tule, and Kern River basins, and an estimated 93 TAF of unmeasured inflow from other drainages.[139] The 1983 four-river watershed runoff was even higher than in 1969 and the estimated inflow volumes to the Lakebed from the Kings, Kaweah, and Tule River were higher than in 1969 (1,069 MAF in 1983 for the three rivers compared to 0.840 MAF in 1969).[140] No comparable estimate for the total lakebed inflow in 1983 can be made since no figures were obtained for the Kern River and other drainages' inflows but it is assumed that the 1983 inflow into the Lakebed exceeded the 1969 inflow.[141] The 1983 inflow produced a peak lake stage of 191.44 ft and DWR stated that "officials estimate that 82,000 acres of prime agricultural land was taken out of production in 1983 because of the 880,000

---

[135] USBR 1970, United States Army Corps of Engineers, Sacramento District, 1996.
[136] United States Army Corps of Engineers, Sacramento District, 1996.
[137] United States Army Corps of Engineers, Sacramento District, 1996.
[138] Tulare Lake Basin Water Storage District, 1981. USBR 1970.
[139] USBR 1970. The inflow of 93 TAF from other drainages was estimated by the USACOE and presumably included Westside drainages, Deer and Poso creeks although no drainages are named in USBR 1970.
[140] Although much of the floodwater entering the Lakebed can be measured, total Lakebed inflow in high water years is an estimate and caution must be used when using those numbers.
[141] Even though 759 TAF of Kern River was routed into the California Aqueduct in 1983 via the Kern River Intertie, and thus was prevented from flowing into the Lakebed, it is assumed that the combination of Kern River floodwater and other drainage floodwater in 1983 combined with the 1,069 MAF of inflow from the other three rivers exceeded the 1969 total of 1,155 MAF.

acre-ft of water trapped in the Basin".[142] USACOE (1996) stated that about 101,600 acres were flooded in the lakebed in 1983, so it is likely that DWR estimates did not include the acreage and impoundment in the south end (Wilbur and Hacienda) flood detention areas. It also appears from aerial photos and maps drawn by the TLBWSD district that the area flooded in 1983 was slightly greater than the area flooded in 1969.[143]

In 1969 and 1983, evaporation and in-basin irrigation use could not dispose of all the water within one year. Some agricultural land on the Lakebed stayed flooded for one or two years afterward. In the other flood years, water was disposed of by evaporation or in-basin use.

Following the 1983 flood, a plan was devised to pump water from the Tulare Lakebed northward to the San Joaquin River, to bring the flooded land back into agricultural production more quickly. The plan as described by DWR was for the water to be lifted a total of 43 ft (13.1 m) in elevation in four stages over a distance of roughly 15 mi (24.1 km). Water was to be pumped up the South Fork of the Kings River, where it would empty into the North Fork of the Kings River and flow downstream via the James Bypass and Fresno Slough to the San Joaquin River, and into the Sacramento-San Joaquin Delta.[144] The first series of pumps, with a capacity of 1,300 cfs, was located at Nevada Avenue inside the Tulare Lakebed; the number 2 pumping station, with a capacity of 1,150 cfs, was installed at Empire Weir No. 1. The third station at Smith Crescent was capable of pumping 1,000 cfs; the final lift was at North Crescent with a capacity of 1,000 cfs. The declining capacity toward the North Fork of the Kings River was designed to allow pumping for local use during the peak irrigation season. The project was designed to remove approximately 2,000 acre-ft of water per day from the flooded Tulare Lakebed.[145]

Pumping began on October 7, 1983, and was intermittent until the program was terminated on January 19, 1984. About 90 TAF of water was pumped northward.[146] Pumping was stopped earlier than scheduled, due to the potential for white bass to spawn and concern that white

[142] California Department of Water Resources, 1984.
[143] In an insert in TLBWSD (1981) a map is included showing "Conditions in the Tulare Lake Area since completion of Pine Flat Dam" that includes flooded areas through 1984.
[144] California Department of Water Resources, 1984.
[145] California Department of Water Resources, 1984.
[146] United States Army Corps of Engineers, Sacramento District, 1996.

bass larvae would not be screened out and could enter the San Joaquin River system. The Lakebed was not fully drained until water year 1985.

Since the completion of Pine Flat and Isabella Dams in 1954, floodwaters have entered the Tulare Lakebed from one or more of the major rivers 16 times, including water years 1956, 1958, 1967, 1969, 1970, 1973, 1978, 1980, 1982, 1983, 1984, 1986, 1995, 1997, 1998, and 2006. Excess flow into the Tulare Lakebed has occurred in 14 years since the final flood control dam, Terminus Dam, was completed in 1962, or in roughly 31% of the years from 1962 to 2006.[147]

In addition to the extremely high inflows of 1969 and 1983, when monthly inflow volumes exceeded 200 TAF for several winter and spring months, significant winter rain-flood inflows of over 80 TAF during one month occurred in January-February 1997, February-March 1986, February-March 1980, April 1958 and December 1966. Snowmelt flood flows of over 50 TAF in one month occurred in 1998 and 1967.[148] Based on their evaluation of hydrology and reservoir operations, the USACOE indicated that there was about a 1 in 3 chance that excess flow could reach the Tulare Lakebed in any given year or that it would occur in roughly one out of every three years.[149] Some of the years of excess inflow would be of small enough volume to be absorbed by the existing Lakebed channel capacity or flood detention cells and not cause any damage to agricultural lands.[150]

In non-flood times irrigation water is brought into the Lakebed from the Kings River, Cross Creek, Tule River, and the State Water Project.[151] Kings River supply comes from the north via the South Fork channel and Peoples and Last Chance Canals and from the southeast via the Lakeland and Homeland Canal. The State Water Project supply comes in from the west via Lateral A and Lateral B. The principal distribution canals in the Lakebed are: the Blakely Canal,

---

[147] A small amount of excess water may have entered the Tulare Lakebed in 2005 but that cannot be confirmed at this time. Because the south end flood detention cells can absorb floodwaters and the storage volume of Lake Kaweah was recently enlarged, it is likely that the frequency that agricultural lands on the lakebed will flood will decrease in the future if the hydrology is similar to the last 45 years.
[148] USBR 1970 and URS, 2002.
[149] United States Army Corps of Engineers, Sacramento District, 1996., and Johnson, W., 2004., citing USACOE 1990.
[150] United States Army Corps of Engineers, Sacramento District, 1996.
[151] TLBSWD (1981) noted that landowners on the lakebed also have water rights to Deer Creek and Kern River water, although the Kern River water rights have been traded to upstream interests.

Tulare Lake Canal Company Canals, Wilbur Ditch, Gates-Jones Canal, Kings County and Homeland Canal system, and the river channels of the Kings River, Tule River, and Cross Creek.[152] In the 1969 to 1980 period, the State Water Project and river runoff together provided about 71% of the supply total for the Tulare Lake Basin Water Storage District; groundwater and residual floodwaters provided the rest.

4.6 Tulare Lake Basin Imports and Exports

The following sections describe the major facilities used for the import and export of water, and provide an overview of the amounts imported and exported. Water is imported into Tulare Lake Basin using facilities of the California State Water Project (SWP) and the Federal Central Valley Project (CVP). Water is exported from the Basin using the SWP and CVP facilities in combination with those developed by local water districts.[153] The facilities and pathways that export Kings River water to the San Joaquin River are described in the Kings River hydrography section and will not be repeated here.[154]

4.6.1 Import and Export Facilities

The CVP imports San Joaquin River water into the Tulare Lake Basin through the Friant-Kern Canal, and imports Delta water into the Basin through the Delta-Mendota Canal and the San Luis Canal. The San Luis Canal is the joint Federal/State facility that provides Delta water mainly to the Westlands Water District, located in the northeast portion of the Tulare Lake Basin

---

[152] Tulare Lake Basin Water Storage District, 1981. The documents notes: "The existing distribution system is, with a few exceptions, set up for farming in "sections" of approximately 640 acres each. Distribution from the main canals to individual fields is provided by smaller privately owned canals."

[153] Stormwater runoff of the Fresno County Stream Group, including Big Dry, Redbank, and Fancher Creeks, can be exported to the San Joaquin River. These creeks are in the Tulare Lake Basin and would naturally discharge their flow onto the alluvial surface north of the Kings River. Big Dry Creek runoff can be directed through a diversion canal into the Little Dry Creek channel which flows into the San Joaquin River about six miles downstream of Friant Dam. The rural and urban stormwater runoff into the Fresno Metropolitan Flood Control District service can be directed into canals and other drainage features that discharge into the San Joaquin River. Fresno Metropolitan Flood Control District. 2004.

[154] Export of Kings River water to the San Joaquin River can occur through the North Fork of the Kings River and James Bypass as well the Fresno Irrigation District canal system.

lowland area.[155] On maps 3 and 4, the San Luis Canal is included as part of the SWP's California Aqueduct.

4.6.1.1 Delta-Mendota Canal

The Delta-Mendota Canal (DMC) brings Delta water from the Tracy Pumping Plant to its terminus at Mendota Pool. The canal is about 117 mi (188 km) long and has an initial diversion capacity of 4,600 cfs, which gradually decreases to 2,950 cfs at the terminus.[156] Normally the Mendota Pool is supplied by the DMC and groundwater pumped from the surrounding lands but in wet periods the Pool receives inflow from the San Joaquin River from the east, Panoche Creek and other local runoff from the west and the Kings River from the south. Mendota Pool is created by Mendota Dam, located just downstream of the junction of the San Joaquin River and the Fresno Slough; the Pool has a capacity of 3,000 acre-ft and a surface area of 1,200 acres and is generally considered to extend to the south past the Mendota Wildlife Area (MWA) to the terminus of the James Bypass.[157] Pool water is diverted at its southern end to the users in the Tulare Lake Basin by canals and pumping plants.[158] Tulare Lake Basin users include the James Irrigation District, Tranquility Irrigation District, Fresno Slough Water District, and the Westlands Water District. [159]

4.6.1.2 Friant-Kern Canal

The Friant-Kern Canal carries water by gravity over 151.8 miles in a southerly direction, from Millerton Reservoir on the San Joaquin River to the canal terminus at the Kern River, four miles west of Bakersfield.[160] The canal has an initial capacity of 5,300 cfs that gradually decreases to

---

[155] San Luis Canal extends 102.5 miles from the O'Neill Forebay, near Los Banos, in a southeasterly direction to a point west of Kettleman City.
[156] United States Bureau of Reclamation, 2001. The design capacity is 3,200 cfs and the actual capacity is 2,950 cfs.
[157] McBain and Trush, eds., 2002., and United States Bureau of Reclamation, 2001. The Mendota Wildlife Area is a State of California managed wildlife area.
[158] Most of Mendota Pool water is sent north in canals or released into the San Joaquin River for downstream diversion. Although the area around much of the James Bypass drains into the San Joaquin River, it is included within the Tulare Lake Basin.
[159] James Irrigation District (ID) has a CVP contract of 45,000 acre-ft per year and Tranquility ID's CVP contract is for 34,000 acre-ft per year.
[160] In addition to its import of San Joaquin River water, the Friant-Kern canal can also carry water from the Fresno River that is diverted into the San Joaquin River through the Soquel diversion.

2,500 cfs at the Kern River.[161] There are approximately 110 points where water can be diverted from the canal, primarily to serve irrigation and groundwater recharge needs.[162] The canal can discharge water into the following natural drainages, given in north to south order: Little Dry Creek, Kings River, Cottonwood Creek, St. John's River, Kaweah River, Porter Slough, Tule River, Deer Creek, White River, Poso Creek, and the Kern River.[163,164]
Water can be pumped into the canal at stations along the Kings River (800 cfs capacity), St. John's River (900 cfs capacity), and Tule River (800 cfs capacity).[165] These pumping stations are used to divert excess river flow into the Friant-Kern Canal to other users along the canal, or to the Kern River for use within the Basin or export into the California Aqueduct.[166] The Tule River pumps and platform are a permanent installation; on the Kings and St. John's rivers, the pumping platforms are permanent but the pumps are brought in only when needed.[167] A permanent pumping facility at Wutchumna Dam occasionally pumps water into the Friant-Kern Canal (see pages 21 and 27). Water can also enter the canal through small inlet drains and pumps.[168]

The Friant-Kern Canal is used mainly to import water into the Basin for water supply purposes. In wetter years the canal is used as a flood control facility to reduce high flows in the San Joaquin River and to reduce flows into the Tulare Lakebed. The flood flows in the canal can be discharged into the Kern River and exported out of the Basin via the Kern River Intertie and the Cross Valley Canal into the California Aqueduct or can be used for water supply purposes within the Tulare Lake Basin.[169] Flood flows imported from the San Joaquin River are also occasionally

---

[161] URS, 2002. A USBR web site states the initial capacity is 5,000 cfs decreasing to 2,000 cfs http://www.usbr.gov/dataweb/html/friant.html
[162] The canal can make deliveries to 20 long-term agricultural water contractors, three long-term municipal contractors, 8 Cross Valley Canal contractors, and at least 17 short-term or temporary users. URS, 2002.
[163] Gary Perez, Friant Water Authority, personal communication, April 13, 2005. The wasteway into Little Dry Creek was built for maintenance and emergency purposes; no canal water has been discharged into Little Dry Creek for past 25 years.
[164] Jerry Pretzer, USBR, personal communication, May 2005.
[165] Johnson, W., 2004.
[166] See discussion of frequency of pump-ins in the following section on import and export amounts. Daily records of the Friant-Kern Canal pump-ins are available for 1997 and 1998. In 1997 the Kaweah/St. John's River and Tule River pump-ins occurred for 53 and 42 days, respectively, during the winter. In 1998 the Kaweah and Tule River pump-ins occurred for 113 and 121 days in the winter and spring.
[167] Gary Perez, personal communication June 29, 2006
[168] Gary Perez personal communication, May 2005. At some of the locations where intermittent drainages enter the canal, sump pumps are occasionally required to drain water that backs up into adjoining fields.
[169] Currently water from the Friant-Kern canal enters the CVC through a gravity turnout from the Arvin-Edison Canal located just downstream of that canal's intake at the Friant-Kern Canal. For accounting purposes, the flood flows in

discharged back into the Kings River, such as occurred in late May and early June of 2005, and routed back to the San Joaquin River via the North Fork of the Kings River and James Bypass.[170] Hydrographic pathways for the possible conveyance of water from the Friant-Kern Canal to the California Aqueduct also exist through its connection with the Arvin Edison Canal, the Kern River Canal (which connects to the California Aqueduct through the Kern Water Bank Canal), the Shafter-Wasco Irrigation District system (which connects to the California Aqueduct through Semitropic Water Storage District), and Poso Creek (which connects with the Shafter-Wasco system).[171] These pathways are described in technical memoranda for the Friant-MWD partnership but are currently not used for conveying water from the Friant-Kern Canal to the California Aqueduct.[172]

4.6.1.3 California Aqueduct

The 444-mile-long California Aqueduct starts at the Delta Pumping Plants and flows south by gravity into the San Luis Joint-Use Complex, which includes O'Neill Forebay, San Luis Reservoir, the Gianelli Pumping-Generating Plant, Dos Amigos Pumping Plant, and the San Luis Canal. The San Luis Canal section of the California Aqueduct serves both the SWP and the CVP; it ends near Kettleman City, shortly before the Coastal Branch Aqueduct branches off of the main California Aqueduct. Below Kettleman City, the main aqueduct has 40 turnouts and 4 pumping plants in the Tulare Lake Basin.[173] The last pumping plant, A.D. Edmonston, lifts the Aqueduct water over the Tehachapi Mountains where the Aqueduct splits into the East and West branches. In Southern California, the Aqueduct branches flow into four reservoirs: Quail, Pyramid, Castaic, and Silverwood Lakes.

The California Aqueduct supplies water to five SWP contractors in the Tulare Lake Basin: County of Kings, Dudley Ridge Water District, Empire West Side Irrigation District, Tulare Lake Basin

the Friant-Kern Canal that are routed to the California Aqueduct are normally derived from the pump-ins of the Tulare Basin rivers while the San Joaquin River flood flows are assumed to stay in the Tulare Basin.

[170] Kevin Richardson, USACOE, personal communication, June 2005. This routing of San Joaquin River high runoff occurs relatively infrequently only when there is insufficient capacity in the San Joaquin River channel below Friant Dam but sufficient capacity exists further downstream and exists in the Friant-Kern Canal and Kings River and James Bypass.

[171] SAIC, 2003a

[172] SAIC 2003a and SAIC 2003b

[173] California Department of Water Resources, 1999b.

Water Storage District, and the Kern County Water Agency.[174] The Aqueduct also transports (or "wheels") CVP water to the Cross Valley Canal for use by the Cross Valley Canal contractors and their exchange partners.[175] In addition to its primary function as a facility to import water to the Tulare Lake Basin, the California Aqueduct exports Tulare Lake Basin water received through the Cross Valley Canal, Kern Water Bank Canal, Arvin-Edison Intertie, Kern River Intertie, and Semitropic Water Storage District to Southern California.[176]

4.6.1.4 Cross Valley Canal

The Cross Valley Canal (CVC) is a locally controlled facility built in 1975 to transport water from the California Aqueduct approximately 16 mi (26 km) through a series of seven pump lifts to the east side of the Tulare Lake Basin near the City of Bakersfield. Water from the Kern River, the Friant-Kern Canal and various water production wells can be introduced into the CVC, and delivered by the normal eastward flow pumping operation, gravity reverse flow, or both at once.[177] Currently water from the Friant-Kern Canal enters the CVC through a gravity turnout from the Arvin-Edison Canal located just downstream of that canal's intake at the Friant-Kern Canal. CVC capacity into the California Aqueduct in the westward gravity flow direction is currently 500 cfs, but this section can be bypassed by diversion to the Kern Water Bank Canal, which can carry 630 cfs to the California Aqueduct.[178]

[174] The Kern County Water Agency provides the SWP water to its 16 member units consisting of various types of water districts.
[175] Through exchange agreements the CVC water in the California Aqueduct may be diverted to users in the Tulare Lake Basin prior to reaching the CVC.
[176] In the 1987-92 drought, temporary siphons were used to put water into the California Aqueduct from the Buena Vista Aquatic Lakes to export water to Southern California (Martin Milobar, Buena Vista Water Storage District, personal communication, May 2005). That connection was described as a future potential pathway for water from the Tulare Lake Basin to move into the California Aqueduct (SAIC, 2003a). During the dry winters of 1991 and 1994, groundwater in the Westlands Water District was pumped into the California Aqueduct (Russ Freeman, Westlands Water District, personal communication, December 5, 2006).
[177] SAIC, 2003a. Water can be pumped eastward from the California Aqueduct at the same time water from the Friant-Kern Canal flows westward. Friant-Kern Canal water can also be siphoned into the Cross Valley Canal flowing to the east but since that operation interferes with the diversions into the Arvin-Edison Canal, it is rarely used (Gary Perez, personal communication, Oct. 27, 2006).
[178] There are plans and funding to build a permanent bi-directional connection directly between the Friant-Kern Canal and the CVC and to increase the capacity of the CVC into the California Aqueduct.

4.6.1.5 Kern Water Bank Canal

The Kern Water Bank Canal, which was completed in 2001, has a capacity of 750 cfs to convey California Aqueduct flow east to recharge basins and can convey 630 cfs of recovered groundwater or other water by "reverse" flow west to the California Aqueduct. The Aqueduct turnout for the Kern Water Bank Canal is less than a mile south of the turnout for the Cross Valley Canal but is in a different California Aqueduct check pool so that it has a greater capacity for reverse flow.[179] The Kern Water Bank Canal was designed to provide as much flexibility as possible with flow in both directions and has the capability to divert flow to or from the Cross Valley Canal. The Kern Water Bank Canal can receive water directly from the Kern River and is also connected to the City of Bakersfield's Kern River Canal, which diverts and transports Kern River water.

4.6.1.6 Arvin-Edison Intertie

The Arvin-Edison Water Storage District (AEWSD) recently constructed an intertie pipeline from its delivery canal to the California Aqueduct as part of the AEWSD / Metropolitan Water District Management Program. The water is pumped from the end of the canal into a 175 cfs capacity 4.5-mi (7.2 km) pipeline to the California Aqueduct.[180] However, the current capacity is limited to 150 cfs, which is the capacity of the AEWSD South Canal that conveys water to the Intertie Pipeline.[181]

4.6.1.7 Kern River Intertie

The Kern River Intertie, completed in 1977, is located just downstream from the Buena Vista Inlet Canal and consists of a sedimentation basin, a gated concrete lined diversion channel from the sedimentation basin to the California Aqueduct and an emergency bypass channel from the sedimentation basin to the Kern River/Buena Vista Outlet channel. It has a capacity of 3,500 cfs and is used only when very high flows on the Kern River cannot be utilized and has the

---

[179] SAIC, 2003a.
[180] The reverse gravity flow capacity from the California Aqueduct back to the AEWSD canal is 125 cfs.
[181] A proposal to expand the South Canal capacity is currently being reviewed (Jeevan Muhar, personal communication, Dec. 2006).

potential to cause flooding on the Buena Vista or Tulare lakebeds, as previously described in the Kern River Hydrology section of this report.

4.6.1.8 Semitropic Water Storage District

The Semitropic Water Storage District (SWSD) can convey water to the California Aqueduct at an existing turnout. Currently SWSD can pump up to 300 cfs of banked groundwater back into the California Aqueduct.[182] SWSD can receive water from the Shafter-Wasco Irrigation District (SWID) through a small, 25 cfs pipeline. SWID receives water from the Friant-Kern Canal and from Poso Creek.[183] The SWID-SWSD connection provides a potential pathway for a water exchange program currently being evaluated between Friant Water Users Authority members and the Metropolitan Water District.[184]

4.6.2 Import and Export Amounts

The annual amount of Tulare Lake Basin imports and exports varies with the amount of runoff in the source and receiving hydrologic basins.[185] Since 1990, imports from the SWP and CVP are the highest when the source basin has above-average but not extremely high runoff, such as occurred in 1993, 1996, 1999; especially if runoff in the Tulare Lake Basin is somewhat lower than average, as in 1999. The imports are reduced in dry years because of limited runoff and are reduced in the very wet years because the local Tulare Lake Basin supplies are abundant and more economical to use than the imported supply. In average and drier years, the net import of water from the San Joaquin River and the Delta is generally higher than the water available from Tulare Lake Basin runoff.

Imports from the San Joaquin River via the Friant-Kern Canal occur year round and are interrupted periodically in the late fall or winter for canal maintenance. The highest canal diversions generally occur in the period from June to August.

[182] Semitropic Water Storage District, 2004.
[183] Poso Creek has seasonal runoff from its watershed and also receives Friant-Kern Canal water and Calloway Canal water derived from the Kern River.
[184] SAIC, 2003a.
[185] The Sacramento River Basin is the source basin for the SWP and the San Luis Canal and DMC deliveries of the CVP. The San Joaquin River mainstem runoff is the source basin for the Friant-Kern Canal.

The highest exports from the Tulare Lake Basin occur in the very wet years when Tulare Lakebed flooding concerns require that Kings River runoff be sent north to the San Joaquin River; and Kings, Kaweah, and Tule River water is pumped into the Friant-Kern Canal and sent south into the Kern River or the Cross Valley Canal for export to the California Aqueduct. During the 1978-2006 period when records for the Kern River Intertie and Friant-Kern Canal pump-ins are available, Kings River water was pumped into the Friant-Kern Canal on five occasions, the Kaweah River was pumped in seven times, the Tule River was pumped in nine times, the Kern River Intertie was used 10 times, and Kings River water was exported to the San Joaquin River 14 times in the 29-year period.[186] In 1978, 1980, 1983, 1986, 1998, and 2006 the combined export into the San Joaquin River and California Aqueduct was 700 TAF or more. The combined export in 1983 was over 3 MAF, more than double the next higher amount in 1998 of approximately 1.3 MAF.

In drier years, groundwater banked in Kern County is exported into the California Aqueduct. These dry year exports occurred in 1991, 1992, 1994, 2001, and 2004 and are comparatively much smaller than the wet year exports; in 2001 the total export was 158 TAF.[187] Groundwater is pumped into the canal systems that connect with the California Aqueduct such as those in Arvin-Edison and Semitropic Water Storage Districts, or the Kern Water Bank Canal. It is also possible that surface water already in the systems is co-mingled with the groundwater and transported into the Aqueduct.[188]

Table 8 shows the import and export amounts for the 1998, 2000, and 2001 water years. The Tulare Lake, San Joaquin River, and Sacramento River Basins were all very wet in 1998; 2000 was above average in the Sacramento River Basin, about average in the San Joaquin River Basin, and below average in the Tulare Lake Basin; 2001 was moderately dry in the Sacramento River and even drier in the San Joaquin River and Tulare Lake Basin.

---

[186] KWCA, 2003a, USBR, 2004 and Gary Perez, personal communication, June 29, 2006. The Tule River pump-in during 1980 and the Kings River pump-in during 1995 were used within the Tulare Lake Basin according to KCWA records.

[187] Dan Peterson, DWR, personal communication, April 7, 2005.

[188] From an accounting standpoint, only the recoverd groundwater is exported, but the water that is actually exported may include surface water from the Kern River or Friant-Kern Canal that is already in the distribution system, although the type of water actually exported (groundwater or surface water) cannot be verified without a site visit and further investigation. The accounting of the groundwater recovery and export programs is beyond the scope of this report.

The amount of Kings River irrigation tailwater discharged into the San Joaquin River through the Fresno Irrigation District system is unknown but is likely less than 5 TAF in most years.

4.7 Summary of Surface Water Movement in the Tulare Lake Basin

In most years and in most areas, the quantity and movement of surface water in the lowland Tulare Lake Basin is largely determined by irrigation and other water supply requirements, such as moving water to groundwater recharge areas. In years of high winter rainfall and spring snowmelt runoff, the movement of water is also influenced by flood control concerns. Surface water is derived from a combination of Basin runoff and imported water from the San Joaquin River and the Delta.

In the average and drier years, surface water moves throughout the Basin primarily by gravity flow in natural stream channels and constructed canals or ditches. Pumping is needed in some locations to distribute irrigation water and to drain water both on a large-scale level (such as the Tulare Lakebed) and on the small-scale, farm level. Surface water generally does not leave the Basin in average and drier years, except for occasional tailwater from the Fresno Irrigation District and urban runoff from the Fresno Metropolitan Flood Control District.[189]

In wet years, large amounts of runoff can exceed the capacity of numerous channels in the Basin, allowing surface water to move over a more extensive area. During these years, water is also exported out of the Basin into the San Joaquin River or California Aqueduct for flood control purposes. Water in natural and man-made conveyance that connects, either by pumping or gravity, with the Kings or Kern River systems has the potential to be exported in the wetter years. Excess water that cannot be exported, stored or used for water supply purposes is directed to the former lakebeds of the Basin (Kern Lake, Buena Vista Lake and Tulare Lake). In the extremely high-runoff year of 1983, water was pumped out of the Tulare Lakebed and out of the Basin.

---

[189] Groundwater recovery (banking) programs in Kern County in drier years may also cause surface water to be transported into the California Aqueduct. In past dry years such as 1991 and 1994, groundwater was also directly pumped into the California Aqueduct from the Buena Vista Lakebed and from Westlands Water District.

Table 9 (Hydrographic and Hydraulic Connections) summarizes the principal surface water pathways that connect the four major watersheds of the Tulare Lake Basin to each other, to the Tulare Lakebed, and to areas outside of the Basin. The table shows the river reaches, major canals, and Tulare Lakebed facilities that are immediately connected to each other through gravity or pumps, and identifies the frequency of that connection. In the cases where the connection shown is not direct, the water body or bodies providing the connection are listed in a footnote.

The principal pathways for water and organisms to move out of the Basin are listed in Table 11a. These pathways can also be traced step-by-step following the connections shown in Table 9. For example, water that flows into the San Joaquin River from the mainstem Kings River passes first from the mainstem Kings to the North Fork Kings River/James Bypass, then to the Mendota Pool and into the San Joaquin River. Another example shows how water can be traced from the Kings, St. John's, or Kaweah rivers into the California Aqueduct: water is pumped from these rivers into the Friant-Kern Canal, which flows to the Kern River; the Kern River then connects via gravity-flow to the California Aqueduct through the Kern River Intertie. Table 11b identifies potential pathways for organisms that can swim upstream against the current to move out of the Basin. In the following section, the potential for aquatic species and toxicants to use these non-swimming and swimming pathways is evaluated.

5.0 POTENTIAL FOR MOVEMENT OF AQUATIC SPECIES AND TOXICANTS OUT OF THE BASIN

5.1 Overview of Aquatic Species and Toxicant Movement

The remainder of this report describes the potential for aquatic organisms and toxicants to move within the Tulare Lake Basin and potentially move or be transported out of the Basin using the hydrographic pathways described in the previous section. This evaluation is confined to the Tulare Lake Basin lowlands and the terminal reservoirs on the four principal rivers. West side Tulare Lake Basin drainages were not included in this evaluation due primarily to their ephemeral nature and minimal runoff contribution to the lowlands relative to the major east side drainages.

Aquatic organisms (both swimming and planktonic forms) and toxicants can potentially move or be transported between river drainages via stream channels, canals, and other waterways in the Basin. Limited information is available regarding the actual movement of aquatic organisms within the Basin and between the Tulare and San Joaquin basins, and between the Tulare Lake Basin and Southern California. In addition to the evaluation of natural and man-made water conveyance systems, fisheries information obtained during and after the 1983 high water year was used to describe the potential for movement within the Basin during high outflow conditions. During the 1983-84 period, CDFG documented the escape and subsequent distribution of white bass within the lowlands of the Tulare Lake Basin and the potential for movement into the San Joaquin River system. Since 1983 represents the longest duration of high runoff in the historical record and white bass were considered a potentially significant threat to several fish species outside the Basin, 1983 appears to represent a "worst-case scenario" relative to the potential for aquatic species (especially exotics) and toxicants to move outside of the Basin.[190]

Potential movement pathways were evaluated for both non-swimming organisms and toxicants that move with the flow (gravity and pumping), and for swimming organisms (i.e. fish) that can move with or against the flow. Specific movement pathways through natural and man-made channels (e.g., connections between the St. John's/Kaweah and Kings rivers) were evaluated, where possible, during a site visit conducted in 2006. Although some potential pathways and/or connections were not evaluated, data were obtained from the literature and from knowledgeable local experts. Movement corridors for mobile (swimming) organisms were evaluated relative to the presence of potential fish barriers or other obstructions to fish movement. A field visit was conducted on June 29 and 30, 2006 to evaluate some of the hydrographic features within the Basin and examine potential pathways for aquatic organisms. Potential pathways and connections that were evaluated during the field visit are provided in

[190] Although larger winter floods occurred in other years, 1983 had the highest annual runoff volume including a large, long duration spring snowmelt flood.

Appendix 2. Relevant information on water movement and aquatic species issues within and around the Basin was also obtained from various agencies (CDFG, DWR, and FWUA).

The following information on Tulare Lake Basin fish populations and associated aquatic habitats was based primarily on information obtained from CDFG (1987), Moyle (2002), and from personal communications with CDFG biologists Randy Kelly, Stan Stephens, and Jim Houk (2004, 2005) from the Fresno, California office. The majority of the information regarding white bass was derived from CDFG (1987), Moyle (2002), and from CDFG biologists Randy Kelly and Stan Stephens.[191]

5.2 Aquatic Habitats and Fish Assemblages in the Basin

5.2.1 Aquatic Habitats

Aquatic habitats within the Basin generally favor warm-water fish species. Substantial water diversions, stream channelization, and construction of canals and levees have dramatically altered both aquatic and riparian habitats in this region. Of the three major basins in California (Sacramento, San Joaquin, and Tulare) the most substantial alteration and loss of aquatic/wetland habitats has occurred in the Tulare Lake Basin.[192, 193, 194] The extensive lake bottom and associated marshes of historical Tulare Lake have been transformed to other land uses and the native flora and fauna have primarily disappeared from this area.

Many of the stream channels and canals in the Basin are seasonally dry as a result of routine irrigation and farming practices. When inundated, these altered rivers, streams, and canals still provide acceptable habitat for many of the fish species that occur in the Basin. Canals and stream sections that normally hold water year-round may support perennial fish populations, though species composition may vary seasonally.

---

[191] Randy Kelly and Stan Stephens, CDFG, personal communications, 2004, 2005, and 2006.
[192] San Joaquin Valley Drainage Program (SJVDP), 1990.
[193] The Bay Institute, 1998.
[194] Davis, 1998a

5.2.2 *Fish Assemblages in the Tulare Lake Basin*

Approximately 35 fish species are known to occur in the Basin, most of which are introduced (both game and non-game species) and are also present throughout the Sacramento and San Joaquin river drainages. A list of fish species that are known or expected to occur in the Basin including the four major low-elevation reservoirs (see Map 4) is provided in Table 12. Minnows comprise the majority of the remaining native fish species including Sacramento pikeminnow (*Ptychocheilus grandis*), Sacramento splittail (*Pogonichthys macrolepidotus*), Sacramento blackfish (*Orthodon microlepidotus*), hardhead (*Mylopharodon conocephalus*), and California roach (*Lavinia symmetricus*). Other native species in the Basin include Sacramento sucker (*Catostomus occidentalis*), riffle sculpin (*Cottus gulosus*), threespine stickleback (*Gasterosteus aculeatus*), western brook lamprey (*Lampetra richardsoni*), Kern brook lamprey (*L. hubbsi*), and rainbow trout (*Oncorhynchus mykiss*) (which are transported downstream from higher elevation areas during high flow periods).

5.2.3 *Fish Species of the Lowland Tulare Lake Basin Rivers*

Fish species compositions present in the Kings, St. John's/Kaweah, Tule, and Kern River drainages downstream of their respective reservoirs are generally typical of most of the large, low-elevation reservoirs on the western slopes of the Sierra Nevada. Of the four large reservoirs in the Basin, the most diverse fish assemblage occurs in Pine Flat Reservoir, which is typically managed as a two-story fishery (warm-water species on top, cold-water species on the bottom) in average or higher water years. Lake Isabella is also occasionally managed as a two-story reservoir and has a relatively diverse fish population. Kaweah Reservoir and Lake Success are too warm in the summer to support cold-water fish species, though trout are planted in these two reservoirs during the winter. As a result, fish populations are typically less diverse in the two reservoirs.[195]

In general, fish species compositions in the Kings, Kaweah, Tule, and Kern rivers downstream of each of the above reservoirs are similar to the species assemblages present in the

[195] Stan Stephens, CDFG, personal communication, July 2006.

reservoirs.[196] In average and drier years, fish assemblages below these reservoirs are geographically restricted to the upper reaches below the dams for a substantial portion of the year. During most of these years, the majority of the canals and waterways west of Highway 99 do not continuously hold water through the late summer and fall.[197] The Friant-Kern Canal may also be dry, at least in portions, for short maintenance periods each year, generally in the late fall and early winter. However, according to CDFG, a small amount of water (several inches deep) typically remains in the canal, even during these maintenance periods[198]. Water also remains in most of the siphons, which can support a large fish population during maintenance periods. At these times, fish die-offs can occur, usually as a result of low dissolved oxygen concentrations. Fish that survive these periodic low water conditions are available to repopulate the canal when water movement is reestablished.

In drier years during the summer/fall irrigation period, downstream areas on all four rivers may have intermittent or minimal surface flows. In these years, the lower extent of continuous surface flows on the four major rivers generally occurs around Highway 99. In this report, river and stream reaches below Highway 99 are designated as "downstream areas" (see Map 4 - *Hydrography of the Lowland Tulare Lake Basin*). Table 12 shows the fish species known to occur within the Tulare Lake Basin, and expected presence in Pine Flat, Kaweah, Success, and Isabella reservoirs and in downstream river reaches.

In higher runoff years, flows in the four major rivers extend well into the Basin, allowing fish populations to move downstream and laterally into numerous canals and stream channels, and eventually into the Tulare Lakebed. During irrigation periods, game and non-game fishes present in the Basin can migrate upstream through canals, sloughs, and ditches that branch off of the Kings River. Fish will often remain in these canals as long as water is present (see Table 6).

The Kings River, from Pine Flat Dam downstream to Kingsburg, supports a year-round cold-water fishery that is maintained by CDFG. Historically, both Chinook salmon and steelhead

[196] Jim Houk, CDFG, personal communication, May 2005.
[197] Jim Houk, CDFG, personal communication, May 2005.
[198] Stan Stephens, CDFG, personal communication, July 2006.

occurred in the Kings River. The last documented sighting of Chinook salmon in the Kings River system occurred in 1970 by Peter Moyle who observed juveniles near the mouth of Mill Creek, a tributary just below Pine Flat Dam. Below Kingsburg much of the Kings River is commonly dewatered when there are no irrigation or flood control requirements. As a result, fish are only found seasonally in this middle reach and generally originate from upstream areas, though fish may also move into this reach from downstream locations. The lower reach of the river above Empire Weir No. 1 typically remains inundated year-round and provides habitat for many of the fish species present in the drainage.

The St. John's/Kaweah River downstream of Terminus Dam primarily supports a warm-water fishery. A cold-water trout fishery exists immediately below the dam during the fall and winter, and is supported by trout moving out of Lake Kaweah. Summer water temperatures in this area are too warm to sustain cold-water fish species throughout the year. Many of the same fish species that occur in Lake Kaweah are also present in the river downstream of the lake.

The Tule River immediately below Success Dam supports a small fish community and limited sport fishery. The river downstream of the dam is frequently dry, limiting the size of the seasonal fish population. The composition of fish species in this reach is similar to that found in the lake.

The Kern River below Isabella Dam generally supports a similar assemblage of warm-water fish species as those present in the rivers below Pine Flat Reservoir, Lake Kaweah, and other locations within the Tulare Lake Basin. However, CDFG stocks rainbow trout below the dam, where a relatively good cold-water fishery exists for a portion of the year. Further downstream (below Bakersfield) the river is usually dewatered as a result of diversions for agriculture or groundwater recharge.[199] Very few fish are capable of surviving these seasonally dewatered conditions.

---

[199] In recent years, summer recreational flows have been maintained through Bakersfield.

5.2.4 White Bass and Other Introduced Species

The majority of fish species present within the Tulare Lake Basin have been introduced. Many of these introduced species can negatively affect native fishes, especially those species that are in direct competition with native fish for available resources or those that may hybridize with native fish. Most of the non-native species present within the Basin also occur in the San Joaquin and Sacramento basins, as well as in other regions of California. However, white bass, which were present in the Basin from the 1970's to 2000, represented a potentially significant threat to some native and introduced fishes outside the Basin, especially in the Sacramento-San Joaquin Delta.[200]

In 1983, high runoff caused substantial flooding within the Basin allowing white bass to escape from Lake Kaweah and Pine Flat Reservoir. As a result, large numbers of fish were washed downstream and rapidly became well established in Tulare Lake and in several other areas in the Basin. During this period, CDFG became concerned that pumping operations to transport water out of the Basin could potentially provide a pathway for white bass to leave the Basin and migrate to the Delta. In response, fish barriers and pump screens were installed to contain white bass, and eventually chemical treatment was employed to eliminate the bass altogether. Due to the potential negative impact of white bass introductions into the San Joaquin and Sacramento basins, this report uses the 1983 flood event and white bass incident as a worst-case scenario for evaluating the current potential for swimming and non-swimming organisms to move outside the Basin.

5.3 White Bass and Potential Impacts on Native Fishes

The following discussion provides information on: the life history of white bass; the distribution of white bass within the Basin prior to, during, and following the 1983 flood event; and potential impacts of white bass on native species in California, especially the Sacramento-San Joaquin Delta. [201]

---

[200] Moyle, P. B., 2002.

[201] California Department of Fish and Game, 1987., and personal communications with CDFG fisheries biologists Randy Kelly and Stan Stephens from the Fresno, California office, May 2005.

5.3.1 General Life History of White Bass

White bass are native to the Great Lakes region, the Mississippi River system, and the southern United States. White bass inhabit open waters of large lakes and reservoirs and slow-moving rivers. Although this species prefers warm, slightly alkaline lakes and reservoirs, white bass are highly adaptable and may be found in a wide variety of lakes and rivers, and in estuaries along the Gulf of Mexico.[202] They can tolerate salinities of 20 ppt, but are normally found at lower salinities. Optimum water temperatures for white bass range from about 28-30 °C (82-86 °F), but can tolerate water temperatures approaching 34 °C (93 °F) for extended periods of time.[203]

White bass tend to swim in schools and remain near the surface of the water. They are capable of moving long distances in short periods, both upstream and downstream and quickly colonize new areas. Tagged fish have been documented moving up to 131 mi (211 km) in 131 days.[204] This species has also been known to contribute to tail-water fisheries below dams, especially during the winter and early spring. White bass are voracious, visual piscivores (fish predators) and feed primarily on small fish, though some rely almost entirely on zooplankton.

Spawning normally takes place in the late winter/early spring (mid-January to early May), starting with 2-year olds. Spawning typically occurs in lakes at the mouths of inlet streams, and preferentially in large streams where they have been found to migrate up to about 125 mi (200 km) to spawn. During spawning activities, white bass typically form large aggregations in the water column and spawning groups will rise to the surface and release eggs and sperm. Eggs are fertilized as they sink to the bottom and stick to the substrate. Larvae initially stay in shallow water near spawning areas, but soon become planktonic. This species is highly fecund, producing from about 61,000 to nearly 1 million eggs per female.[205]

[202] Moyle, P. B., 2002.
[203] Moyle, P. B., 2002.
[204] California Department of Fish and Game, 1987.
[205] Egg production can be highly variable between populations.

5.3.2 Potential Impacts of White Bass on the Sacramento-San Joaquin Delta

The introduction of white bass into the Sacramento-San Joaquin Delta could potentially create significant ecological and economic impacts to existing fisheries in both the Delta and in the Sacramento and San Joaquin river systems.[206] Existing Delta fish assemblages do not include any species with life history characteristics comparable to white bass. Even though the effects of such an introduction on Delta fisheries are unknown, it is likely that conditions in the Delta would be highly favorable for white bass.[207]

The establishment of white bass in the Sacramento and San Joaquin river systems and in the Delta could significantly affect existing sport and commercial fisheries for Chinook salmon and striped bass.[208] Negative impacts to native species including Central Valley steelhead, Sacramento splittail, and delta smelt could also be substantial. Based on life history characteristics, white bass would likely conflict with striped bass via competition, predation, and hybridization. It is likely that the ecology and foraging behavior of white bass are sufficiently different from those of striped bass that white bass would create additional predation pressure on native fishes and their larvae.[209] The presence of white bass in the Sacramento and San Joaquin rivers and in the Delta could also have deleterious effects on the recovery of threatened and endangered fish species and increase the likelihood of additional listings. In addition to ecological impacts, economic losses (based on 1987 data) that could potentially result from the establishment of white bass in these systems could exceed 14 million dollars annually.[210]

Based on information regarding white bass interactions with other fish species, white bass adults would likely prey on young striped bass and the young of both species would be in direct competition for limited food resources.[211] The food base for young game fish in the Delta has severely declined in recent years, and competition with white bass could substantially affect survival of young striped bass and other fish.[212]

[206] California Department of Fish and Game, 1987., and Moyle, P. B., 2002.
[207] Moyle, P. B., 2002.
[208] California Department of Fish and Game, 1987., and Moyle, P. B., 2002.
[209] Moyle, P. B., 2002.
[210] California Department of Fish and Game, 1987.
[211] Moyle, P. B., 2002.
[212] California Department of Fish and Game, 1987.

Chinook salmon would also be adversely affected, primarily due to predation on young salmon by adult white bass. White bass, which have a tendency to migrate upstream and contribute to tail-water fisheries, have also been known to concentrate on spawning riffles in the winter and spring. This behavior would likely result in increased densities of predatory fishes in salmon spawning habitats and increased predation on emerging salmon fry.

5.3.3 The History of White Bass in California

In 1965, CDFG introduced white bass into Lake Nacimiento within the Salinas River watershed (San Luis Obispo County) to evaluate their suitability as a gamefish in other California reservoirs. The Salinas River drainage was selected due to its isolation from other watersheds, which would restrict potential movement to within the drainage. By 1970, white bass had become well established in the reservoir and in the Salinas River above and below the reservoir. In 1977, CDFG biologists verified the unexpected presence of white bass in Lake Kaweah (Tulare County). Based on undercover investigations by law enforcement, several individuals from Tulare County were found to be responsible for illegally introducing white bass into Lake Kaweah over a period of years prior to 1977.[213] By 1977, there was a self-sustaining population of white bass in the lake.

For the next several years, CDFG considered a variety of options to eliminate or control the spread of white bass. Finally, in 1983, CDFG management mandated a plan to stock Lake Kaweah with sunshine bass, a hybrid cross between white bass and striped bass. CDFG was aware that white bass and striped bass or their hybrids could successfully reproduce in the laboratory, though successful spawning had not been documented in the wild. In addition, they had been informed that this species was sterile.[214] Although, available literature indicated that a small percentage could be fertile. It was hoped that mature sunshine bass would compete with white bass for food and space resources, resulting in decreased numbers of white bass. However, white bass continued to thrive in the lake indicating that the experiment did not reduce the numbers of white bass.[215]

[213] California Department of Fish and Game, 1987.
[214] Stan Stephens, CDFG, personal communication, July 2006.
[215] California Department of Fish and Game, 1987.

In the winter and spring of 1983, record rainfall in the Basin created high runoff conditions in all four major river drainages. During this period, high runoff into Lake Kaweah created spill conditions at Terminus Dam that lasted for several months. Water that spilled over the dam and into the river below, as well as floodwaters from the other three major rivers, flowed through streams, canals, and sloughs into the Tulare Lakebed. As a result, the Lakebed was quickly flooded, inundating a total of 101,600 acres. This substantial level of flooding occurred despite efforts by local reclamation districts to divert floodwaters into the Friant-Kern Canal, and the export of over three million acre-feet of primarily Kings River and Kern River water out of the Basin.

During the several months that Lake Kaweah spilled, large numbers of white bass escaped over the spillway and moved downstream into the Tulare Lakebed. In a relatively short amount of time, white bass became well dispersed throughout Tulare Lake and surrounding canals and waterways. The population rapidly increased in numbers and a popular fishery for white bass developed in the Basin. CDFG documented one-year-old white bass that had grown up to 12 inches in length in one year, and were reproducing.[216]

In 1986, white bass were also discovered in Pine Flat Reservoir. Anglers caught several bass, and additional specimens were captured during intensive sampling efforts conducted by CDFG and Fresno State University. Individuals that wanted to impair CDFG's attempts to control white bass in Lake Kaweah were likely the source of this illegal introduction.[217] Within the same general time frame, several fishermen also documented a few white bass in Lake Success, also a result of illegal introductions.

---

[216] Randy Kelly and Stan Stephens, CDFG, personal communication, August 2006.
[217] California Department of Fish and Game, 1987.

5.4 White Bass Issues During and Following the 1983 Flood Event

The following section focuses on efforts by CDFG to restrict and manage the distribution and movement of white bass within and potentially outside of the Basin during and following the 1983 flood event.[218] The current status of non-native fishes within the Basin is also discussed.

5.4.1 Efforts to Restrict the Movement of White Bass

In 1983, the Tulare Lake Reclamation District developed a program to dewater Tulare Lake by pumping floodwaters north into the South Fork Kings River and eventually into the San Joaquin River system. The dewatering program was conducted to reclaim farmland within the lakebed that had been inundated since the spring of 1983. Pumping was initiated in October 1983 and continued intermittently until the program was terminated in January 1984, due to the onset of white bass spawning activities. During the pumping program, the potential movement of white bass out of the Basin was prevented by the efforts of the Tulare Lake Reclamation District No. 749 (TLRD No. 749), local farm companies, and several irrigation districts in cooperation with CDFG and USFWS.

To prevent possible white bass movement north out of Tulare Lake, a large fish barrier was constructed in the South Fork Kings River, approximately 5 mi (8 km) north of the lakebed (see Map 5 - *Tulare Lake Bottom Hydrography*). The barrier, which was installed near Empire Weir No. 1, was designed to prevent passage of fish one-inch in length or longer. Additionally, 18 temporary barriers were installed in selected irrigation canals and ditches north of the Tulare Lakebed and the St. John's/ Kaweah River system (see Map 6: *Lowland Kaweah-Kings Hydrography)* that CDFG believed were hydraulically connected to the Kings River.[219]

Several types of temporary barriers were installed, including perforated plate drop structures, inclined perforated plate screens, grate drop structures, head gates, and electrical fields. In addition to the above barriers, six existing irrigation structures also functioned as barriers, and

---

[218] California Department of Fish and Game, 1987., and personal communications with CDFG fisheries biologists Randy Kelly and Stan Stephens, May 2005.
[219] California Department of Fish and Game, 1987.

restricted the northward movement of white bass out of the flooded lakebed and the St. John's River and Cross Creek systems. These structures were all located on canals that could provide a hydraulic link to the Kings River.[220] White bass were found within these canals at locations downstream of the barriers. The locations and types of fish barriers installed in the 25 canals and ditches are presented on Map 4.

In January 1984, at the beginning of the white bass spawning period, pumping was permanently halted to avoid the potential for moving small larval white bass (less than one-inch in length) past screens that were designed to preclude passage of juvenile and adult fish.

CDFG continued to maintain the 25 fish barriers for several years following the dewatering of the Lakebed. According to CDFG, the barriers functioned properly to restrict the movement of white bass northward or upstream in these canals.[221] By 1987, the barriers had been improved to include more permanent structures that were maintained during normal irrigation and high runoff periods. As part of this white bass containment program, CDFG also required that all permits to physically divert or pump water out of the Basin would incorporate the use of the fish barriers and seasonal pumping restrictions.

5.4.2 Potential White Bass Movement

Based on information obtained during the 1983 flood event and during subsequent dewatering activities, CDFG determined that at least three mechanisms or situations existed for white bass to move out of the Basin.[222] These conditions and pathways included the following:

1) During the period that Tulare Lake and surrounding areas were flooded, CDFG concluded that additional flooding would provide a hydraulic link that could allow white bass to swim up the South Fork Kings River to the mainstem or North Fork Kings River. The Kings River provided a direct link to the San Joaquin River and Delta via Fresno Slough and the James Bypass.

[220] California Department of Fish and Game, 1987.
[221] California Department of Fish and Game, 1987.
[222] California Department of Fish and Game, 1987.

2) Several suspected hydraulic links between the St. John's/ Kaweah River and the Kings rivers exist in a number of irrigation canals that deliver Kings River water to Alta Irrigation District and Tulare Lake that could provide access for white bass into the Kings River. As a result, CDFG installed and maintained 25 barriers in these canals and ditches (see Map 4) to prevent the upstream and northward movement of adult white bass. Without these barriers, CDFG determined that these canals provided the pathways for fish to swim upstream into the Kings River and eventually into the San Joaquin River and Delta.

   In addition to the canals between the St. John's/ Kaweah and Kings rivers, the northern section of the Friant-Kern Canal (operated by the USBR) could potentially provide a pathway for white bass to enter the Kings River through a turnout located upstream of the Kings River siphon. To restrict potential fish movement at this location, CDFG and USBR negotiated an agreement to operate the Kings River Turnout and Siphon to prevent escape of white bass into the Kings River. The head differential and velocity gradient established at the turnout during normal operation create turbulent conditions that fish would not actively move into.

3) Individuals can plant or introduce white bass (and other fish species) into aquatic habitats throughout the state. Introductions of non-native fish species into aquatic habitats have occurred throughout the state. As a result of CDFG efforts to control white bass following the 1983 flood event, CDFG received threats from several individuals regarding planting of white bass into the Delta. To deter the intentional introduction of white bass, the State Legislature increased the penalties for possessing and transporting live white bass.

5.4.3 CDFG White Bass Management Program

In 1987, CDFG finalized the Environmental Impact Report (EIR) for the White Bass Management Program as required by the California Environmental Quality Act (CEQA). This report described the history of white bass in California, the spread of white bass in the Tulare Lake Basin during and after the 1983 flood, and the control methods used to restrict white bass movement northward out of the Basin. The report also addressed the potential repercussions of introducing white bass into the Sacramento and San Joaquin river systems and the Delta, and provided an evaluation of several alternatives designed to either control or eliminate white bass in California. Based on this assessment, CDFG proposed the use of Alternative 4 (of the EIR) to control white bass in the Tulare Lake Basin. This alternative involved the use of chemical treatments (rotenone) only to remove white bass from Lake Kaweah and from Tulare Lake Basin drainages known to contain white bass. According to CDFG, the success of the containment and rotenone program would require the cooperation of irrigation districts and farm companies as well as a stable manpower and funding base. [223] CDFG did not consider the elimination of white bass from California to be feasible or necessary.

The preferred alternative required three separate actions to ensure removal of all white bass from these systems:

1) short-term continuation of CDFG's containment program using fish barriers, as described in the EIR's Alternative 3 (containment alternative);

2) chemical treatment of all waters within Lake Kaweah and the Tulare Lake Basin that might contain white bass; and

3) post-treatment monitoring for the presence of white bass. The containment program would be continued for the duration of chemical treatment and for a limited monitoring period following treatment. A discussion of the containment program is provided in the previous section of this report.

5.4.3.1 Rotenone Control of White Bass

In 1987, CDFG applied Noxfish (rotenone as the active ingredient) to Lake Kaweah and Bravo Lake, the entire drainage area downstream of Lake Kaweah, the lower Tule River, the Friant-Kern Canal, and Tulare Lake Basin canals and irrigation ditches. Barrier operation and

[223] California Department of Fish and Game, 1987.

maintenance continued through the chemical treatment period and for a short period following treatment, until CDFG determined that white bass had been eliminated from the canal systems below these barriers. This decision was based on successfully meeting at least one of the two following criteria: 1) the canal system was chemically treated and all fish were dead; or 2) the canal system was dry with no remaining aquatic habitat.[224]

Approximately one year later, CDFG also chemically treated Lake Success to remove potential white bass that had been previously reported by fisherman. Even though CDFG was not able to confirm the presence of white bass in the lake, they were not willing to risk presence given the illegal introduction into Pine Flat Reservoir.[225]

Following the chemical treatments and associated monitoring efforts, CDFG dismantled some of the 18 temporary fish barriers, and the irrigation districts removed the remaining barriers. The only barrier still in operation occurs at Empire Weir No. 1, where a dam (approximately 12 feet high) limits the upstream migration of fish from the Lakebed and associated canals into the South Fork Kings River.[226] Although, according to CDFG, there may be a potential pathway around Empire Weir No. 1 through the lateral canals in the Tulare Lakebed that connect with canals that bypass the weir on the west side.[227]

5.4.4 Current Status of Non-Native Fish in the Basin

Based on an evaluation of the fish species that occur or have occurred within the Basin, white bass still represents the only known species that could potentially pose a threat to existing fisheries outside of the Basin, especially fish assemblages in the Sacramento and San Joaquin river systems and Delta.[228] White bass life history characteristics and the potential for substantial negative effects on both native and non-native fishes in California, make this species particularly troublesome. All other fish species that currently occur or are known to occur in the Basin are typical of fish species assemblages present throughout much of the Sacramento and

[224] Randy Kelly, CDFG, personal communication, July 2004.
[225] Stan Stephens, CDFG, personal communication, July 2006.
[226] Randy Kelly, CDFG, personal communication, May 2005.
[227] Randy Kelly, CDFG, personal communication, August 2006. However, due to time constraints this pathway could not be verified during the site visit.
[228] According to CDFG, Lake Nacimiento currently contains the only known population of white bass in California.

San Joaquin river systems and the Delta. According to Moyle, white bass may still be present in Pine Flat Reservoir.[229] However, white bass have not been caught in Pine Flat Reservoir in organized angling tournaments, captured during CDFG routine sampling, or reported by anglers since 2000.[230]

Monitoring results from the white bass rotenone program indicated that white bass were eliminated from Lake Kaweah, and from the drainages, farm ponds, and private waters downstream of the dam. Bravo Lake and the Friant-Kern Canal were also chemically treated. CDFG has conducted annual sampling (gill nets, electro-fishing, seines, etc.) for white bass in both Pine Flat reservoir and in the river below the dam for the last 10+ years, and white bass have not been captured in the last seven years. In addition, sport-fishing tournaments have been held in the reservoir annually and white bass have not been observed.[231] Based on the results of CDFG sampling efforts and fishing derbies conducted over several years in Pine Flat Reservoir, it is unlikely that breeding populations still exist in the reservoir. Additionally, spawning habitat within the reservoir is highly limited due to the cold-water input from the Kings River during the spawning period.[232] White bass have not been observed in Lake Kaweah, Bravo Lake, or the Friant-Kern Canal since they were chemically treated in 1987.

Because white bass reproduce quickly and have large numbers of young, can occupy numerous aquatic habitats, and have a propensity to migrate long distances in short periods, caution should be exercised regarding the potential for this species or other similar species to move out of the Tulare Lake Basin.

Currently, the only remaining known population of white bass in California occurs in Lake Nacimiento and in the Salinas River watershed below the lake. This population is considered to be isolated, since the Salinas River drains into the Pacific Ocean.

There is also a potential for other fish species to be established in the Basin via illegal introductions (e.g., northern pike in Lake Davis). The potential effects of introductions of other

[229] Moyle, P. B., 2002.
[230] Stan Stephens and Randy Kelly, CDFG, personal communications, January 2005.
[231] Stan Stephens, CDFG, personal communication, July 2004.
[232] Stan Stephens, CDFG, personal communication, July 2006.

species into the Sacramento and San Joaquin river system would depend on species-specific life history characteristics, behavioral issues, migration and swimming ability, species interactions, and other factors.

5.5 Potential Planktonic Organisms and Toxicants of Concern in the Basin

There were no non-swimming aquatic organisms (planktonic species) identified within the Basin that pose a potential threat to aquatic resources of the Sacramento and San Joaquin rivers or the Delta.

Both manufactured and naturally occurring toxicants occur in the Basin. The most common compounds include a wide variety of chemical fertilizers, herbicides, pesticides, and petroleum products. These chemicals and many others are commonly transported by trucks on surface roads and by railway within the Basin and to locations outside the Basin. Many of these chemicals are also applied to crops within the Basin. As a result, chemical spills could potentially enter natural and man-made waterways and be transported to other locations. In addition, elevated concentrations of naturally occurring trace elements are also present in shallow groundwater in portions of the Basin including arsenic, boron, selenium, molybdenum, uranium, and vanadium.[233]

When flow is present in stream channels, sloughs, canals, and other waterways in the lower portion of the Basin, water borne toxicants could potentially be transported through a variety of hydraulic pathways by gravity flow and by pumping. In general, aerial and ground applications of chemicals are the most likely sources of toxicant releases into Basin waterways. Accidental spills associated with the movement or transportation of chemical products within and through the Basin is also possible. Depending on the magnitude and duration of seasonal flows in a given year and associated water distribution/management requirements and needs in the Basin, toxic chemical spills could potentially be transported for substantial distances via stream channels, sloughs, canals, and other waterways.

---

[233] U.S. Geological Survey, 1998.

5.6 Known and Potential Pathways for Aquatic Organisms and Toxicants to Move Outside of the Basin

The following discussion focuses on two primary conditions that affect the distribution of water within the Basin: gravity flow conditions in streams channels, canals, and other waterways, and associated routine pumping activities during average or drier runoff periods; and high runoff conditions with non-routine pumping patterns. These conditions were evaluated relative to potential pathways for swimming organisms (i.e., fish) and non-swimming (planktonic) organisms and toxicants to move within and outside the Basin.

Detailed information regarding the major hydrographic connections within the Basin (both gravity and pumped) including frequency of occurrence is provided in the hydrology and hydrography section of this report, and is summarized in tables 10 and 11. Some of these connections provide direct distribution pathways for water to move from one location to another, while others involve the movement of water through one or more canals or irrigation systems where mixing of water from several river systems may occur. As a result, fish from one river system can move into other drainages through inter-connecting canals and distributaries.

The hydrographic connections and potential pathways for swimming and non-swimming organisms or toxicants identified in this report, and the potential for fish to migrate or be transported outside the Basin is based largely on surface water distribution patterns associated with both high runoff and average or drier runoff periods. This information includes irrigation water distribution, pumping activities, and natural/gravity flow conditions in the Basin. The white bass management program report prepared by CDFG[234] and CDFG fisheries biologists Randy Kelly and Stan Stephens from the Fresno, California office provided the majority of the information on documented and suspected movement of white bass within the Basin during and following the 1983 flood. Randy Kelly also assisted in identifying possible pathways and connections for fish to move or be transported within and out of the Basin.

---

[234] California Department of Fish and Game, 1987.

Many of the potential fish movement pathways and connections identified below have been verified on the ground. Some barriers (e.g., weirs) or obstructions to upstream movement may be present in one or more of these potential hydrographic pathways that could preclude the passage of fish. In addition to the larger permanent canals, the locations of minor canals and pumps can change periodically and seasonally depending on crop requirements and land use patterns. During extremely high runoff periods, major changes in water movement can occur as a result of natural high flow events and land management activities. As a result, some potential pathways could not be verified during the site visit or through personal communications with knowledgeable individuals.

5.6.1 Hydrographic Pathways and the Potential Movement of Non-Swimming (Planktonic) Organisms or Toxicants Outside of the Basin

5.6.1.1 Gravity Flow Pathways

In average and drier years, most of the water from the four major rivers, including regulated and unregulated ancillary sources, is distributed within the Basin. This distribution is primarily via gravity flow through natural stream channels and constructed canals and ditches, along with routine pumping of surface water into canals and rivers within the Basin. In general, surface waters do not leave the Basin in average and drier years, except for occasional tailwater releases into the San Joaquin River from FID canals and small stream and urban storm-water runoff regulated by the Fresno Metropolitan Flood Control District. However, surface waters in the Kern Water Bank and Cross Valley Canal may be mixed with pumped ground water that occasionally flows to the California Aqueduct in drier years.

Kings River water from below Pine Flat Dam is diverted north and south via numerous canals into the Kings River delta and the remaining water normally flows through the South Fork Kings River to the canals in the Tulare Lakebed. Gravity flow pathways out of the Basin are present at the Gould and Fresno canal diversions on the Kings River (at or above the Friant-Kern Canal), from the Fresno County Stream Group, and from the Kern River, Kern Water Bank, and the Cross Valley Canal. The Gould and Fresno canals operate throughout much of the year, flows from the Fresno County Stream Group are seasonal, and the Kern Water Bank and Cross Valley

Canal connections to the California Aqueduct are restricted to drier periods. Kings River water can also flow to the St. John's River and Cross Creek via the Lakeland Canal and the outflow from the Alta Irrigation District distribution system. During average and drier years, water does not normally flow from the mainstem Kings River into the North Fork Kings River.

Water distribution patterns within the Basin are generally similar during average and drier years. Waters from the St. John's River and Cross Creek commonly flow to the Tule River Canal and other canals serving the Tulare Lakebed. Lower Kaweah River water can flow into Cross Creek via Mill Creek, and to the Tule River via Elk Bayou and the Tulare Irrigation District outflow. San Joaquin River water in the Friant-Kern Canal is diverted into the mainstem Kings, St. John's, lower Kaweah, Tule, and Kern rivers as well as Deer and Poso creeks, and Porter Slough. During average or drier years, the Tule River only occasionally flows into the Tulare Lakebed canals; and Kern River water does not connect with any of the other three major rivers in the Basin.

In addition to the gravity flow connections that typically occur during average or drier runoff years, high runoff periods often necessitate the use of other gravity flow pathways. During these periods, excess water flows out of the Basin through three pathways: the Kings River to James Bypass to the Mendota Pool and the San Joaquin River; the Friant-Kern Canal to the Kern River and Cross Valley Canal connections to the California Aqueduct, and the Kern River directly into the California Aqueduct.[235] In general, during wetter years, flows in channels and canals that connect with either the Kings River or Kern River have the potential to be exported out of the Basin. Excess water that cannot be exported or used for water supply purposes is transported to the Tulare Lakebed and stored in the south end flood detention cells and eventually flows onto agricultural land during very high runoff periods. In years of extremely high runoff (i.e. 1983) water can be pumped out of the Tulare Lakebed and out of the Basin. In addition to the normal gravity flow pathways used to transport water during high runoff periods, extensive pumping can occur to help control and re-direct the movement of water

[235] Water from the Kings River has flowed into the Mendota Pool and the San Joaquin River in 20 out of the 53 years since Pine Flat Dam was completed (1954). Since 1977 water from the Friant-Kern Canal and the Kern River has been exported into the California Aqueduct in 10 out of the 30 years.

within the Basin. High runoff can also exceed the capacity of both natural and man-made channels in the Basin allowing surface waters to spread over larger areas.

5.6.1.1.1 Potential for Non-Swimming Organisms or Toxicants to Move Outside of the Basin through Gravity Flow Pathways

In general, there is limited potential for non-swimming organisms or toxicants, which only move with the flow, to move out of the Basin through surface channels during average and drier years, due primarily to the relatively short durations (up to several days) that these flow connections occur. However, in high runoff periods, the flow durations may last from weeks to months, increasing the potential for non-swimming organisms or toxicants to leave the Basin.

In most years, water that enters the Kings River from the release at the base of Pine Flat Dam, from the Friant-Kern Canal, and from tributary streams above the diversions for the Gould and Fresno canals may provide potential pathways for non-swimming organisms or toxicants to move out of the Basin. In addition, the Kern River Intertie and the Cross Valley Canal also provide potential pathways for non-swimming organisms or toxicants to leave the Basin. Based on the limited duration that water flows out of the Basin during average and drier years, it is unlikely that non-swimming organisms or toxicants pose any real threat to water bodies outside of the Basin. However, in wet years, longer duration outflows increase the likelihood of non-swimming organisms or toxicants leaving the Basin.

Depending on the location, it could be extremely difficult or impossible to isolate toxicant spills or releases into stream channels, sloughs, canals, and other waterways during large flood events.

The movement of swimming organisms (i.e. fish), which can also move around the Basin via these gravity flow connections, is addressed in Section 5.6.2.

5.6.1.2 Pumping Pathways – Routine and Non-Routine

In addition to the gravity flow pathways described in the previous section, routine pumping is used during average and drier years to move water around the Basin; and non-routine pumping is utilized during high runoff years to help control and re-direct excess water to areas within and outside of the Basin. These pumping pathways provide additional opportunities for aquatic species to move or be transported within and potentially outside of the Basin.

In average and drier years, pumping of water is generally not necessary to distribute runoff within the Basin. However, Kaweah River runoff in the Wutchumna Ditch is occasionally pumped into the Friant-Kern Canal for downstream distribution. Pumping is also used on the Tulare Lakebed to distribute irrigation water, move drain water into evaporation ponds, and transport water out of the south end storage cells. In general, these routine pumping operations, which occur in most years, can potentially move organisms around the Tulare Lakebed. In addition, water may also be pumped out of the Basin. In drier years, surface water in the Arvin-Edison system, from the Friant-Kern Canal, and from the Kern River may potentially co-mingle with groundwater pumped into the California Aqueduct through the Arvin-Edison Intertie although this cannot be verified without additional investigation. Similarly, the recovered groundwater that Semitropic Water Storage District pumps into the California Aqueduct in drier years could potentially be co-mingled with surface water.[236]

During high runoff periods, pumping at the major facilities located along the Friant-Kern Canal and at the other river and canal locations can substantially alter routine flow pathways and directions. Three major facilities on the Friant-Kern Canal can pump water into the canal from the mainstem Kings, St. John's, and Tule rivers. In very wet years, Kings River water flowing into the Mendota Pool is occasionally pumped into the California Aqueduct via the Lateral 7L Canal. As a result of the high runoff in 1983, water was pumped north out of the Tulare Lakebed and up the South Fork Kings River/Crescent Bypass to Crescent Weir. At Crescent

[236] Again without additional investigation, it is unknown whether surface water from the Kern River system and from the Friant-Kern Canal can mix with pumped groundwater that is discharged into canals and transported to the California Aqueduct.

Weir, water was pumped into the North Fork Kings River/James Bypass and allowed to flow downstream into Mendota Pool and eventually into the San Joaquin River.[237]

5.6.1.2.1 Potential for Non-Swimming Organisms or Toxicants to Move Outside of the Basin through Pumping Pathways

The potential for non-swimming organisms or toxicants to move outside of the Basin in average and drier years is unlikely due to the general short duration of the pumped flows and the lack of verification of a temporal link between the time water enters the Friant-Kern Canal and eventually leaves the Basin. The only Tulare Basin water present in the Friant-Kern Canal in average and drier years is the Wutchumna pumped water and potentially several seasonal creek inputs along the Canal.

In high runoff years, water in the Friant-Kern Canal generally moves through the system rapidly and a continuous link is established to pathways outside the Basin. During these periods there is an increased likelihood for non-swimming organisms or toxicants to move outside of the Basin.

5.6.2 Hydrographic Pathways and the Potential Movement of Swimming Organisms (i.e., Fish) Outside of the Basin

In addition to potentially utilizing the gravity flow and routine pumping pathways identified for non-swimming (planktonic) organisms, fish (and possibly other swimming organisms such as aquatic reptiles and amphibians) can also potentially move out of the Basin by swimming upstream through canals and other waterways, and via non-routine pumping pathways or a combination of the two.

Even though the hydrographic connections identified in this report are linked to the potential movement pathways for fish, most of the connections do not result in a complete pathway for

---

237 CDFG indicated that water from the Tulare Lakebed can be transported to pumping locations adjacent to the California Aqueduct and pumped into the Aqueduct for downstream transfers; though, this pathway could not be verified.

fish to move out of the Basin. In many instances, the presence of structural barriers and/or other physical obstructions preclude upstream movement along these potential pathways. In most years, fish in the Tule River system can potentially swim upstream to the lower Kaweah River system via Elk Bayou, Tulare Irrigation District spill, Lakeland Canal, and Cross Creek (extension of the St. John's River). Fish in the lower Kaweah and Tule river drainages can potentially access the St. John's River/Cross Creek system; however, it is not known if upstream fish movement is hindered by drop structures or other obstructions. Within the St. John's River/Cross Creek system, fish can potentially migrate into the Lakeland Canal and the Alta Irrigation District distribution system using Cottonwood Creek and the Cross Creek Wasteway. These waterways and canals were identified by CDFG as hydrographic links between the Kings River and St. John's River/Cross Creek system during the 1983 high runoff year (see Map 4 and inset barrier information table).[238] However, based on observations made during the site visit, upstream fish passage within these canals is likely hindered in all conditions (except during periods of over bank flooding) by the numerous drop structures present along these canals.

Most of the drop structures observed during the field visit varied from approximately 1.7 to 6 ft (0.5 to 1.8 m) in height and may or may not be equipped with grate structures. Fish can move upstream through many of the drop structures that are low in height [< 2 ft (0.6 m)] and lack grate structures, even if the canals are relatively full. Upstream fish passage at the higher drop structures (> 2 ft) is unlikely for warm-water fish species (which are generally poor jumpers) due to the increased height, water velocities, and turbulence. The presence of grate structures on most of the higher drop structures further decreases the potential for fish to move upstream. Additionally, it is unknown whether jump pools below these structures have sufficient depth and size to allow fish to pass upstream. Fish populations within these canals consist primarily of warm-water fish species, though rainbow trout could be present during the winter and spring. Salmonids are likely the only species occurring in the Basin that could potentially migrate upstream through some of the higher drop structures. In the event that a few fish were able to move past these apparent barriers, it is unlikely that sufficient numbers of the same species would be able to complete this journey to maintain the population. This is especially true for those species that are group spawners, such as white bass.[239]

[238] California Department of Fish and Game, 1987.
[239] Moyle, P. B., 2002.

During high runoff periods, many of the stream channels, canals, sloughs, and waterways in the lower portion of the Basin may be used to transport floodwaters. During wet years when the Kings, Kaweah, Tule, and Kern rivers are flowing into the Tulare Lakebed, a hydraulic connection between these rivers is established allowing fish from one drainage to move into other systems without any barriers, except for some irrigation structures. As documented by CDFG[240] during the 1983 flood event, fish present in the upper reaches of these four major rivers (below the reservoirs) were distributed downstream throughout much of the Basin. A large number of these fish eventually moved into the flooded Tulare Lakebed. It is highly likely that this same downstream movement of fish occurs, to a greater or lesser extent, during all high runoff events. When flows in natural and man-made channels exceed maximum capacities and flood adjacent lands, fish can move to new locations that may have previously been isolated. In general, these flooded areas provide additional hydrographic connections for fish to disperse within the Basin that were not present during average or drier runoff periods. Natural channels in the lower Kaweah and St. John's river system are particularly susceptible to over bank flooding. In high runoff periods, foothill streams north of the Cottonwood Creek/St John's system that flow into the lower Kings River could provide a pathway from the Lower Kaweah/St John's system into the Kings River. This pathway, which is generally of short duration, bypasses the barrier at the intake structure on the Alta main canal.

In years of high runoff (including non-routine pumping patterns), known hydrographic connections and potential fish pathways show that several potential routes exist for fish to move out of the Basin by gravity and pumping depending on the magnitude, duration, and timing of high runoff events. Fish can potentially leave the Basin via the Kings River to the James Bypass to the Mendota Pool and the San Joaquin River. Fish can also potentially leave the Basin at several locations along the California Aqueduct where water enters from the Kern River, Kern Water Bank Canal, and the Cross Valley Canal. This water may originate from the Kern River or from the Friant-Kern Canal, which mainly carries San Joaquin River water and possibly Kings, St. John's, and Tule river water. Even though these hydrographic links have been verified, the hydrographic pathway from the Friant-Kern Canal to the California Aqueduct was not evaluated on the site visit for potential fish passage issues.

[240] California Department of Fish and Game, 1987.

During most flow conditions, fish present in the Friant-Kern Canal can move out of the canal through many of the 110 turnouts located along its length and into numerous drainages and channels within the Basin.[241] The design of each turnout and associated hydraulic properties vary with location, and the ability of fish to pass through these turnouts is likely site specific.

In most years, fish can generally only enter the Friant-Kern Canal from Millerton Reservoir on the San Joaquin River.[242] However, fish may also occasionally enter the canal at the pumping stations, and possibly at several other locations where gravity flow of water into the canal occurs via drains and inlets.[243] Turnout structures at locations where water is diverted from the Friant-Kern Canal to lateral canals generally have vertical drops greater than 4 ft (1.2 m) high with attendant high water velocities and turbulence.[244] Grate structures are also present at these locations. Based on the hydraulic characteristics observed at these diversions, it is highly unlikely that fish could move upstream into the Friant–Kern Canal through any of the turnouts.

The population of fish in the Friant-Kern Canal varies annually. The lowest numbers of fish likely occur following periodic canal dewatering and associated routine maintenance activities, which include the use of algaecides and other chemicals. Other than losses due to predation and potentially low dissolved oxygen levels in some of the siphons, a large number of fish appear to survive canal-dewatering operations.[245] As the canal drains, fish tend to move into the numerous siphons located along its length, which provide deeper water and adequate cover.[246] Depending on water quality conditions in the siphons, fish could potentially survive for relatively long periods. As the canal is re-filled, fish can move out of these siphons and into the turnouts. When the turnouts are operated, fish present in the structure can potentially move directly into the Kings, St. John's, and Tule rivers and into numerous other stream drainages along the canal. Since the hydraulic barrier at the Kings River turnout was only operated in association with the 1983 white bass issue, fish that move from the Friant-Kern Canal into the

---

[241] Randy Kelly, CDFG, personal communication, May 2005.
[242] Occasionally in average or drier years, Wutchumna Ditch water and less frequently Tule River water is pumped into the Friant-Kern Canal for transport to other locations.
[243] However, these drains and inlets are associated with ephemeral drainages that likely do not contain viable fish populations. The frequency, magnitude, and duration of these additional flows via drains and inlets were not available; though, these potential fish pathways likely only occur during high runoff conditions.
[244] Gary Perez, Friant Water Users Authority, personal communication, July 2006.
[245] Stan Stephens, CDFG, Personal Communication, July 2006.
[246] Stan Stephens, CDFG, personal communication, July 2006.

Kings River can potentially reach the San Joaquin River. During this filling period, fish can easily move both north and south along the canal. At the northern end of the canal, fish could potentially pass through the turnout at Little Dry Creek and move directly into the San Joaquin River, though this turnout has not been used in the last 25 years.[247]

Fish present in the Friant-Kern Canal can also move to the California Aqueduct via the Kern River, the Cross Valley Canal, Kern Water Bank Canal, Arvin-Edison Intertie, and the Kern River Intertie. Once in the California Aqueduct, fish can swim upstream (north toward the Sacramento-San Joaquin Delta) or downstream (south) toward Southern California. However, the Dos Amigos pumping plant on the California Aqueduct, located west of the Mendota Pool complex, represents a barrier to fish movement north of this facility. Normal pumping operations transport water south to Southern California; though, on one occasion water was pumped north to the San Joaquin River drainage.[248] This activity could potentially provide a pathway for fish to enter the Delta. Fish that swim upstream could potentially leave the Aqueduct through one of the turnouts south of the Dos Amigos Pumping Plant and potentially move through lateral canals and other waterways adjacent to the Aqueduct, eventually reaching the Mendota Pool complex or the San Joaquin River.[249] These potential connections have not been verified on the ground and the actual pathways to the Mendota Pool complex or the San Joaquin River has not been evaluated.

5.6.2.1 Potential for Swimming Organisms to Move Outside of the Basin

In general, there is an increased potential for swimming organisms to move within and outside the Basin during high runoff periods, relative to average and drier runoff years. This increase is primarily due to the greater geographic extent that water distribution systems are utilized, the substantially larger volumes of water that are transported during these periods, and the alternative pathways (including pumping) that are utilized during periods of high runoff.

[247] Jerry Pretzer, USBR, personal communication, May 2005. It is unknown if the turnout has ever been used.
[248] Randy Kelly, CDFG, personal communication, May 2005.
[249] Lateral 7L in the Westlands Water District connects the California Aqueduct (aka as the San Luis Canal in this reach) with the Mendota Pool.

The potential for fish to move from the Kings River to the San Joaquin River is increased during high runoff periods. Fish in the Kings River can move downstream from below Pine Flat Dam or upstream from the South Fork Kings River and potentially move out of the Basin via Fresno Irrigation District diversions (Gould and Fresno canals) or down the North Fork Kings River to the San Joaquin River. However, the potential for fish to move through the Fresno Irrigation District canals to the San Joaquin River has not been ground verified and potential barriers to downstream movement may be present. There is a much lower probability of fish moving out of the Basin from the St. John's/Kaweah or Tule rivers through the Kings River, due to the longer travel/swimming distance; the numerous drop structures (some of which function as barriers to upstream movement) present in Lakeland and Alta Irrigation District canals between the St. John's/Kaweah rivers and the Kings River; and the relatively short period of time that water is transported north to the San Joaquin River.[250] In general, fish that move to the Kings River via any pathway could potentially be moved out of the Basin during high runoff periods. The only other major pathway for fish or other swimming organisms to move out of the Basin involved Kings River and Tulare Lake floodwaters that were pumped from the South Fork Kings River to the North Fork Kings River via the Crescent Bypass. Fish that enter the North Fork Kings River can move directly to Mendota Pool and the San Joaquin River. This pathway was only used from October 1983 to January 1984, and will likely not be used again.[251]

Even though existing water distribution systems have the ability to move water around the Basin, there is a relatively high potential for fish or other aquatic organisms to leave the Basin during most high runoff periods. Since Pine Flat Dam was completed in 1954, Kings River water has flowed into the San Joaquin River and out of the Basin in over one-third of the years and since 1977, outflow to the San Joaquin has occurred in 14 years or nearly half of the years. Since the Kern River Intertie was completed in 1977, it has been utilized to export Tulare Lake Basin water in 33% of the years. During large floods, the potential for fish to be pumped or to move out of the Basin increases, due primarily to: the higher volumes of water that must be moved around the Basin to minimize flooding; the increased number of pathways used to

[250] In above average runoff years, high flows in the James Bypass normally last for days to weeks; however, in wet years flows may persist for many months during the winter and spring.
[251] Representatives from the Tulare Lake Basin interests at the November 2004 meeting in Fresno, California, indicated that this type of pumping operations would likely not occur in the future.

transport water; and the potential for creating new hydraulic connections between previously isolated drainages or channels.

5.7 Summary of the Potential for Swimming and Non-Swimming Organisms or Toxicants to Move Outside of the Basin

The major hydrographic connections within the Basin (both gravity and pumped) including frequency of occurrence is summarized in tables 10 and 11.

In average and drier years, the majority of the water from the four major rivers (Kings, St. John's/Kaweah, Tule, and Kern) including regulated and unregulated ancillary sources is distributed primarily within the Basin. Based on available information, the only verified gravity flow pathways for non-swimming and swimming organisms (i.e., fish) to move out of the major rivers of the Basin during these periods occur at the Kings River diversions to the Gould and Fresno canals. Water is generally present within the Gould and Fresno Canals during most months of the year, but the tailwater release into the San Joaquin River is intermittent. In drier years, surface water from the Kern River and possibly the Friant-Kern Canal may also co-mingle with recovered groundwater and be moved to the California Aqueduct via pumping or by gravity flow. However, these potential pathways were not verified during the field visit.

Fish access to diversions on the mainstem Kings River in average and drier years can occur via three pathways: the Kings River and associated tributaries upstream of the Gould and Fresno canal diversions, the Kings River drainage downstream of the diversions, and the Friant-Kern Canal. It is also possible for fish from the St. John's, lower Kaweah and Tule river drainages to potentially access the Kings River via the canals and natural drainages between the Kings River and St. John's River/Cross Creek system. However, in these years, there is a very low probability of fish moving from these drainages out of the Basin via the Kings River due to the longer travel distance, the presence of numerous drop structures in the Lakeland and Alta Irrigation District canals which hinders or precludes the upstream movement of fish, and the relatively short period of time that water is directed north to the San Joaquin River, if at all. During high runoff periods, many of the stream channels, canals, sloughs, and waterways in the lower portion of the Basin may be used to transport floodwaters. During these periods, fish and other aquatic organisms present in the upper reaches of the four major rivers (below the reservoirs) are typically re-distributed downstream throughout much of the Basin via these waterways.

Fish in the Kings River can potentially move downstream from below Pine Flat Dam or upstream from the mainstem and South Fork Kings River and out of the Basin to the San Joaquin River via the Gould and Fresno canal diversions. Fish in the Kings River may also move down the North Fork Kings River to Mendota Pool and the San Joaquin River. In addition, fish present in the lower Kaweah and Tule river drainages can access the St. John's River/Cross Creek system, and potentially migrate into the Lakeland Canal and the Alta Irrigation District distribution system and into the Kings River. However, the probability of fish moving out of the Basin from the St. John's/Kaweah or Tule rivers through the Kings River is likely relatively low due to: the long travel/swimming distance; the numerous drop structures (some of which are high enough to function as barriers to upstream movement) present in Lakeland and Alta Irrigation District canals; and the relatively short period of time that water is transported north to the San Joaquin River.

In high runoff years, fish and other organisms can also move out of the Basin through connections between the Friant-Kern Canal and the California Aqueduct including the Kern River and Cross Valley Canal, and from the Kern River to the California Aqueduct through the Kern River and Arvin-Edison interties and the Kern Water Bank Canal. Additionally, pumping of Kings River and Tulare Lake floodwaters from the South Fork Kings River to the North Fork Kings River to the San Joaquin River via the Crescent Bypass provides another potential pathway for fish and other organisms to move out of the Basin. Even though this pathway was utilized during the 1983 flood event, it is unlikely that this avenue will be used again during future flood events.[252]

Based on available information, fish can potentially migrate out of the Tulare Lake Basin in most years, especially during periods of high runoff. However, with the exception of fish present in the Kings River below Pine Flat Reservoir and in the Friant-Kern Canal and potentially other

[252] Tulare Lake Basin water associations and irrigation districts stated that this pumping pathway would not be proposed in future flood events.

Tulare Lakebed canals that move water to the California Aqueduct, it is unlikely that sufficient numbers of fish of the same species would be able to migrate out of the Basin in most years to maintain viable populations. During large flood events, increased hydrographic connections allow for easier movement of fish from one location to another within the Basin and potentially to locations outside of the Basin.

6.0 REFERENCES

Alexander, Lieut. Col. B. S., Maj. G. H. Mendell, and Prof. G. Davidson. 1874. Report of the Board of Commissioners on The Irrigation of The San Joaquin, Tulare, and Sacramento Valleys of the State of California. Government Printing Office, Washington D.C.

Anonymous. 1873. Irrigation in California, The San Joaquin and Tulare Plains: A Review of the Whole Field. Record Steam Book and Job Printing House, Sacramento, CA.

Bookman-Edmonston Engineering. 1972. Report on Investigation of the Water Resources of Kaweah Delta Water Conservation District. Glendale, CA.

Bookman-Edmonston Engineering. 1979. Water Resources Management in the Southern San Joaquin Valley California. Prepared for the San Joaquin Valley Agricultural Water Committee. Glendale, CA.

California Department of Fish and Game. 1987. Final Environmental Impact Report White Bass Management Program. Sacramento CA.

California Department of Public Works (CDPW). 1931. San Joaquin River Basin. Bulletin 29.

California Department of Water Resources. 1983. Kaweah River Flows, diversions and Storage 1975-80. Bulletin 49-F. Sacramento, CA.

California Department of Water Resources. 1984. California High Water 1982-83. Bulletin 69-83. Sacramento, CA.

California Department of Water Resources. 1999a. California Water Plan Update, Volume 1. Bulletin 160-98(1). Sacramento, CA.

California Department of Water Resources. 1999b. California State Water Project Atlas. Sacramento, CA.

City of Bakersfield. 2003. Kern River Parkway 2003 Recreational Flow Guide. Retrieved May 2005 from http://www.bakersfieldcity.us/cityservices/water/index.htm

City of Bakersfield Water Resources Department. 2003a. The Kern River Purchase. Retrieved May 2005 from http://www.bakersfieldcity.us/cityservices/water/

City of Bakersfield Water Resources Department. 2003b. The Kern River Parkway Recreational Flow Guide for 2003. Retrieved May 2005 from http://www.bakersfieldcity.us/cityservices/water/

Clapp, W. B. and F. F. Henshaw. 1911. Surface Water Supply of the United States. 1909. Department of the Interior, United States Geological Survey. Water Supply Paper 271. Government Printing Office, Washington, D.C.

Cloern, J. E. and F. H. Nichols, eds. 1985. Temporal dynamics of an estuary: San Francisco Bay. Dr. W. Junk Publishers, Dordrecht. (Original work published in 1985 in Hydrobiologia, v. 129.)

Coulter, T. 1835. Notes on Upper California. Journal of the Royal Geographical Society of London 5:59-70.

Davis, F. W., D. M. Stoms, A. D. Hollander, K. A. Thomas, P. A. Stine, D. Odion, M. I. Borchert, J. H. Thorne, M. V. Gray, R. E. Walker, K. Warner, and J. Graae. (1998a). The California Gap Analysis Project--Final Report. Santa Barbara, CA. University of California.

Davis, G. H., J. H. Green, F. H. Olmsted and D.W. Brown. 1959. Ground-Water Conditions and Storage Capacity in the San Joaquin Valley, California. U.S. Geological Survey Water-Supply Paper 1469.

Farquhar, F. P., ed. 1932. The Topographical Reports of Lieutenant George H. Derby, Part II. Report on the Tulare Valley of California, April and May 1850. California Historical Society XI(2):247-265.

Farquhar, F. P., ed. 1974. Up and Down California in 1860-1864: The Journal of William H. Brewer. Third edition. University of California Press, Berkeley, CA. (Original work published 1861, by Brewer, W.H.)

Fredrickson, David A. 1983. Buena Vista Lake (CA-KER-116) Revisited. Coyote Press Archives of California Prehistory, 6:75-81, 1986. (Original work published 1983 in Symposium: A New Look at some Old Sites. Papers from the Symposium Organized by Francis A. Riddell. Presented at the Annual Meeting of the Society for California Archaeology, March 23-26, 1983, San Diego, California.)

Fremont, J. C. 1964. Geographical Memoir upon Upper California in Illustration of his Map of Oregon and California by John Charles Fremont. Newly Reprinted from the Edition of 1848 with Introductions by Allan Nevins and Dale L. Morgan and a Reproduction of the Map. The Book Club of California, San Francisco, California. (Original published in 1848.)

Fresno Metropolitan Flood Control District. 2004. 2004 District Services Plan.

Fugro West, Inc. 2003. Water Resources Investigation of the Kaweah Delta Water Conservation District.

Graumlich, L. J. 1987. Precipitation variation in the Pacific Northwest (1675-1975) as reconstructed from tree rings. Annals of the Association of American Geographers 77:19-29.

Grunsky, C. E. 1898a. Irrigation near Bakersfield, California: U.S. Geological Survey Water Supply Paper 17.

Grunsky, C. E. 1898b. Irrigation near Fresno, California: U.S. Geological Survey Water Supply Paper 18.

Hall, W. H. 1886a. Physical Data and Statistics of California: Tables and Memoranda. State Engineering Department of California, Sacramento, California.

Hall, W. H. 1886b. Topographical and Irrigation Map of the San Joaquin Valley. California State Engineering Department, Sacramento. The Dept., 1887. San Francisco, California. Lithographers: Britton & Rey.

Hall, W. H. 1887. Topographical and Irrigation Map of the Great Central Valley of California: Embracing the Sacramento, San Joaquin, Tulare and Kern Valleys and the Bordering Foothills. California State Engineering Department, Sacramento. The Dept., 1887. San Francisco, California. Lithographers: Britton & Rey.

Ingerson, I. M. 1941. The hydrology of the Southern San Joaquin Valley, California, and its relation to imported water supplies. Pages 20-45, American Geophysical Union Transactions, Part I, Reports and Papers (A). Section of Hydrology, National Research Council, Washington, D.C.

Johnson, W. 2004. Water Connections Tulare Lake Basin. USACOE, Sacramento District Office Report.

Kings River Conservation District and Kings River Water Association. 1994, The Kings River Handbook

Kings River Water Association. 1980. Watermaster Report 1978-79

Kings River Water Association. 1989. Watermaster Report 1987-88

Kings River Water Association. 1996. Watermaster Report 1994-95

Kern County Water Agency. 2003. Water Supply Report 1999.

Kern County Water Agency. 2002. Water Supply Report 1998.

Latta, F. F. 1937. Little Journeys in the San Joaquin.

Mayfield, Thomas Jefferson. 1993. Indian Summer Traditional Life Among the Choinumne Indians of Califronia's San Joaquin Valley. Heyday Books, Berkeley, California.

McBain and Trush, eds. 2002. San Joaquin River restoration study background report. Prepared for Friant Water Users Authority, Lindsay, California, and Natural Resources Defense Council, San Francisco, California.

Mendenhall, W. C., R. B. Dole, and H. Stabler. 1916. Ground Water in San Joaquin Valley, California. USGS Water Supply Paper 398.

Moyle, P. B. 1976. Inland Fishes of California. University of California Press, Berkeley, California.

Moyle, P. B. 2002. Inland Fishes of California. University of California Press, Berkeley California.

Page, R. W. 1986. Geology of the Fresh Ground-Water Basin of the Central Valley, California, with Texture Maps and Sections. U.S. Geological Survey Professional Paper 1401-C.

Preston, W. L. 1981. Vanishing Landscapes: Land and Life in the Tulare Lake Basin. University of California Press, Berkeley, California.

Regional Water Quality Control Board, Central Valley Region. September 2004. Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Salt and Boron Discharges into the Lower San Joaquin River. Final Staff Report.

SAIC. 2003a. Existing East Side Conveyance and Exchange Facilities. Technical Memorandum for Task 807. Prepared for the FWUA/MWD Partnership.

SAIC. 2003b. Existing West Side Conveyance and Exchange Facilities. Technical Memorandum for Task 806. Prepared for the FWUA/MWD Partnership.

San Joaquin Valley Drainage Program (SJVDP). 1990. Fish and Wildlife Resources and Agricultural Drainage in the San Joaquin Valley, California, Volume I.

Schroeder, R. A. et al. 1988. Reconnaissance Investigation of Water Quality, bottom Sediment, and Biota Associated with irrigation Drainage in the Tulare Lake Bed Area, Southern San Valley, California, 1986-87. USGS Water-resources investigation Report 88-4001.

Semitropic Water Storage District. 2004. Groundwater Banking FAQ. Retrieved June 2005, from http://www.semitropic.com/GndwtrBankFAQs.htm

Stine, S. 1990. Late Holocene fluctuations of Mono Lake, eastern California. Palaeogeography, Palaeoclimatology, Palaeoecology 78:333-381.

Stine, S. 1994. Extreme and persistent drought in California and Patagonia during mediaeval time. Letters to Nature, Department of Geography and Environmental Studies, California State University, Hayward, California, v. 369.

Stine, S. 1996. Climate, 1650-1850. Sierra Nevada Ecosystem Project (SNEP): Final Report to Congress. Vol. II: Assessments and Scientific Basis for Management Options. University of California. Wildland Resources Center Report No. 37. University of California, Davis, California.

The Bay Institute. 1998. From the Sierra to the Sea: The Ecological History of the San Francisco Bay-Delta Watershed. Novato, California.

Tulare Lake Basin Water Storage District. 1981. Report on Irrigation, Drainage, and Flooding in the Tulare Lake Basin.

Tule River Association. 1989. Annual Report 1988 Water Year.

Tule River Association. 1997. Annual Report 1996 Water Year.

Tule River Association. 1999. Annual Report 1998 Water Year.

URS. 2002. Water Supply Study Development of Water Supply Alternatives for Use in Habitat Restoration for the San Joaquin River. Prepared for FWUA and NRDC Coalition.

United States Army Corps of Engineers, Sacramento District. 1972. Flood Plain Information Sand and Cottonwood Creeks and the Lower Kaweah River Visalia California.

United States Army Corps of Engineers, Sacramento District. 1996. Kaweah River Basin Investigation, California Final Feasibility Report and EIS/EIR.

United States Bureau of Reclamation. 1970. A Summary of Hydrologic Data for the Test Case on Acreage Limitation in Tulare Lake. Sacramento, California.

United States Bureau of Reclamation. 2001. Mendota Pool Exchange Agreement Draft Environmental Assessment.

United States Bureau of Reclamation. 2004. Reclamation District 770 Pump-In Project Environmental Assessment.

U.S. Geological Survey. 1998. Environmental Setting of the San Joaquin-Tulare Basins, California. Water Resources Investigations Report 97-4205. Sacramento, California.

Vorster, Peter. 1985. A Water Balance Forecast Model for Mono Lake, California. Earth Resources Monograph No. 10, USDA United States Forest Service.

Warner, R. F. and K. Hendrix. 1985. Riparian Resources of the Central Valley and California Desert, A Report On Their Nature, History and Status with Recommendation For Their Revitalization and Management. Final Draft, California Department of Fish and Game.

Williamson, Lieutenant R. S. 1853. Corps of Topographical Engineers Report of Explorations in California for Railroad Routes, to connect with the routes near the 35th and 32nd parallels of north latitude. War Department: Washington, D.C. 1855.

Williamson, A. K., D. E. Prudic, and L. A. Swain. 1985. Ground-Water Flow in the Central Valley, California. USGS Open-File Report 85-345.

Williamson, A. K., D. E. Prudic, and L. A. Swain. 1989. Ground-Water Flow in the Central Valley, California. USGS Professional Paper 1401-D.

Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle. 1996. Historical and present distribution of Chinook salmon in the Central Valley drainage of California. Sierra Nevada Ecosystem Project. Final report to Congress, Vol. II: Assessments, Commissioned Reports, and Background Information. Wildland Resources Center Report No. 37. University of California, Davis, California.

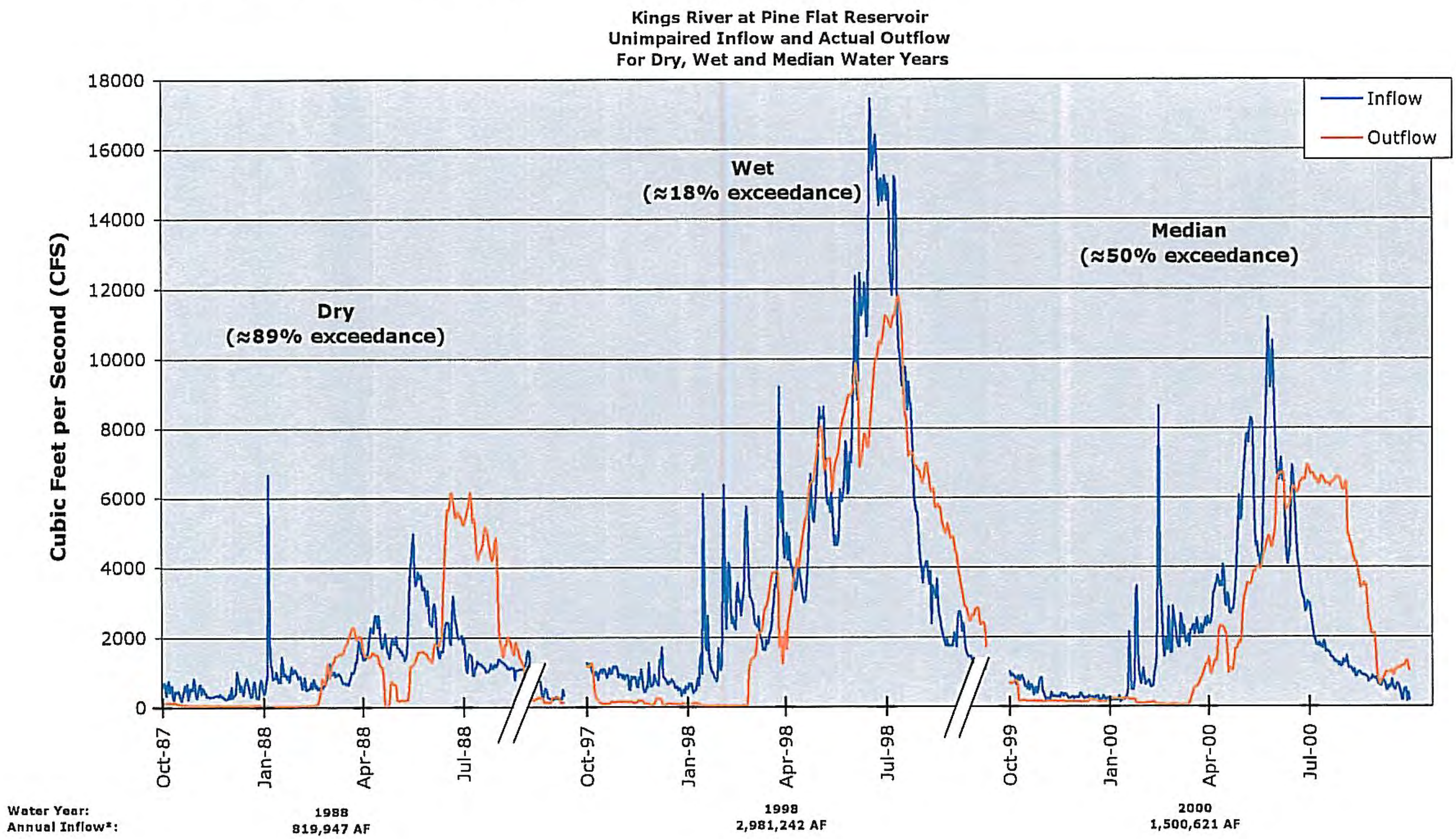
7.0 TEXT FOR FOOTNOTE REFERENCES

Alexander, Lieut. Col. B. S., Maj. G. H. Mendell, and Prof. G. Davidson, 1874.
Alexander et. al., 1874.
Anonymous, 1873.
Bookman-Edmonston Engineering, 1979.
Bookman-Edmonston Engineering, 1972.
California Department of Fish and Game, 1987.
California Department of Water Resources, 1983.
California Department of Water Resources, 1984.
California Department of Water Resources, 1999a.
California Department of Water Resources, 1999b.
City of Bakersfield Water Resources Department, 2003a.
City of Bakersfield Water Resources Department, 2003b.
City of Bakersfield. 2003.
Clapp, W. B. and F. F. Henshaw, 1911.
Cloern, J. E. and F. H. Nichols, eds., 1985.
Coulter, T, 1835.
Davis, 1998a.
Davis, G. H., J. H. Green, F. H. Olmsted and D.W. Brown, 1959.
Davis et. al., 1959.
Farquhar, F. P., ed., 1932.
Farquhar, F. P., ed., 1974.
Fredrickson, David A., 1983.
Fresno Metropolitan Flood Control District. 2004.
Fugro West, Inc., 2003.
Graumlich, L. J., 1987.
Grunsky, C. E. 1898a.
Grunsky, C. E. 1898b.
Hall, W. H., 1886a.
Hall, W. H., 1886b.
Hall, W. H., 1887.
Ingerson, I. M., 1941.
Johnson, W., 2004.
Kings River Water Association, 1996.
Kings River Water Association, 1980.
Kings River Water Association, 1989.
Latta, F. F., 1937.
Kern County Water Agency, 2003.
Mayfield, Thomas Jefferson, 1993.
McBain and Trush, eds., 2002.
Mendenhall, W. C., R. B. Dole, and H. Stabler, 1916.
Mendenhall et. al., 1916.
Moyle, P. B., 1976.
Moyle, P. B., 2002.
Page, R. W., 1986.

Preston, W. L., 1981.
Regional Water Quality Control Board, Central Valley Region, September 2004.
SAIC, 2003a.
SAIC, 2003b.
San Joaquin Valley Drainage Program (SJVDP), 1990.
Schroeder, R. A. et al., 1988.
Stine, S., 1990.
Stine, S., 1994.
Stine, S., 1996.
The Bay Institute, 1998.
Tulare Lake Basin Water Storage District, 1981.
Tule River Association, 1999.
Tule River Association, 1997.
Tule River Association, 1989.
URS, 2002.
United States Army Corps of Engineers, Sacramento District, 1972.
United States Army Corps of Engineers, Sacramento District, 1996.
United States Bureau of Reclamation, 1970.
United States Bureau of Reclamation, 2001.
United States Bureau of Reclamation, 2004.
U.S. Geological Survey, 1998.
Vorster, Peter, 1985.
Warner, R. F. and K. Hendrix, 1985.
Williamson, Lieutenant R. S., 1853.
Williamson, A. K., D. E. Prudic, and L. A. Swain, 1985.
Williamson et. al., 1985.
Williamson, A. K., D. E. Prudic, and L. A. Swain, 1989.
Williamson et. al., 1989. Yoshiyama, R. M., E. R. Gerstung, F. W. Fisher, and P. B. Moyle, 1996.
Yoshiyama et. al., 1996.

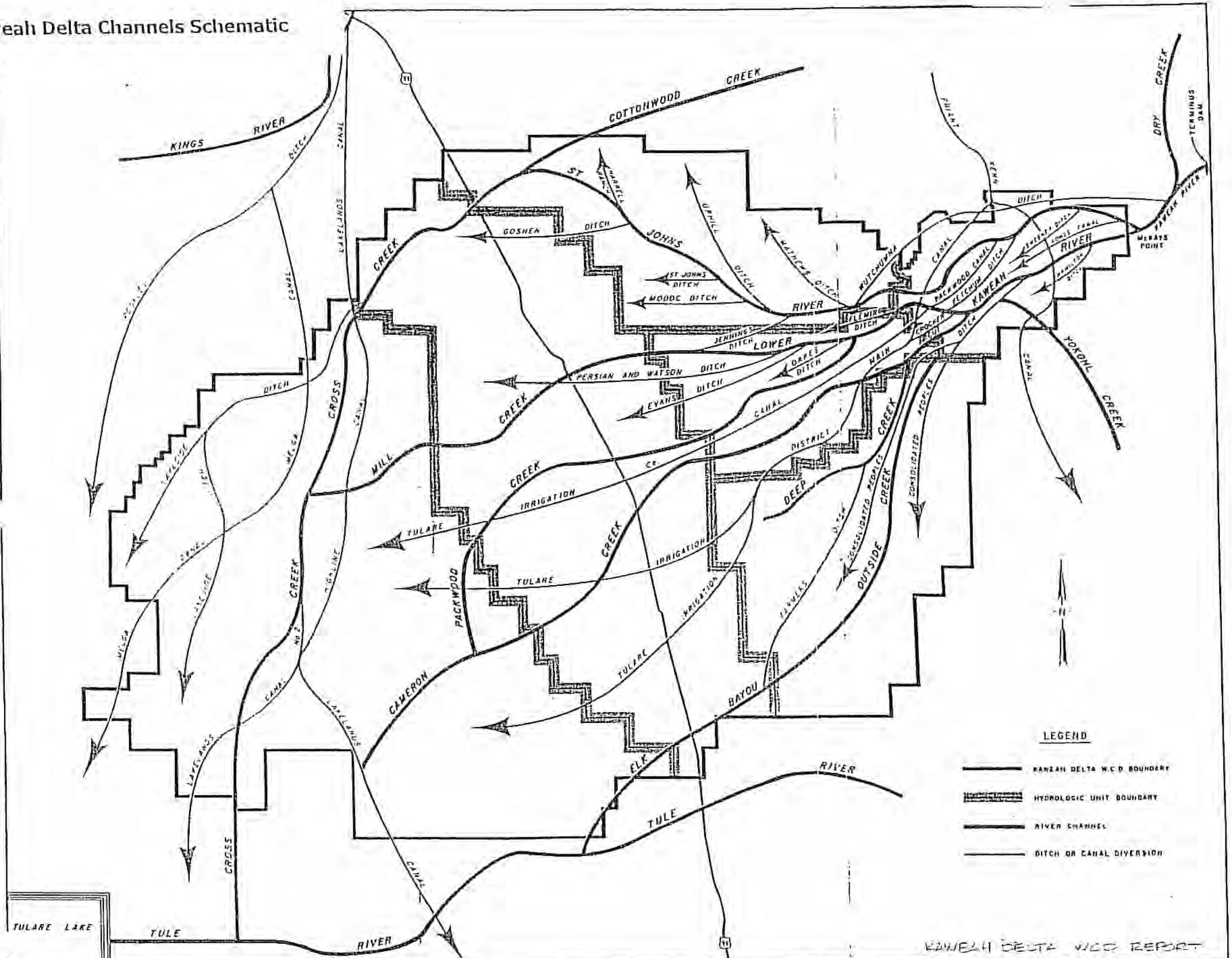
LIST OF FIGURES

Figure 1: Kings River Hydrograph



*Long-term average annual inflow for period of record 1962-2006 is 1,791,366 AF
Source: USACOE data

Figure 2: Kaweah Delta Channels Schematic

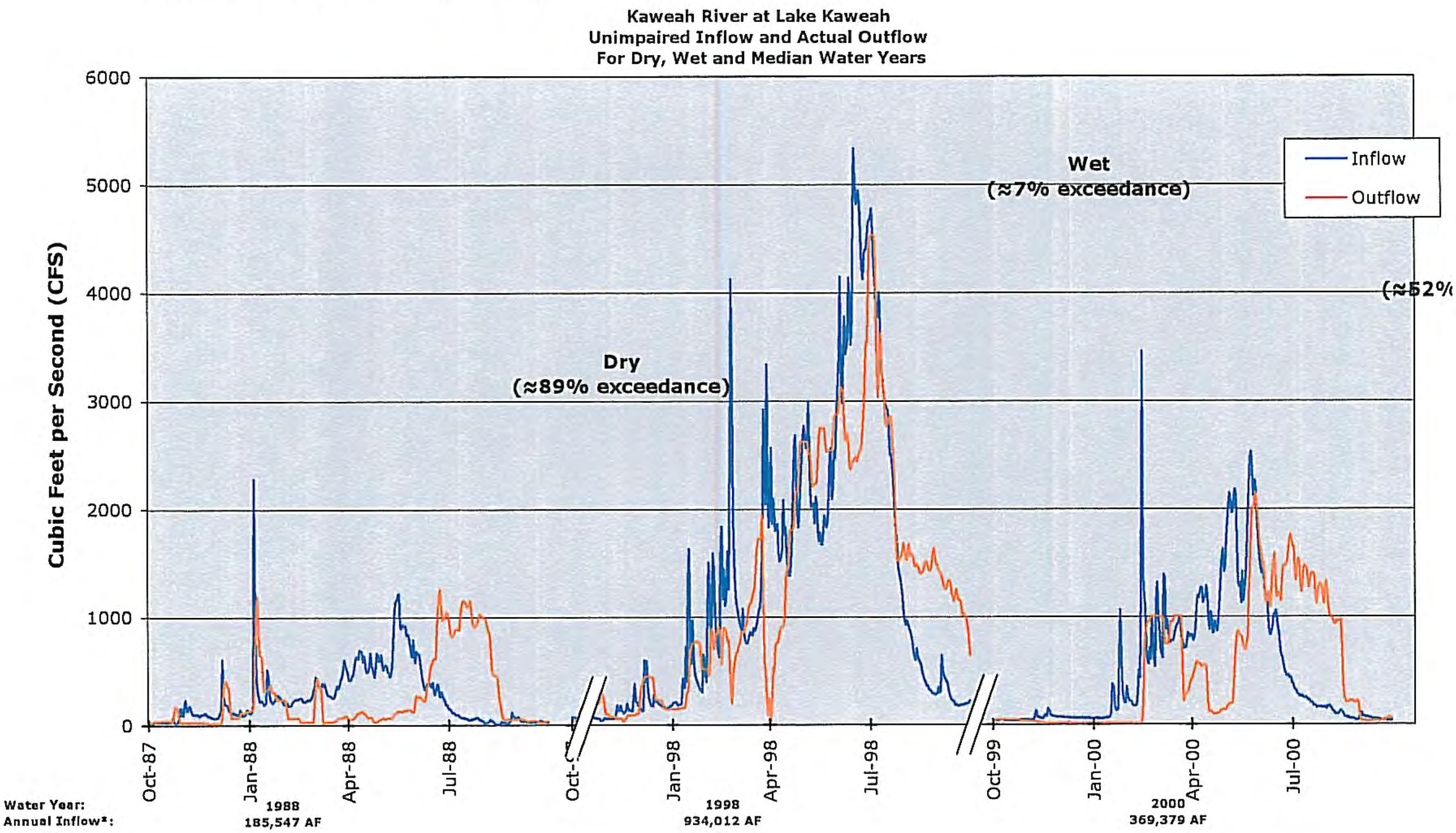


SCHEMATIC DIAGRAM OF CHANNELS AND DIVERSIONS IN KAWEAH DELTA

BOOKMAN and EDMONSTON
CONSULTING CIVIL ENGINEERS

FEBRUARY 1972

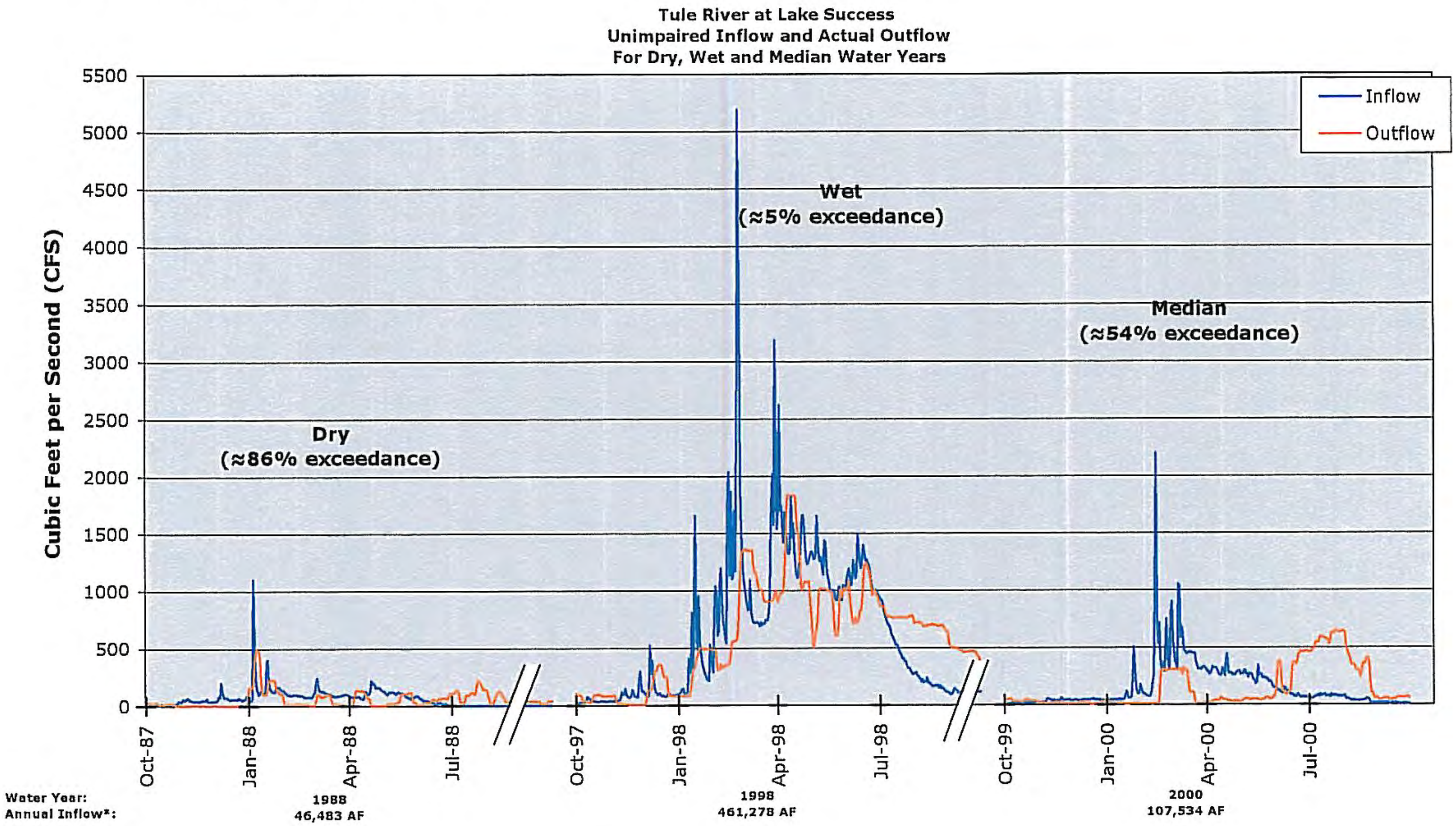
Figure 3: Kaweah River Hydrograph



*Long-term average annual inflow for period of record 1962-2006 is 473,636 AF

Source: USACOE data

Figure 4: Tule River Hydrograph



*Long-term average annual inflow for period of record 1962-2006 is 155,503 AF
Source: USACOE data

Figure 5: Intersection of the Cross Valley Canal and Kern River

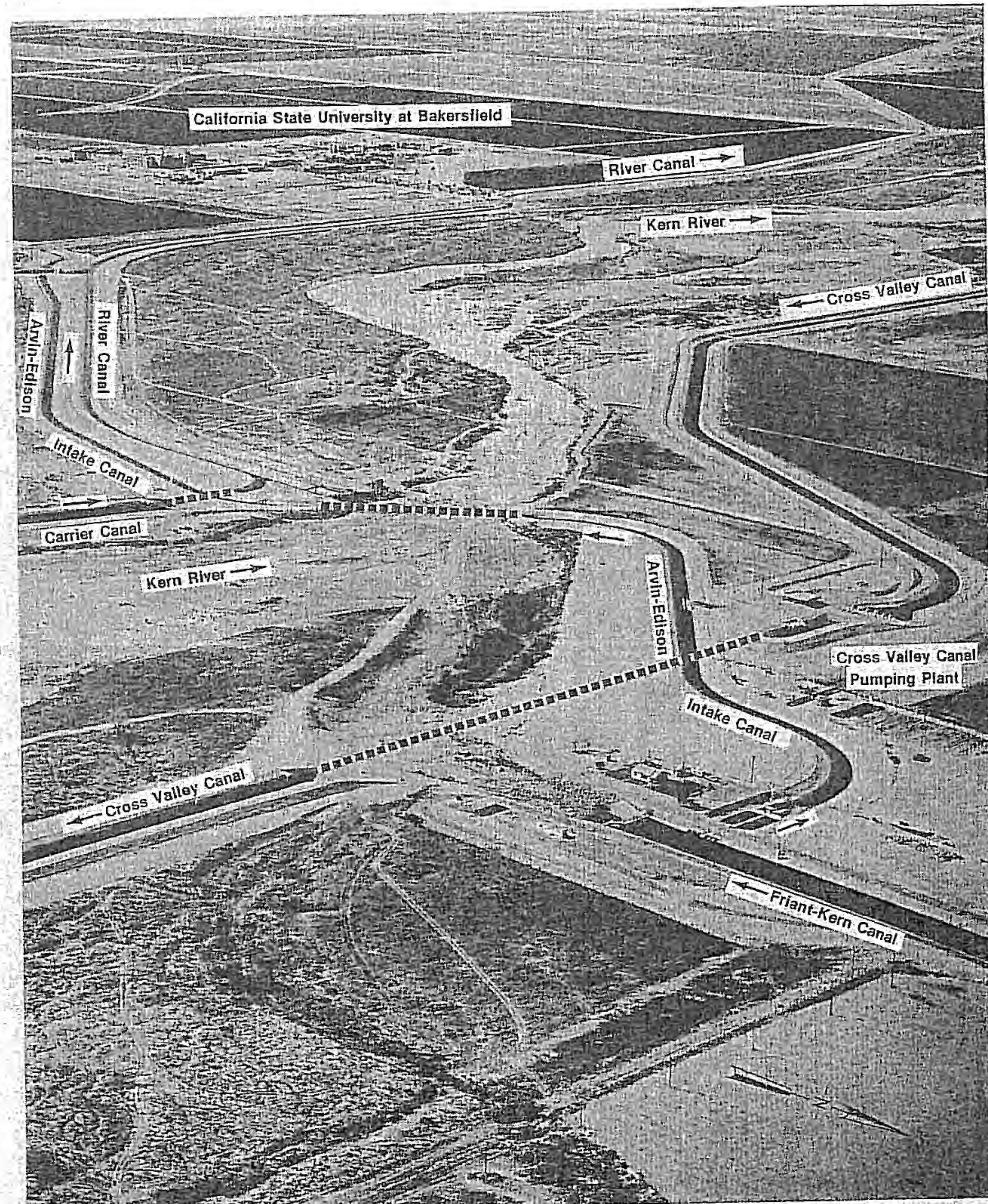
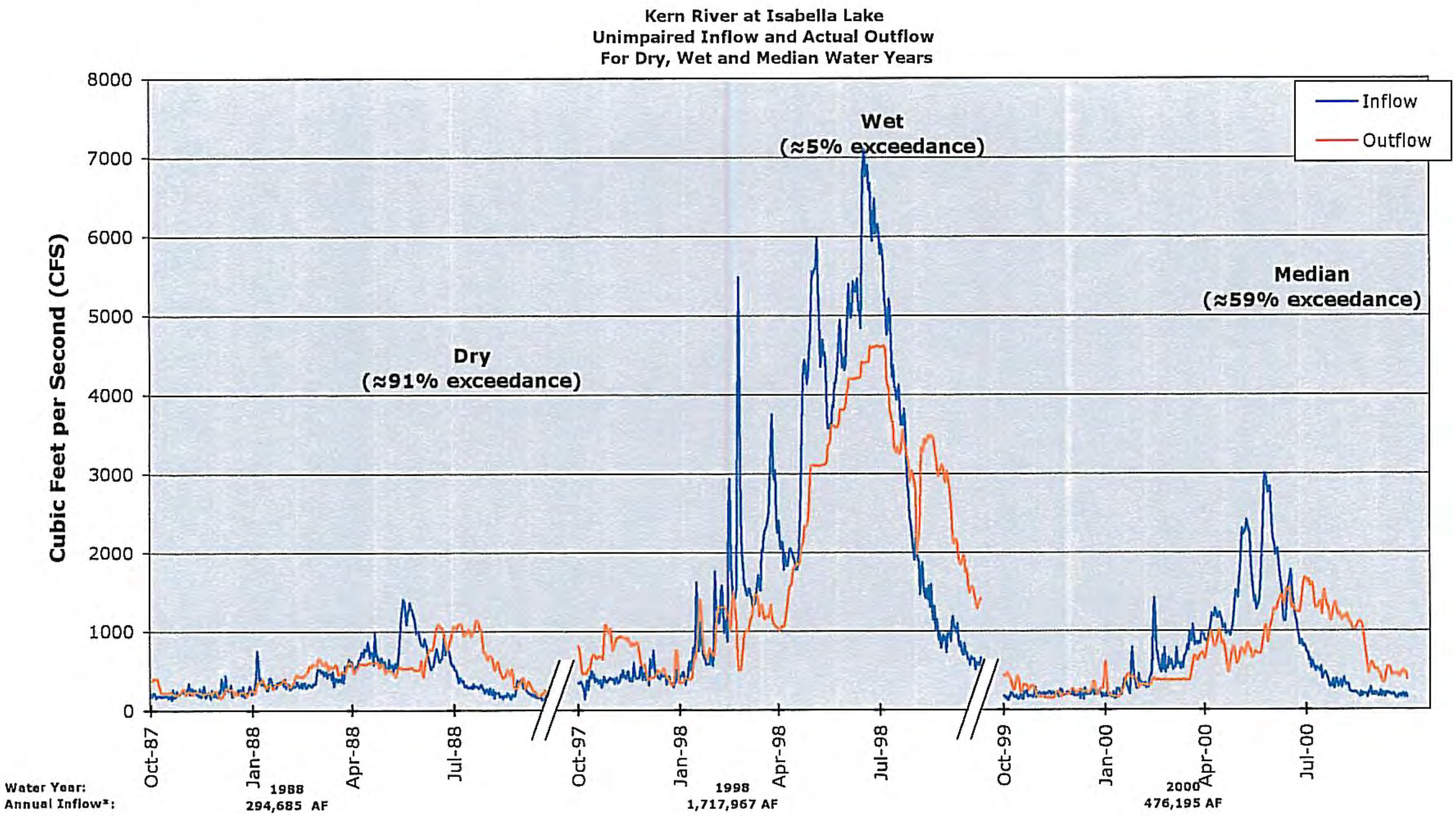


Photo Courtesy Kern County Water Agency.

Management and conjunctive use of water supplies from Central Valley Project, State Water Project and Kern River are made possible by water transfers in interconnecting water conveyance facilities westerly of Bakersfield.

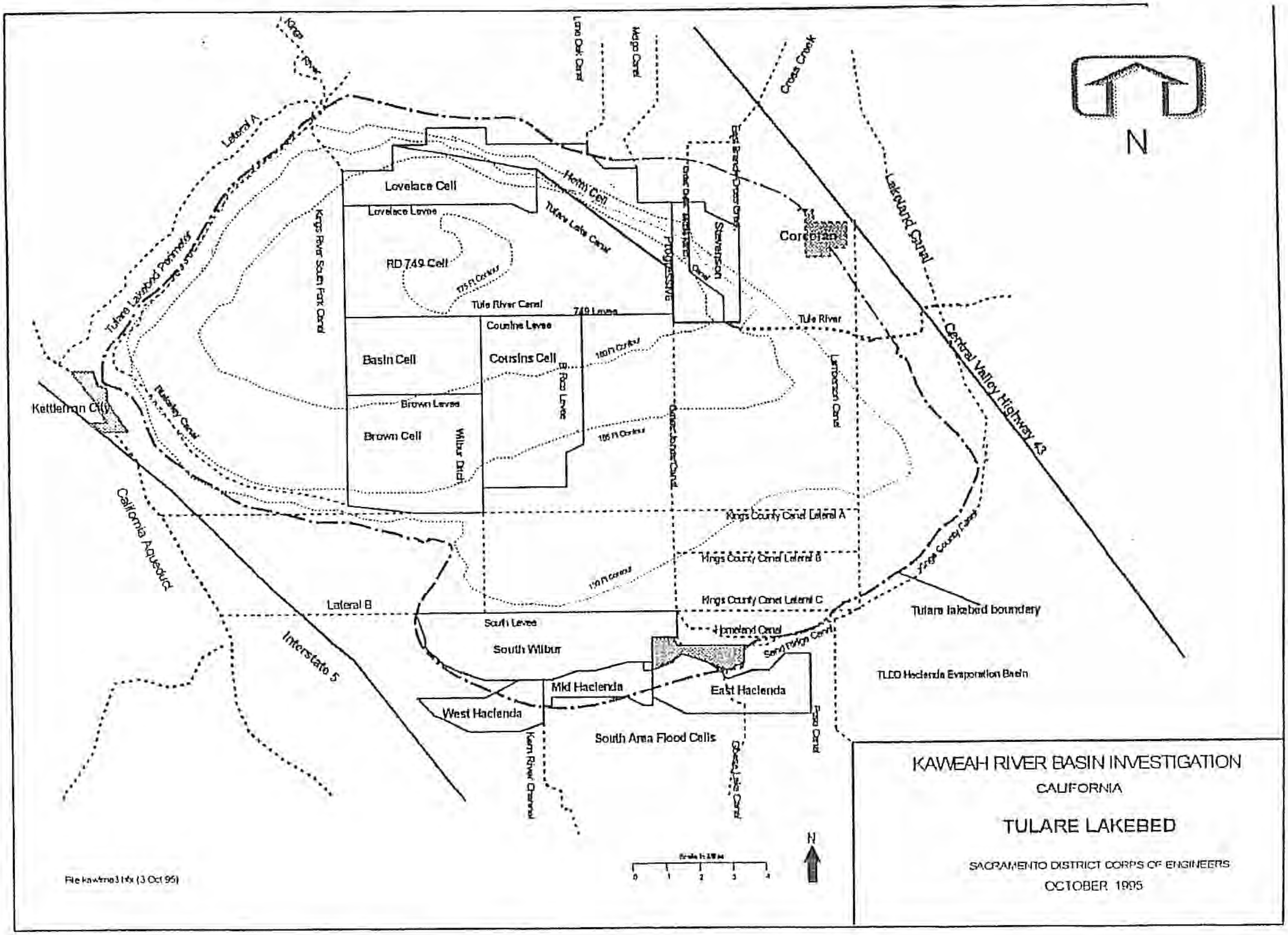
Figure 6: Kern River Hydrograph



*Long-term average annual inflow for period of record 1962-2006 is 802,384 AF

Source: USACOE data

Figure 7: Tulare Lake Bottom Storage Cell Map



LIST OF TABLES

Table 1: Drainage Areas and Mean Annual Runoff

	Drainage area (sq mi)	Mean Annual Runoff (MAR) (AF)
KINGS RIVER		
Above Pine Flat Dam[1]	1,545	1,790,536
Mill Creek near Piedra[2]	127	30,625
COTTONWOOD CREEK		
Near Elderwood	60	9,484
KAWEAH RIVER		
Above Terminus Dam - Lake Kaweah	561	475,223
Dry Creek near Lemoncove	80	15,783
at McKay Point	647	
TULE RIVER		
Above Success Dam	391	158,911
DEER CREEK		
Near fountain springs	83	23,892
WHITE RIVER		
Near Ducor	91	6,842
POSO CREEK		
Near Oildale	230	32,218
KERN RIVER		
Above Isabella Dam	2,074	
Near Bakersfield (Kern River at first point of measurement)	2,407	813,400
CALIENTE CREEK		
At Caliente	322	1,636
LOS GATOS CREEK		
Above Nunez Canyon near Coalinga	96	2,563
At I-5	514	

[1] Four river runoff above reservoir is mean annual unimpaired runoff for the 1962-2001 period.
[2] All other stream runoff is for 1974 calendar year, which was an approximately average runoff year (109% of the 1962-2001 average).

Table 2: Runoff Totals for the Four Tulare Basin Rivers

Year	Kings TAF	Kings % of avg	Kaweah TAF	Kaweah % of avg	Tule TAF	Tule % of avg	Kern TAF	Kern % of avg	Total TAF	1894-2001 % of avg	1962-2001 % of avg
1894	1459	87%	352	82%	104	75%	533	73%	2448	82%	76%
1895	2242	134%	579	135%	208	149%	1023	140%	4052	136%	125%
1896	1536	91%	377	88%	117	84%	620	85%	2650	89%	82%
1897	1948	116%	500	117%	177	127%	893	122%	3518	118%	109%
1898	881	52%	194	45%	38	27%	252	34%	1365	46%	42%
1899	1278	76%	274	64%	48	34%	339	46%	1939	65%	60%
1900	1307	78%	277	65%	45	32%	332	45%	1961	66%	61%
1901	2956	176%	680	159%	174	125%	880	120%	4690	157%	145%
1902	1505	90%	360	84%	104	75%	553	75%	2522	85%	78%
1903	1640	98%	382	89%	101	72%	546	74%	2669	90%	82%
1904	1687	100%	385	90%	99	71%	493	67%	2664	89%	82%
1905	1448	86%	348	81%	105	75%	532	73%	2433	82%	75%
1906	3900	232%	1149	268%	469	337%	1901	259%	7419	249%	229%
1907	2733	163%	609	142%	208	149%	991	135%	4541	152%	140%
1908	997	59%	257	60%	110	79%	499	68%	1863	63%	58%
1909	2742	163%	802	187%	284	204%	1839	251%	5667	190%	175%
1910	1718	102%	409	95%	156	112%	659	90%	2942	99%	91%
1911	2748	164%	546	127%	184	132%	1013	138%	4492	151%	139%
1912	967	58%	207	48%	43	31%	387	53%	1604	54%	50%
1913	940	56%	221	51%	46	33%	368	50%	1574	53%	49%
1914	2475	147%	486	113%	159	114%	1114	152%	4233	142%	131%
1915	1795	107%	370	86%	84	60%	646	88%	2894	97%	89%
1916	2938	175%	762	178%	310	223%	2520	344%	6531	219%	202%
1917	1862	111%	471	110%	133	96%	823	112%	3290	110%	102%
1918	1349	80%	228	53%	53	38%	539	74%	2168	73%	67%
1919	1190	71%	259	60%	71	51%	499	68%	2018	68%	62%
1920	1392	83%	350	82%	86	62%	601	82%	2428	81%	75%
1921	1507	90%	348	81%	97	70%	510	70%	2461	83%	76%
1922	2167	129%	461	108%	123	89%	861	117%	3613	121%	112%
1923	1535	91%	363	85%	99	71%	501	68%	2498	84%	77%
1924	392	23%	102	24%	24	17%	188	26%	706	24%	22%
1925	1275	76%	325	76%	85	61%	466	64%	2152	72%	66%
1926	1024	61%	219	51%	57	41%	367	50%	1667	56%	51%
1927	1941	116%	483	113%	164	117%	793	108%	3381	113%	104%
1928	959	57%	203	47%	59	43%	313	43%	1534	51%	47%
1929	848	51%	223	52%	48	34%	323	44%	1442	48%	45%
1930	857	51%	218	51%	51	37%	350	48%	1476	50%	46%
1931	466	28%	114	27%	25	18%	186	25%	791	27%	24%
1932	2038	121%	520	121%	138	99%	738	101%	3434	115%	106%
1933	1176	70%	284	66%	80	57%	441	60%	1980	66%	61%
1934	647	39%	131	30%	20	15%	228	31%	1026	34%	32%
1935	1599	95%	358	83%	89	64%	474	65%	2519	85%	78%
1936	1829	109%	487	114%	171	122%	796	109%	3283	110%	101%
1937	2273	135%	677	158%	306	219%	1260	172%	4516	152%	139%
1938	3181	190%	871	203%	355	255%	1359	185%	5766	193%	178%
1939	962	57%	247	58%	83	60%	461	63%	1754	59%	54%
1940	1717	102%	513	120%	211	151%	789	108%	3229	108%	100%
1941	2465	147%	642	150%	236	169%	1401	191%	4743	159%	146%
1942	1980	118%	491	114%	136	97%	772	105%	3378	113%	104%
1943	1973	118%	671	157%	364	262%	1221	167%	4230	142%	131%
1944	1149	68%	315	74%	102	73%	626	85%	2193	74%	68%
1945	2018	120%	551	128%	203	146%	938	128%	3709	124%	115%
1946	1599	95%	356	83%	94	67%	651	89%	2700	91%	83%
1947	1098	65%	265	62%	52	37%	407	56%	1822	61%	56%
1948	989	59%	261	61%	64	46%	330	45%	1645	55%	51%
1949	953	57%	219	51%	49	35%	303	41%	1524	51%	47%
1950	1272	76%	301	70%	62	44%	601	82%	2236	75%	69%
1951	1576	94%	421	98%	154	111%	442	60%	2593	87%	80%
1952	2751	164%	825	192%	320	230%	1501	205%	5397	181%	167%
1953	1146	68%	308	72%	99	71%	549	75%	2102	71%	65%
1954	1300	77%	306	71%	89	64%	528	72%	2223	75%	69%
1955	1100	66%	276	64%	65	46%	444	61%	1884	63%	58%
1956	2516	150%	725	169%	209	150%	841	115%	4291	144%	133%
1957	1246	74%	295	69%	65	47%	444	61%	2050	69%	63%
1958	2454	146%	640	149%	223	160%	1105	151%	4422	148%	137%
1959	810	48%	155	36%	32	23%	258	35%	1254	42%	39%
1960	713	42%	180	42%	48	35%	300	41%	1241	42%	38%
1961	555	33%	117	27%	25	18%	178	24%	875	29%	27%
1962	1837	109%	401	93%	86	62%	698	95%	3021	101%	93%
1963	1855	111%	491	115%	120	86%	801	109%	3268	110%	101%
1964	856	51%	230	54%	60	43%	339	46%	1485	50%	46%
1965	1930	115%	488	114%	138	99%	720	98%	3275	110%	101%
1966	1197	71%	248	58%	47	34%	679	93%	2171	73%	67%
1967	3225	192%	1025	239%	374	268%	1396	190%	6020	202%	186%
1968	822	49%	220	51%	67	48%	454	62%	1564	52%	48%
1969	4198	250%	1271	296%	504	362%	2461	336%	8434	283%	260%
1970	1298	77%	359	84%	122	88%	589	80%	2369	80%	73%
1971	1156	69%	293	68%	84	60%	427	58%	1960	66%	61%
1972	849	51%	168	39%	35	25%	268	37%	1320	44%	41%
1973	2085	124%	616	144%	225	162%	980	134%	3906	131%	121%
1974	2056	122%	490	114%	157	112%	819	112%	3521	118%	109%
1975	1558	93%	384	89%	122	88%	565	77%	2629	88%	81%
1976	535	32%	147	34%	42	30%	249	34%	974	33%	30%
1977	386	23%	94	22%	16	11%	197	27%	693	23%	21%
1978	3363	200%	834	194%	273	196%	1654	226%	6124	205%	189%
1979	1701	101%	416	97%	114	82%	673	92%	2904	97%	90%
1980	2992	178%	885	206%	330	237%	1640	224%	5846	196%	181%
1981	1028	61%	248	58%	80	58%	449	61%	1806	61%	56%
1982	3053	182%	772	180%	230	165%	1271	173%	5326	179%	164%
1983	4287	255%	1402	327%	615	441%	2489	340%	8793	295%	272%
1984	1935	115%	517	121%	187	134%	822	112%	3460	116%	107%
1985	1236	74%	332	78%	112	80%	672	92%	2352	79%	73%
1986	3190	190%	815	190%	247	177%	1445	197%	5697	191%	176%
1987	764	46%	192	45%	57	41%	376	51%	1389	47%	43%
1988	820	49%	186	43%	46	33%	295	40%	1347	45%	42%
1989	897	53%	215	50%	55	39%	397	54%	1564	52%	48%
1990	684	41%	141	33%	30	21%	204	28%	1059	36%	33%
1991	1061	63%	252	59%	60	43%	406	55%	1779	60%	55%
1992	699	42%	149	35%	31	22%	297	41%	1177	39%	36%
1993	2479	148%	549	128%	140	101%	854	116%	4023	135%	124%
1994	867	52%	192	45%	46	33%	336	46%	1441	48%	44%

Table 2: Runoff Totals for the Four Tulare Basin Rivers (Continued)

Year	Kings		Kaweah		Tule		Kern		Total	1894-2001	1962-2001
	TAF	% of avg	TAF	% of avg	TAF	% of avg	TAF	% of avg	TAF	% of avg	% of avg
1995	3371	201%	866	202%	252	181%	1385	189%	5874	197%	181%
1996	2062	123%	528	123%	169	121%	1038	142%	3796	127%	117%
1997	2563	153%	764	178%	357	257%	1182	161%	4866	163%	150%
1998	2981	178%	934	218%	461	331%	1718	234%	6095	205%	188%
1999	1242	74%	266	62%	97	70%	434	59%	2039	68%	63%
2000	1501	89%	369	86%	108	77%	476	65%	2454	82%	76%
2001	1002	60%	262	61%	59	42%	381	52%	1704	57%	53%

	Kings TAF	Kaweah TAF	Tule TAF	Kern TAF	Total TAF
1894-2001 Averac	1,681	430	140	735	2,985
1962-2001 Averac	1,789	477	161	816	3,244

Notes
1. Percent of average is for the 1894-2001 long-term average
2. Kings, Kaweah, and Tule- 1909-2000 from USACE data; 1894-1908 from USBR 1970 which uses USGS and USACE data for Kings and correlation for Kaweah and Tule; 2001 data from DWR CDEC web site
3. Kern data from 1894-1999 from KWCA 1999 water supply report; 2000 and 2001 from CDEC; 1916 runoff total of 2.5 MAF is suspect since USGS gaging station only shows about 2.0 MAF

Table 3: Minor Stream Runoff

	Calendar Year			
	1977	1978	1979	1983
4-river runoff % of average	23%	205%	97%	295%
Minor Stream	**Runoff (AF)[1]**	**Runoff (AF)**	**Runoff (AF)**	**Runoff (AF)**
Mill Creek	2,165	88,328	25,412	143,352
Cottonwood Creek	94	27,946	7,747	51,621
Sand Creek	25	11,801	3,077	20,924
Dry Creek	796	42,716	12,163	86,156
Deer Creek	3,504	36,345	15,856	107,876
White River	557	16,869	4,967	34,028
Poso Creek	1,853	50,752	22,734	155,660
Caliente Creek	109	24,761	3,374	N/A[2]
Los Gatos Creek	449	28,815	2,758	34,100

[1] From USGS records available on-line, calendar year values.
[2] N/A - not available.

Table 4: Reservoir Information

	Year completed	Capacity (AF)	Operator
KINGS RIVER			
Pine Flat Dam - Pine Flat Lake	1952	1,000,000	USACOE
Courtwright Reservoir	1958	123,300	PG&E
Wishon Reservoir	1957	128,600	PG&E
KAWEAH RIVER			
Terminus Dam - Lake Kaweah	1961	143,000	USACOE
Spillway raise	2004	185,630	
TULE RIVER			
Success Dam - Success Lake	1961	82,300	USACOE
Temporary storage restriction	2004	29,200	
KERN RIVER			
Isabella Dam - Lake Isabella	1953	568,000	USACOE

Table 5: Kings River Water Distribution

	1979[1] - 102% of average		1988 – 49% of average		1995[2] - 203% of average	
Location	**Volume (TAF)**	**Flow (cfs) and period[3]**	**Volume (TAF)**	**Flow (cfs) and period**	**Volume (TAF)**	**Flow (cfs) and period**
Gould Canal	157.8	< 419 cfs; Oct-Sep, no flow mid-Nov to early Dec	94.1	< 426 cfs; late Dec to early Aug; Apr, May discontinuous	101.1	< 426 cfs; Oct-Sep, Mar discontinuous
Fresno Canal	475.1	< 1406 cfs; Oct-Nov, late Feb-Sep	331.0	< 1538 cfs; late Feb to Sep; Apr, May discontinuous	399.0	< 1510 cfs; Feb, Mar, Apr-Sep
Consolidated Canal	492.4	< 1934 cfs; Oct-Nov, Feb-Sep, continuous Apr-Jul	80.2	< 1535 cfs; Jan, May-Aug, discontinuous	441.2	<1850 cfs; Jan, Mar, Apr-Sept
Alta Canal	210.6	< 939 cfs, Oct, mid-Apr to Aug	59.3	< 670 cfs, Jun-July	235.5	< 945 cfs, Apr-Sep;
Peoples Canal	234.4	< 768 cfs; Oct-Sep; continuous mid-Dec to early Sep	100.5	< 783 cfs; Feb-Sep; continuous June to mid-Sep	210.4	< 927 cfs, Jan-Sep;
Lakelands Canal	34.3	< 340 cfs; Apr-Sep discontinuous	18.9	< 170 cfs; Jun-Aug	53.0	< 478; May, July-Sep
Lemoore Canal	107.8	< 469 cfs, late Jan to Sep; no flow in mid May	76.6	< 448 cfs, mid-Feb to early Apr, Jun to early Sep	79.2	< 410 cfs, Jan-Sep; continuous mid-Mar to Sep
Last Chance Ditch	107.9	< 379 cfs, Oct-Sep; continuous mid-May to Aug	31.2	< 433 cfs; Jan, Jun-July	102.3	< 415 cfs, Jan-Sep; continuous mid-Mar to Sep
Westlake Canal	13.3	< 57 cfs, Oct-Sep; continuous mid May to Aug	2.9	< 61 cfs, Jun-Aug discontinuous	1.4	< 52 cfs; Aug only
Empire Westside Canal	17.1	< 87 cfs, Oct-Sep; continuous mid Apr to early-Sept	4.5	< 68 cfs, Feb, Jun-Aug;	6.0	< 50 cfs, Apr-Sep; continuous June to mid-Sept
Stratford Canal	7.3	< 65 cfs, Oct-Sep discontinuous	4.0	< 65 cfs, Mar, Jun-Aug discontinuous	6.1	< 60 cfs, Apr-Sep; continuous June to mid-Sept
Empire Weir #2 (over weir)	14.3	< 149 cfs, Oct-Sep; discontinuous	9.2	< 149 cfs, Jan, Feb, Jun-Aug; discontinuous	56.6	< 677 cfs, Apr-Sep; continuous June to early Sept
Blakely Canal	43.1	< 215 cfs, Nov-Aug discontinuous	14.1	< 217 cfs, Jun-Aug; discontinuous	23.2	< 197 cfs, Apr-Sep; continuous June to early Sept
Tulare Lake Canal	55.2	< 337 cfs, Oct-Sep discontinuous	17.8	< 356 cfs, Jan, Feb, Jun-Aug discontinuous	48.2	<413 cfs, Apr-Sep; continuous June to early Sept
Friant-Kern Canal into River[4]	191.0	Oct, Nov, Feb-Apr, Jul, Aug	45.1	May-July	58.9	Feb, Mar, Sep
Fresno Slough	11.8	< 984 cfs; Feb-Jul discontinuous	0	N/A	586.5	< 3994 cfs; Mar-Aug
Total Diversions[5]	2223.5	Year round, June and July maximum	857.2	Dec-Sep, June and July maximum	2080.9	Year round, May and July maximum

1 1979 followed wet 1978; fall and early winter water reflects antecedent conditions.
2 1995 followed very dry 1994; fall and early winter lack of water reflects antecedent conditions.
3 Cfs is max flow; all periods listed have continuous flow unless noted otherwise; discontinuous signifies that 2 or more days in month have 0 flow.
4 Friant-Kern Canal discharge into the river through the Kings River wasteway. Does not include additional deliveries up-canal into FID system.
5 Total River diversions minus Fresno Slough flow.

Table 6: Bodies of Water in the Kaweah-Tulare Lake Basin that Contain White Bass (reproduced from CDFG 1987)

Body of Water	Dewatering Code	Volume (acre-feet)	Rotenone Required (gallons)
TULARE COUNTY			
Kaweah Reservoir	5	8000	5333
Kaweah River-- below reservoir	3	180	117
St. Johns River	2	0-680	0-442
Cross Creek to Hwy 99	2	0	--
Cottonwood Creek	5	5	3
Wutchumna Ditch	2	20	13
Bravo Lake	5	1000	650
Borrow Pits-- Lone Star Industries	5	845	550
Lindsay-Strathmore Irrigation District Canal	2	0	--
Tule River from Road 192 to Hwy 43	5	30	20
Subtotal		10,080-10,760	6,686-7,128
Alta Irrigation District Canals Below Barriers			
Banks Ditch	3	2	1
Cross Creek Wasteway	2	0	--
Wiese Ditch	2	0	--
Kennedy Schoolhouse Ditch	2	0	--
Button Ditch	2	0	--
Williams Ditch	3	1	1
Clough Ditch	2	0	--
Sand Creek	2	0	--
Leyendekker's Ditch	3	3	2
Meyer's Pond	4	18	12
Subtotal		24	16
Kaweah Delta Water Storage District Percolation Ponds			
Basin #1	3	4	3
Basin #3	2	0	--
Basin #4	2	0	--
Basin #5	3	100	70
Basin #6	2	0	--
Basin #8	2	0	--
Basin #9	3	3	2

Table 6: Bodies of Water in the Kaweah-Tulare Lake Basin that Contain White Bass (reproduced from CDFG 1987) (Continued)

Body of Water	Dewatering Code	Volume (acre-feet)	Rotenone Required (gallons)
Basin #10	2	0	--
Basin #11	2	0	--
Basin #13	3	11	8
Basin #17	3	2	1
Basin #19	3	1	0.5
Basin #18	2	0	--
Basin #21	2	0	--
Basin #22	2	0	--
Basin #24	2	0	--
Basin #28	2	0	--
Basin #29	2	0	--
Basin #30	2	0	--
Subtotal		118	84.5
Kaweah Delta Water Storage District Canals			
Consolidated People's Ditch System	2	0	--
Johnson Slough	2	0	--
Locust Grove Ditch	2	0	--
Extension Ditch	2	0	--
Davis Ditch	2	0	--
Catron Ditch	2	0	--
Rice Ditch	2	0	--
Outside Creek	2	0-20	0-13
Gray Ditch	2	0	--
Hutchinson Ditch	2	0	--
Inside Creek	2	0	--
Elk Bayou	3	15	10
Deep Creek	2	0-35	0-23
Negro Slough	2	0-5	0-3
Farmers Ditch	2	0-4	0-3
Tulare Colony Ditch	2	0	--
Mill Creek	2	0	--
Tulare Irrigation Canal	2	0-35	0-23
Fleming Ditch	2	0	--
Packwood Creek	2	0-25	0-16
Evans Ditch	2	0	--
Persian Ditch	2	0	--
Watson Ditch	2	0	--
Long Canal	2	0	--
Ketchum Ditch	2	0	--
Packwood Canal	2	0	--
Matthews Ditch	2	0	--
Jennings Ditch	2	0	--
Modoc Ditch	2	0	--

Table 6: Bodies of Water in the Kaweah-Tulare Lake Basin that Contain White Bass (reproduced from CDFG 1987) (Continued)

Body of Water	Dewatering Code	Volume (acre-feet)	Rotenone Required (gallons)
Uphill Ditch	2	0	--
Goshen Ditch	2	0	--
Elbow Creek	3	5	- 3
Tulare Irrigation District Canal	2	0-80	0-52
Cameron Creek	2	0-45	0-29
Miot Ditch	2	0	--
Kaweah Canal	2	0	--
Cardoza Ditch	2	0	--
Bates Slough	3	22	14
Subtotal		44-293	24-190
KINGS COUNTY			
South Fork Kings River below Weir 1	4	425	276
Tule River downstream from Hwy 43	4	700	455
Blakely Canal	4	150	98
Stratford Canal	3	0	--
Tulare Lake Canal	4	165	197
Gates-Jones Canal	4	210	137
Wilbur Ditch	4	115	75
Empire Westside Canal	4	25	16
Hacienda Main Canal	4	65	42
Westlake Farms Canal	4	25	16
Sand Ridge Canal	4	30	20
Homeland Canal	4	340	221
Lovelace Canal	3	80	52
Lemoore Main Canal	2	0	--
McGlassen Ditch	2	0	--
Settler's Ditch East	2	0	--
Settler's Ditch West	2	0	--
Peoples Ditch	2	0	--
Last Chance Ditch	2	0	--
Lakeside Ditch	2	0	--
East Lakeside Ditch	2	0	--
Lakeland Canal	3	185	120
Cross Creek below Hwy 99			
Middle Branch	4	145	94
East Branch	4	55	36
West Branch	3	20	13
Sweet Canal	4	110	72
Lamberson Canal	4	100	67

Table 6: Bodies of Water in the Kaweah-Tulare Lake Basin that Contain White Bass (reproduced from CDFG 1987) (Continued)

Body of Water	Dewatering Code	Volume (acre-feet)	Rotenone Required (gallons)
Tulare Lake Storage District Water			
Lateral A	2	0	--
Lateral B	2	0	--
Melga Canal	2	0	--
Kings County Company Canal			
Lateral A	3	40	27
Lateral B	2	0	--
Lateral C	2	0	--
Tulare Lake Drainage District			
Main Drain	3	100	67
North Percolation Pond	3	660	429
Corcoran Irrigation District Pond	3	200	130
South Wilbur Area	1	0	--
Hacienda Ponds			
East	2	5	3
West	1	0	--
Middle	1	0	--
Subtotal		3950	2663
KERN COUNTY			
Kern River from Interstate 5 to Sand Ridge Canal	3	130	85
Subtotal		130	85
TOTAL		14,346-15,275	9,558-10,167

DEWATERING CODE

1 -- Dry except under flood conditions
2 -- Usually dry in late summer; dry for extended period
3 -- Dewatered periodically for maintenance or other reasons
4 -- Dewatered only by pumping
5 -- Retains water year-round

Table 7: Kaweah River Water Distribution

	1977 - 20% of average		1978 – 176% of average		1979 - 88% of average	
Location	**Volume (TAF)**	**Flow (cfs) and period**	**Volume (TAF)**	**Flow (cfs) and period**	**Volume (TAF)**	**Flow (cfs) and period**
Wutchumna Ditch	27.6	< 173 cfs, Oct- Sep	78.0	< 342 cfs, Oct- Sep	64.8	< 309 cfs, Oct- Sep
Wutchumna Ditch for transfer[1]	12.7	< 166 cfs, Jun- Sep	0		0	
St Johns below McKay Pt.	12	No flow in Nov and Dec, otherwise year-round	381	No flow in Nov, otherwise year-round	146.4	No flow in Sept, otherwise year-round
Lower Kaweah below McKay Pt.	49	No flow in Nov and Dec, otherwise year-round	402	Year-round	210	Year-round
Deep Creek	0.65	No flow most of the year	85.4	100-300 cfs most of the year	55.2	Winter pulse; 100-200 cfs April-Aug
Packwood Creek	0		31.5	50-200 cfs winter, spring and early summer	8.5	Winter pulse; 10-100 cfs late May-June
Mill Creek	5.4	<100 cfs June-Aug	42.7	50-200 cfs most of the year; peak flows May-July	32.4	50-100 cfs year-round
Elk Bayou to Tule River	0		13.8	Winter and spring pulse	0.03	
Lakeside ditch[2]	0		98	100-400 cfs most of the year	64	100-300 cfs Jan-Aug; occasional low/0 flow in winter, July-Aug
Cross Creek from Kaweah River[3]	0		3.6	Feb-Mar pulse	0	
Friant-Kern Canal into St. John's	0		32.5		61.7	
Friant-Kern Canal into Lower Kaweah	0		38.9		76.9	

[1] Assume Transfer into Friant-Kern Canal.
[2] Receives mostly St, John's Water, smaller amounts of Kings River water, Cottonwood Creek, Alta ID tailwater.
[3] Assume other water in Cross Creek from St. John's River, Cottonwood Creek or Alta ID tailwater.

Table 8: Tule River Water Distribution

Location	1998 - 297% of average		2000 – 69% of average		1996 - 108% of average	
	Volume (TAF)	Flow (cfs) and period[1]	Volume (TAF)	Flow (cfs) and period	Volume (TAF)	Flow (cfs) and period
Tule River below Success[2]	435	Year round[3]	96.9	Year round[4]	168.7	Year round[5]
Tule River below Porterville[6]	184[7]	Continuous after 12/9; usually above 150 cfs	24.3	Mid-March pulse (<=150 cfs); June-Aug (100-200 cfs)	54.9	50 – 300 cfs, Oct-Apr; Dec, Jan July, Aug discontinuous
Tule River at Turnball Weir	60	Mid-Jan through Sep; up to 800 cfs	4.7	< 135 cfs; Late Feb to mid-March; June pulse	8.4	10 –50 cfs; late Feb-mid April; sporadic May-July
Friant-Kern into Tule	0		5.9	< 148 cfs; Mid-Mar to early April	13	< 115 cfs; Nov and May; 1 to 10 days in all other months except 0 in Jan & Sep
Friant-Kern into Porter Slough	0		3	< 21 cfs Late Mar-Sep; Apr, May, Aug, Sep discontinuous	1.2	< 30 cfs; Apr-Sep, sporadic
Porter Slough Headgate	30.5	50 to 100 cfs; mid-Jan to Sep	4.8	< 118 cfs; mid-Feb to mid-Mar	30.6	< 108 cfs; Oct to early Dec, mid-Jan to early Apr, mid-June to mid-Sept
RD 770 pump into Friant-Kern	95 to 103 [8]	200 – 700 cfs from 2/26 to 6/19	0		0	
Ditches						
Pioneer	3.7	Year round, <1 cfs Nov – early April; up to 19 cfs Apr-Oct	5.4	Year-round	5.8	All year except winter
Cambell and Moreland	4.1	8 -19 cfs, May-Sep	5.5	Mid-Mar to-Sep; discontinuous in Mar and Apr; nearly continuous after late Apr	7.8	Most of year except for zero cfs in Dec & Jan and short period of no flow in Apr, Jul, Sep
Hubbs and Miner	1.2	3 -10 cfs, March-Sep discontinuous	1.5	Apr-Sep; discontinuous	1.8	Mid-Mar to Sept discontinuous
Poplar	49.2	50 - 100 cfs nearly year-round, zero in Nov and early Jan	19.3	Feb-Sep; nearly continuous from Apr-Sep (2 days of zero flow in May)	40.8	All year except for Dec to early Feb
Woods-Central	55.1	50 –200 cfs; Dec-Aug	22.6	Feb-Mar pulse; late June to Aug	13	Feb-Mar, Aug

[1] Unless otherwise noted flow is continuous for the period given. A note of "discontinuous" indicates no flow for less than 15 days per month during the period; a note of "sporadic" indicates no flow for more than 15 days per month during the period.
[2] 1998 and 2000 Tule River below Success plotted as outflow in Figure 1
[3] Storage above conservation pool from November through July; flood control releases from 12/3/97 to 7/5/98
[4] Storage above conservation pool from late Jan to mid-April; flood control release from 2/17/00 to 3/19/00
[5] Storage above conservation pool from November to mid-April; periodic flood control release during that period
[6] Rockford station
[7] 0 pre-rain; some diversion in winter but still peaks; steady but declining flow through summer
[8] 7 pumps 90 to 100 cfs capacity; Watermaster value (95) different than FWUA value (103)

Table 9: Tulare Lake Basin Water Imports and Exports

	Water Year		
	1998	2000	2001
	189%[1]	76%	53%
Imports[2]	(TAF)	(TAF)	(TAF)
1. CVP			
a. Friant	882	1272	790
b. San Luis Canal	1065	1020	992
c. DMC- Mendota Pool	42	107	106
d. CVC	0	0	14
2. SWP[3]	1296	2073	900
Total	3286	4472	2802
Exports			
1. Kings River			
a. James Bypass	984	0	0
2. Kern River Interitie			
a. Friant-Kern canal	59	0/ND	0/ND
b. Kern River runoff	130	0/ND	0/ND
3. Pumped water into CA Aqueduct	0	0	158
Total	1173	0	158

[1] % of 1962-2006 long-term average
[2] 6% of the volume is added for seepage and evaporation on SWP, San Luis, and CVC.
[3] SWP represents net import; additional water in the Aqueduct is passed through to regions south and west.
0/ND - No Data but assumed 0

Table 10: Hydrographic Connections within the Tulare Lake Basin and to the San Joaquin River and California Aqueduct[1]

From \ To	Upper/Mainstem Kings River	North Fork KingsRiver/ James Bypass	South Fork Kings River	Upper Kaweah River	Wutchumna Ditch	St. John's River/Cross Creek	Lower Kaweah River	Tule River	Kern River	San Joaquin River above Mendota Pool	Mendota Pool	San Joaquin River below Mendota Pool	Friant-Kern Canal	CA Aqueduct	Cross Valley Canal	Arvin-Edison Canal	Kern Water Bank Canal	Tulare Lakebed channels and canals	Tulare Lakebed Flood Cells
Upper/Mainstem Kings River	--	G	G	--	--	G[2]	--	--	--	G[3]	--	--	P	--	--	--	--	--	G[4]
North Fork Kings River/James Bypass	--	--	G	--	--	--	--	--	--	--	G	--	--	--	--	--	--	--	--
South Fork Kings River	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	G	G
Upper Kaweah River	--	--	--	--	G	G	G	--	--	--	--	--	--	--	--	--	--	--	--
Wutchumna Ditch	--	--	--	--	--	G	G	--	--	--	--	--	P	--	--	--	--	--	--
St. John's River/Cross Creek	--	--	--	--	--	--	--	--[5]	--	--	--	--	P	--	--	--	--	G	G
Lower Kaweah River	--	--	--	--	--	G	--	G[6]	--	--	--	--	--	--	--	--	--	G	--
Tule River	--	--	--	--	--	--	--	--	--	--	--	--	P	--	--	--	--	G	G
Kern River	--	--	--	--	--	--	--	--	--	--	--	--	--	G[7]	G	--	G	--	G[8]
San Joaquin River above Mendota Pool	--	--	--	--	--	--	--	--	--	--	G	G[9]	--	--	--	--	--	--	--
Mendota Pool	--	--	--	--	--	--	--	--	--	--	--	G	--	P[10]	--	--	--	--	--
San Joaquin River below Mendota Pool	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Friant-Kern Canal	G	--	--	--	--	G	G	G	G	--[11]	--	--	--	--	G[12]	G	P	--	--
CA Aqueduct	--	--	G[13]	--	--	--	--	--	--	--	--	--	--	--	P[14]	G[16]	G	G[15]	--
Cross Valley Canal	--	--	--	--	--	--	--	--	G	--	--	--	P	G	--	P	G	--	--
Arvin-Edison Canal	--	--	--	--	--	--	--	--	--	--	--	--	--	P[16]	G	--	G	--	--
Kern Water Bank Canal	--	--	--	--	--	--	--	--	--	--	--	--	--	G	G	--	--	--	--
Tulare Lakebed channels and canals	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	G
Tulare Lakebed Flood Cells	--	--	P	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

LEGEND

Connectivity symbols	**Color-coded frequency indicator**
G gravity connection	rare (i.e. severe flood or 1983 flood only)
P pumped connection	infrequent (primarily in wet or dry years only)
	common (majority of years)

[1] Does not include the connections from the Friant-Kern Canal and Poso Creek to the California Aqueduct via the Shafter-Wasco I.D. and Semi-Tropic W.S.D. systems or the connection of the Coast Range creeks (on the West side of the Basin) to the California Aqueduct

[2] Via Lakelands Canal and Alta Irrigation District distribution system.

[3] Via FID irrigation system.

[4] Via Kings Distribution system, documented in 1969 flood; possibly a connection in other wet years.

[5] Joins channelized Tule River on Tulare Lake Bottom; see connection to Tulare Lakebed channels and canals.

[6] Via Elk Bayou and Tulare Irrigation District spill.

[7] Via Kern River Intertie

[8] Via Kern River Flood Channel and Goose Lake Canal.

[9] Via Chowchilla Eastside Bypass.

[10] Via Lateral 7L

[11] Potential for Gravity connection via Little Dry Creek Wasteway, constructed for maintenance purposes to flush sand out of the Friant-Kern Canal but not used to-date.

[12] Currently (2007) via Arvin-Edison Canal; new bi-directional connection being constructed

[13] Via Lateral A.

[14] Water moves by gravity from the Aqueduct into the CVC but pumping is required to move water to the east to the first demand area

[15] Via Lateral B. Water from the California Aqueduct is also stored in the south end flood cells during non-flood years.

[16] Via Arvin-Edison Intertie

Table 11a: Principal Hydrographic Pathways Out of the Tulare Lake Basin for Non-Swimming Organisms and Toxicants

Pathway	Frequency of Flow	Gravity or Pump	Comments
Upper Kings-FID system-SJR	most years, sporadic	gravity	irrigation and winter runoff tailwater
Upper Kings-Lower Kings-James Bypass-SJR	high runoff periods with flood control releases in average and wetter years	gravity	occurred in 14 out of 30 water years since 1977
Upper Kings- Lower Kings- James Bypass-Mendota Pool – CA	high runoff periods in wet years	gravity, pump at end	occurred in 1995, 1998 and 2006
Fresno stream group- Fresno flood control- FID- SJR	high runoff periods	gravity	
Upper Kings- Lower Kings-Tulare Lakebed –SJR;	1983 only	gravity, pump, gravity	
Upper Kings- F-K Canal- Kern River or CVC –CA;	high runoff periods in wet years	pump then gravity	occurred in 4 out of 30 water years since 1977
Upper Kaweah- F-K Canal- Kern River or CVC –CA;	high runoff periods in wet years	pump then gravity	occurred in 7 out of 30 water years since 1977
Upper Kaweah—Wutchumna Ditch- F-K Canal- CVC or Arvin-Edison Canal –CA;	non-wet years, sporadic	pump then gravity or pump	
Upper Tule- F-K Canal- Kern River or CVC –CA;	high runoff periods in wet years	pump then gravity	occurred in 9 out of 30 water years since 1977
Kern River – CA	high runoff periods in wet years	gravity	occurred in 10 out of 30 years since 1977
Kern River – Kern Water Bank or Arvin-Edison canals– CA,	drier years	gravity and pump	surface water may be in canals when groundwater is pumped into canal for export

Notes:
CA- California Aqueduct
CVC- Cross Valley Canal
FID- Fresno Irrigation District
F-K- Friant-Kern
SJR- San Joaquin River
"Upper" river reach is above and "Lower" is below the Friant-Kern Canal
The Kern River Intertie was completed in 1977 so that year is used as the common base year for all pathways out of the Basin

Table 11b: Potential Hydrographic Pathways Out of the Tulare Lake Basin for Swimming Organisms

Pathway	Frequency of Flow	Gravity or Pump	Comments
Upper Kings-F-K Canal- Lower Kings	high runoff periods in wet years	pump	
Upper Kaweah-F-K Canal- Lower Kings	high runoff periods in wet years	pump	
Upper Kaweah—Wutchumna- F-K Canal- Lower Kings	non-wet years, sporadic	pump	
Lower Kaweah/St. John's- Alta ID system-Foothill streams- Lower Kings	high runoff periods		requires flow in foothill streams; likely barriers in non-flood conditions
Lower Kaweah/St. John's- Alta ID system- Lower Kings	high runoff periods and irrigation season		likely barriers in non-flood conditions
Upper Tule-- F-K Canal- Lower Kings	high runoff periods in wet years	pump	
Lower Tule-Lower Kaweah/Cross Creek-Alta ID-Lower Kings	high runoff periods and irrigation season		likely barriers in non-flood conditions
Tulare Lakebed canals-Lower Kings	high runoff periods and irrigation season		CADFG indicates that canal connections may allow fish to swim around the Empire Weirs 1 and 2. These have not been verified.

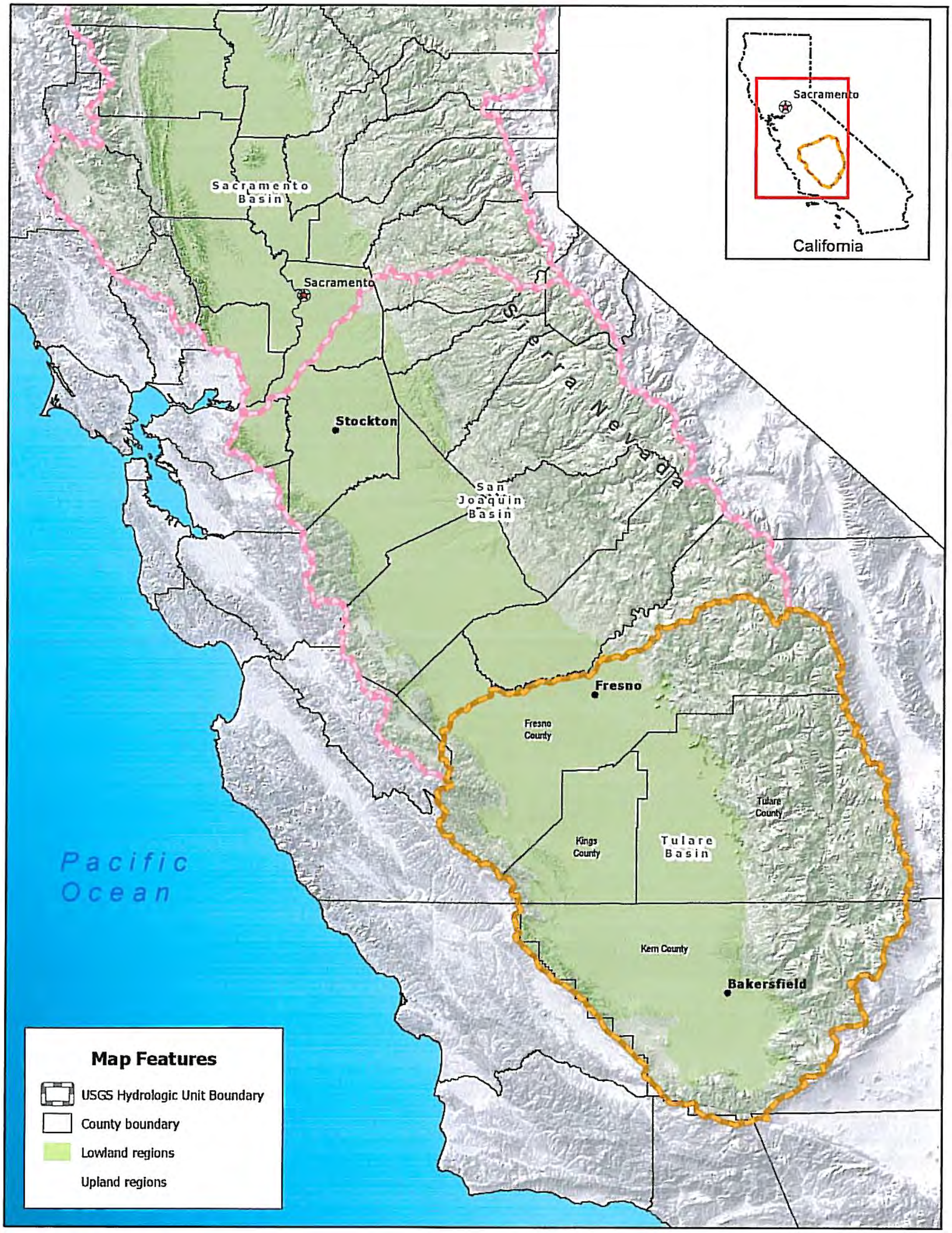
Notes:
F-K- Friant-Kern
"Upper" river reach is above and "Lower" is below the Friant-Kern Canal

Table 12: Fish species of the Tulare Lake Basin

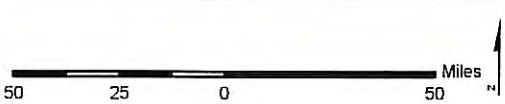
Fish Species of the Tulare Lake Basin		Pine Flat Reservoir	Lake Kaweah	Lake Success	Lake Isabella
Common Name	**Scientific Name**				
Largemouth bass	*Micropterus salmoides*	X	X	X	X
Smallmouth bass	*Micropterus dolomieu*	X	X	X	
Spotted bass	*Micropterus punctulatus*	X	X		
White bass[1]	*Morone chrysops*				
Striped bass	*Morone saxatilis*				
Bluegill	*Lepomis macrochirus*	X	X	X	X
Redear sunfish	*Lepomis microlophus*	X	X	X	X[2]
Green sunfish	*Lepomis cyanellus*	X	X		X
White crappie	*Pomoxis annularis*	X	X	X	X
Black crappie	*Pomoxis nigromaculatus*	X	X	X	X
Bigscale logperch	*Percina macrolepida*				X
Threadfin shad	*Dorosoma petenense*	X	X	X	X
Hardhead	*Mylopharodon conocephalus*	X	X		X
Sacramento blackfish	*Orthodon microlepidotus*		X	X	
Sacramento splittail	*Pogonichthys macrolepidotus*				
Sacramento pikeminnow	*Ptychocheilus grandis*	X	X	X	X
Hitch	*Lavinia exilicauda*	X			X
California roach	*Lavinia symmetricus*	X	X		
Golden shiner	*Notemigonus crysoleucas*	X	X	X	X
Goldfish	*Carassius auratus*	X	X	X	X
Common carp	*Cyprinus carpio*	X	X	X	X
Channel catfish	*Ictalurus punctatus*	X	X	X	X
White catfish	*Ameiurus catus*	X	X	X	X
Brown bullhead	*Ameiurus nebulosus*	X	X		
Chinook salmon	*Oncorhynchus tshawytscha*	X[3]			X
Rainbow trout	*Oncorhynchus mykiss*	X	X	X	X
Brown trout	*Salmo trutta*	X	X	X	X
Inland silversides	*Menidia beryllina*				
Sacramento sucker	*Catostomus occidentalis*	X	X	X	X
Riffle sculpin	*Cottus gulosus*		X		
Threespine stickleback	*Gasterosteus aculeatus*	X	X		
Mosquitofish	*Gambusia affinis*	X	X	X	
Western brook lamprey	*Lampetra richardsoni*				
Kern brook lamprey	*Lampetra hubbsi*				

[1] The last known occurrence of this species within the Basin was documented at Pine Flat Reservoir in 2000. Since white bass have not been observed or captured for the last six years, this species is likely absent from the Basin (Stan Stephens and Randy Kelly, CDFG, personal communication, August 2006).
[2] Redear sunfish x green sunfish hybrid
[3] Both reservoirs have been planted by CDFG.

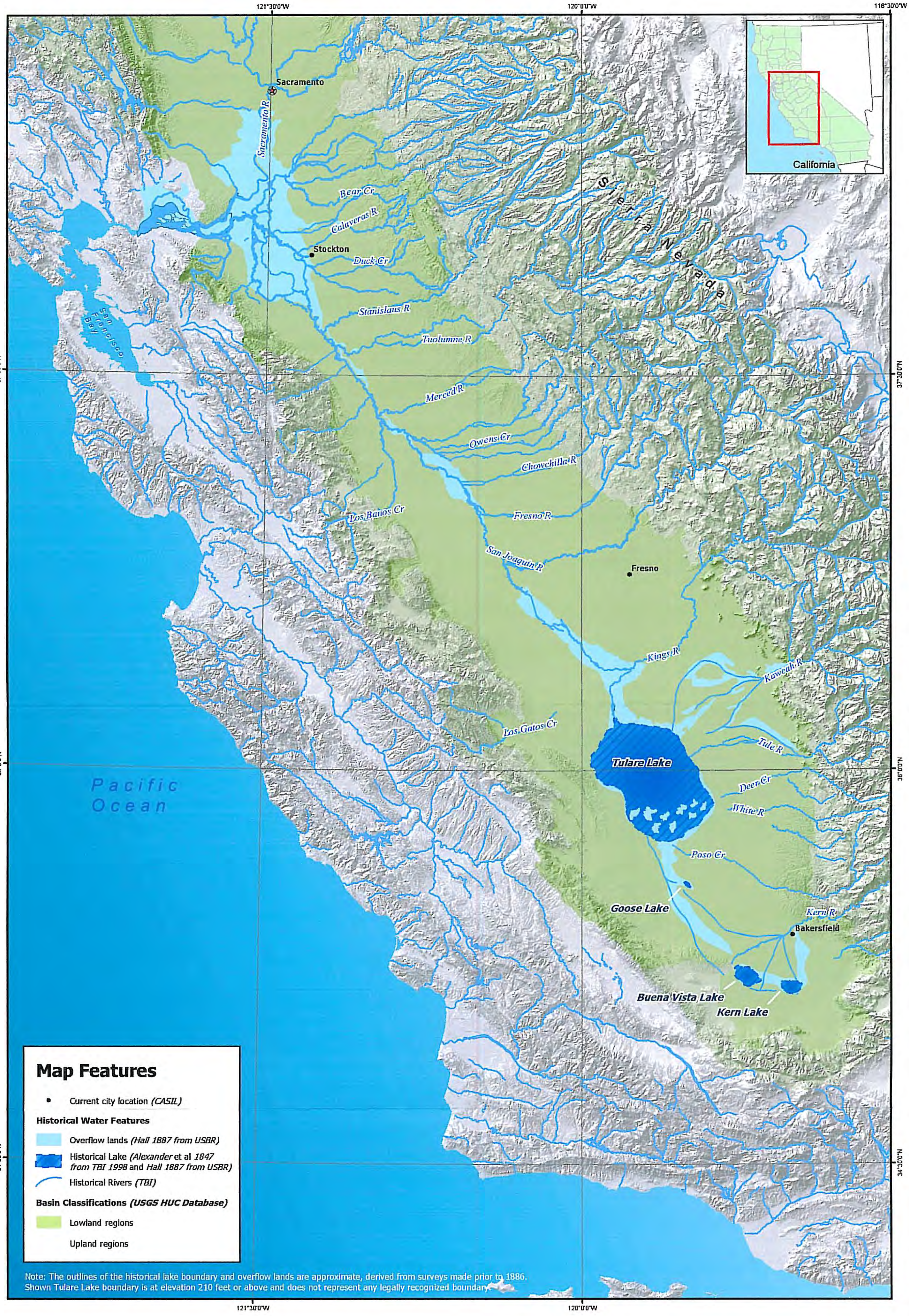
LIST OF MAPS



Map 1: Site and Vicinity



ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map 2: San Joaquin Valley Historical Surface Hydrography

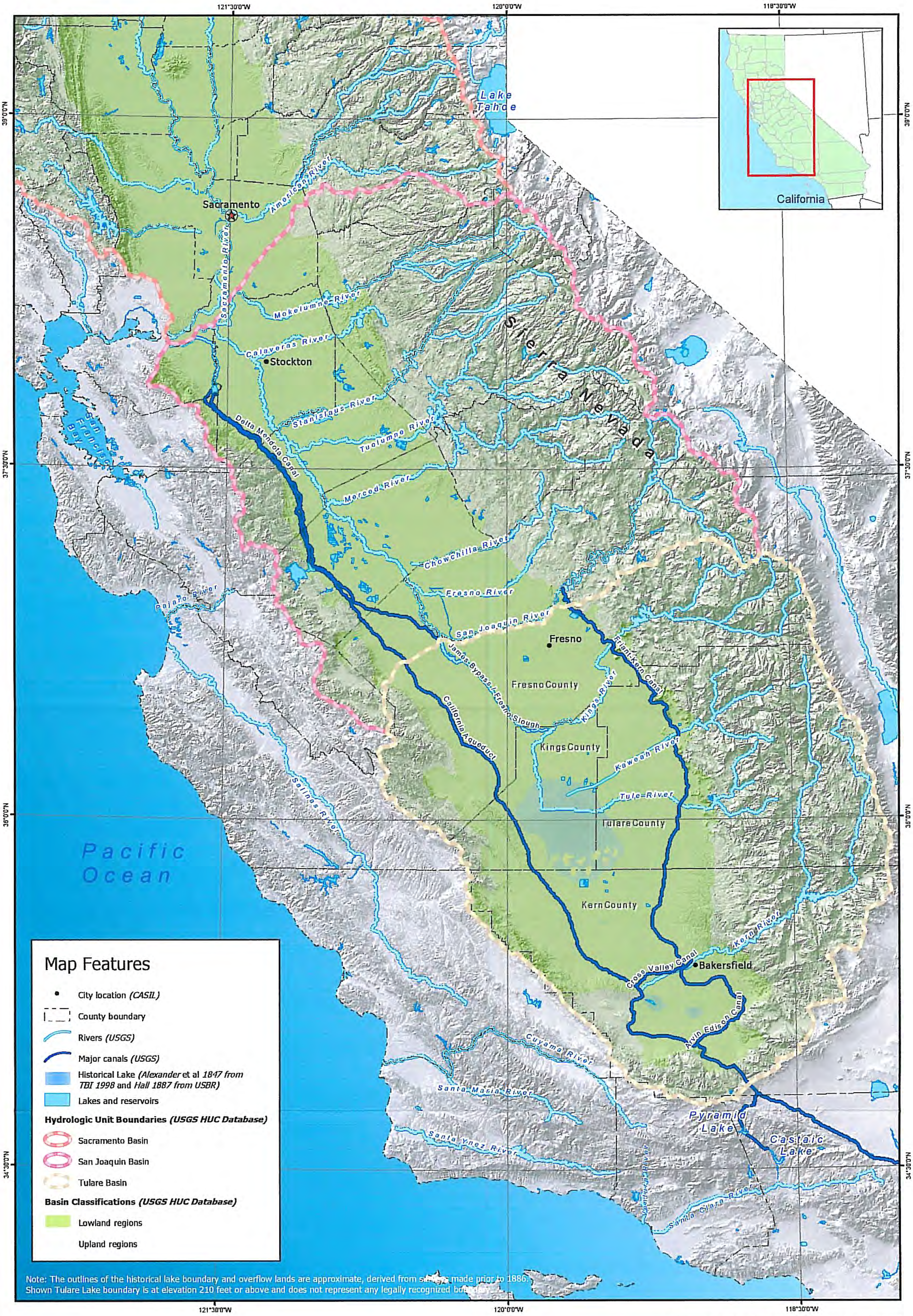
1:1,500,000

30 15 0 30 Miles

N

Map Projection Information: California Teale Albers Projection NAD83
Grid Information: Lat/Long 1° 30' 00"

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



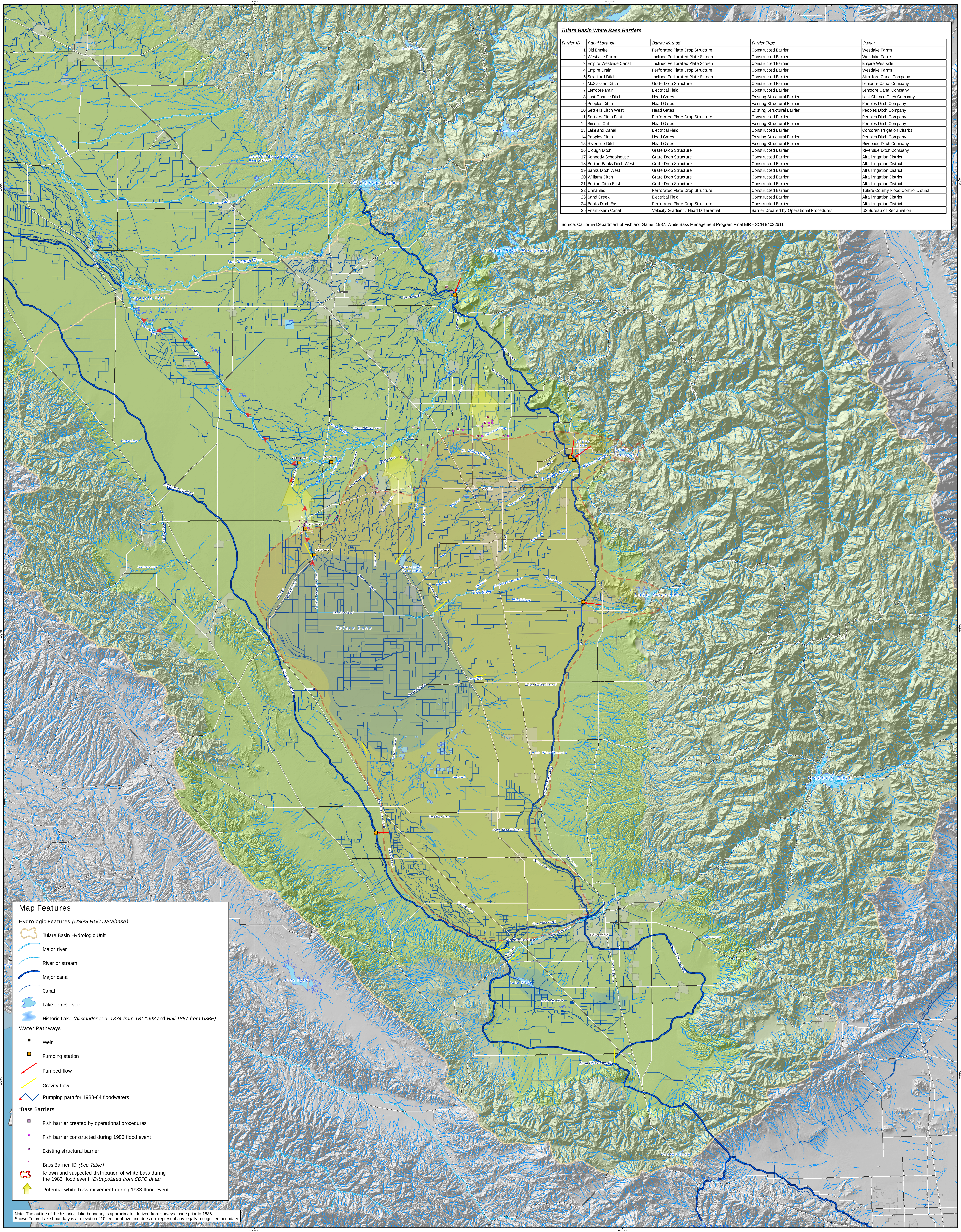
Map Projection Information: California Teale Albers Projection NAD83
Grid Information 1° 30' 00"

Map 3: San Joaquin Valley Current Hydrography

1:1,700,000

50 25 0 50 Miles

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



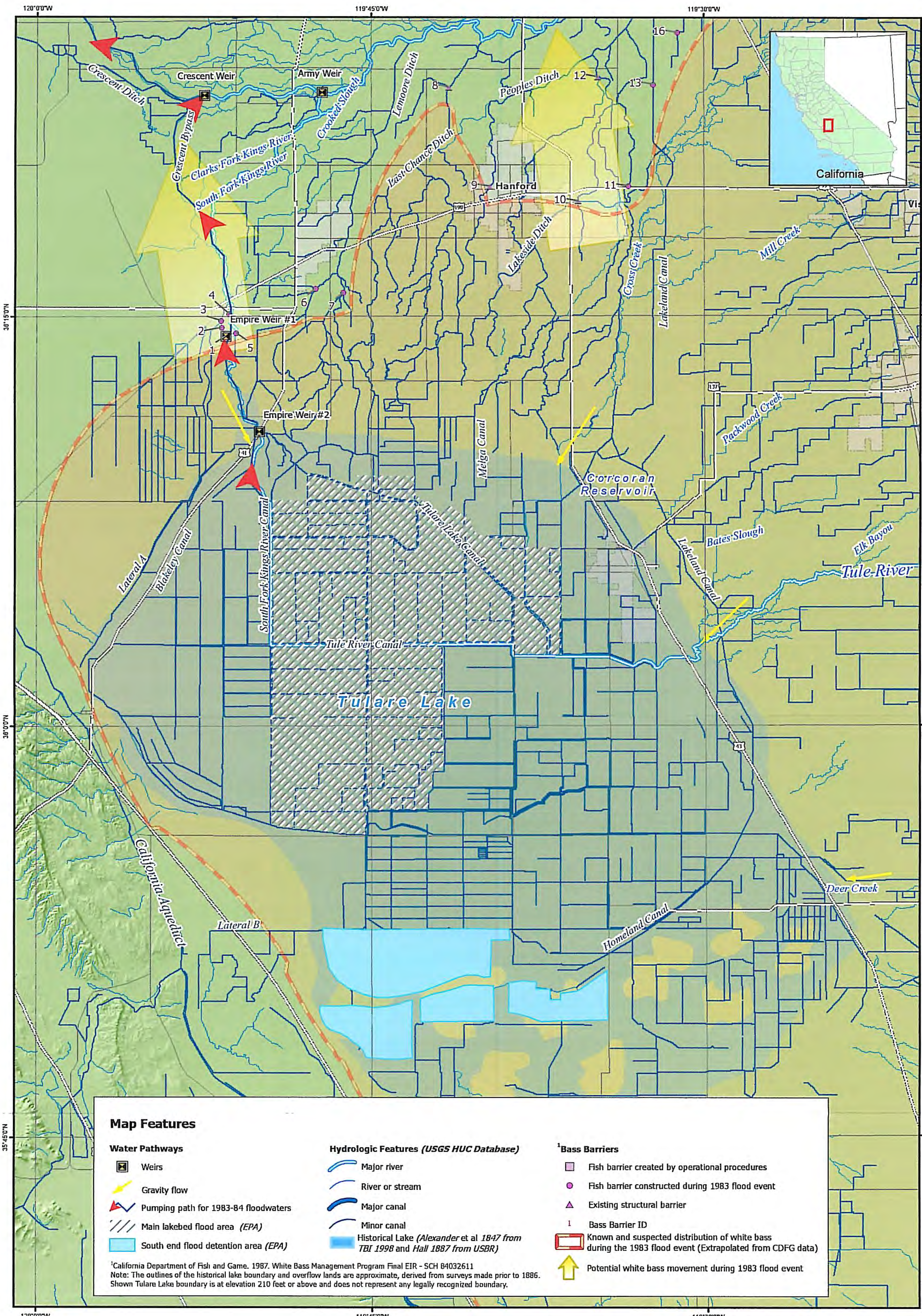
Tulare Basin White Bass Barriers

Barrier ID	*Canal Location*	*Barrier Method*	*Barrier Type*	*Owner*
1	Old Empire	Perforated Plate Drop Structure	Constructed Barrier	Westlake Farms
2	Westlake Farms	Inclined Perforated Plate Screen	Constructed Barrier	Westlake Farms
3	Empire Westside Canal	Inclined Perforated Plate Screen	Constructed Barrier	Empire Westside
4	Empire Drain	Perforated Plate Drop Structure	Constructed Barrier	Westlake Farms
5	Stratford Ditch	Inclined Perforated Plate Screen	Constructed Barrier	Stratford Canal Company
6	McGlassen Ditch	Grate Drop Structure	Constructed Barrier	Lemoore Canal Company
7	Lemoore Main	Electrical Field	Constructed Barrier	Lemoore Canal Company
8	Last Chance Ditch	Head Gates	Existing Structural Barrier	Last Chance Ditch Company
9	Peoples Ditch	Head Gates	Existing Structural Barrier	Peoples Ditch Company
10	Settlers Ditch West	Head Gates	Existing Structural Barrier	Peoples Ditch Company
11	Settlers Ditch East	Perforated Plate Drop Structure	Constructed Barrier	Peoples Ditch Company
12	Simon's Cut	Head Gates	Existing Structural Barrier	Peoples Ditch Company
13	Lakeland Canal	Electrical Field	Constructed Barrier	Corcoran Irrigation District
14	Peoples Ditch	Head Gates	Existing Structural Barrier	Peoples Ditch Company
15	Riverside Ditch	Head Gates	Existing Structural Barrier	Riverside Ditch Company
16	Clough Ditch	Grate Drop Structure	Constructed Barrier	Riverside Ditch Company
17	Kennedy Schoolhouse	Grate Drop Structure	Constructed Barrier	Alta Irrigation District
18	Button-Banks Ditch West	Grate Drop Structure	Constructed Barrier	Alta Irrigation District
19	Banks Ditch West	Grate Drop Structure	Constructed Barrier	Alta Irrigation District
20	Williams Ditch	Grate Drop Structure	Constructed Barrier	Alta Irrigation District
21	Button Ditch East	Grate Drop Structure	Constructed Barrier	Alta Irrigation District
22	Unnamed	Perforated Plate Drop Structure	Constructed Barrier	Tulare County Flood Control District
23	Sand Creek	Electrical Field	Constructed Barrier	Alta Irrigation District
24	Banks Ditch East	Perforated Plate Drop Structure	Constructed Barrier	Alta Irrigation District
25	Friant-Kern Canal	Velocity Gradient / Head Differential	Barrier Created by Operational Procedures	US Bureau of Reclamation

Source: California Department of Fish and Game. 1987. White Bass Management Program Final EIR - SCH 84032611

Map 4: Hydrography of Lowland Tulare Lake Basin

2004-056 Tulare Basin



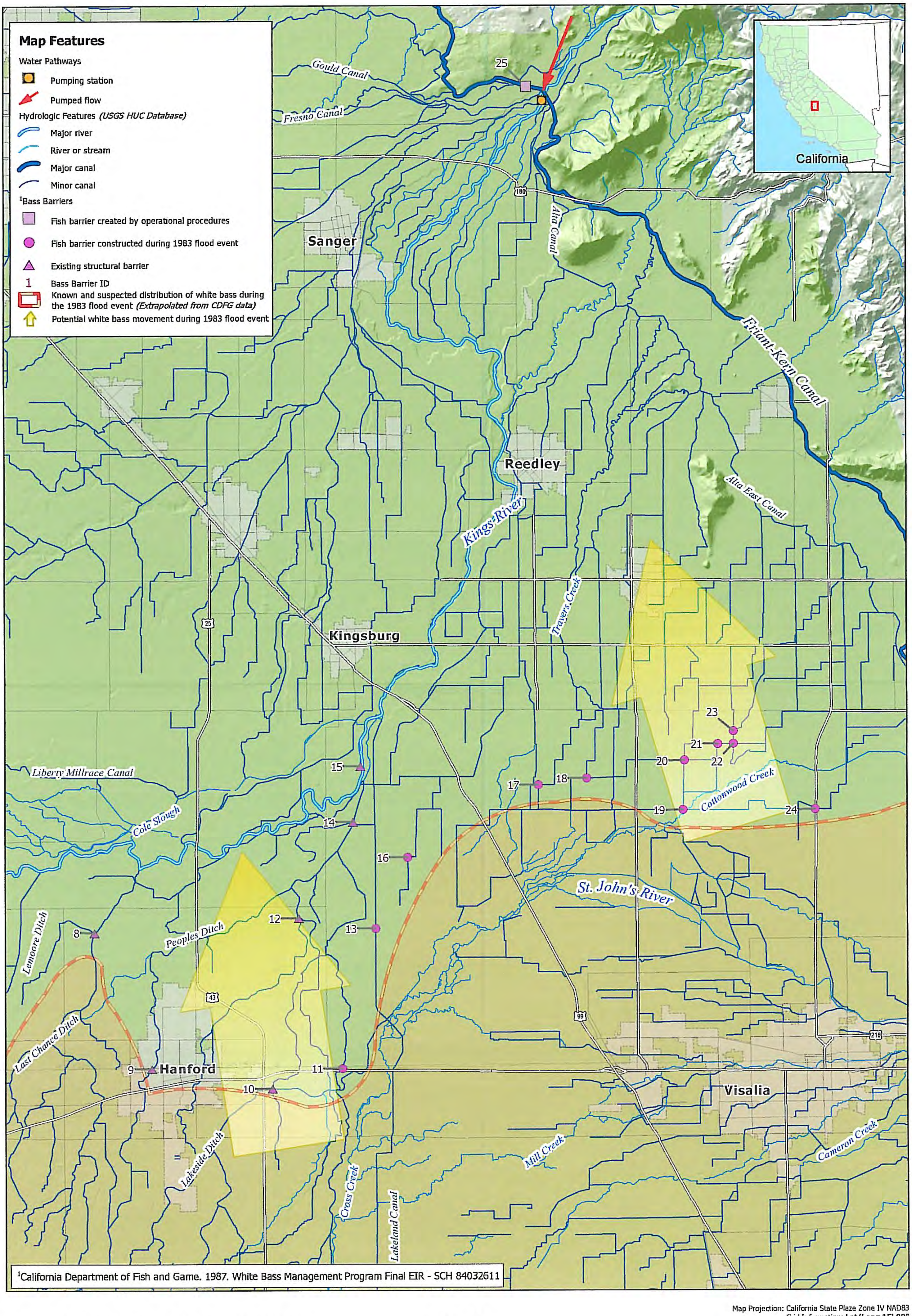
Map Projection: California State Plaze Zone IV NAD83
Grid Information: **Lat/Long 15' 00"**

Map 5: Tulare Lake Bottom Hydrography

1:240,000

5 2.5 0 5 Miles

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS



Map Projection: California State Plaze Zone IV NAD83
Grid Information: Lat/Long 15' 00"

Map 6: Lowland Kaweah-Kings Hydrography

1:175,000

Miles: 5 2.5 0 5

ECORP Consulting, Inc.
ENVIRONMENTAL CONSULTANTS

LIST OF APPENDICES

APPENDIX 1

Summary of Hydrologic Information

Appendix 1: Data Sources and Rationale for Chosen Years in the Daily Flow Figures and Tables

The following table compiles the data sources and the chosen years in the daily flow compilations of Figures 1, 3, 4, and 6 (Unimpaired Inflow and Actual Outflow) and Tables 5, 6, 7 (Lowland Water Distribution).

Figures 3, 4, and 6 graphically display the seasonal and annual range of unimpaired and actual daily river flow into the Tulare Lake Basin Lowlands at the terminal reservoirs using the same very dry (1988) and wet (1998) and median (2000) year-type in each figure.

Tables 5, 6, and 7 compile the annual volumes and seasonal variation of daily flows in the lowland water distribution systems (river and canal) in a range of year types from dry to wet. The water distribution records are generally only published in the watermaster reports for each river. We were not able to obtain those reports directly from the watermasters and thus had to rely on the reports available from the EPA or the Water Resources Archives Library. As demonstrated in the following table, the years of available data were different for each river system.

Figure or Table	Data Displayed	Years Chosen	Data source	Notes
Figure 1 - Kings River	Pine Flat Reservoir unimpaired inflow and actual outflow	1988 (dry) 1998 (wet) 2000 (median)	USACOE	data compiled by Sacramento district and sent on CD
Figure 3 - Kaweah River	Kaweah Reservoir unimpaired inflow and actual outflow	1988 (dry) 1998 (wet) 2000 (median)	USACOE	data compiled by Sacramento district and sent on CD
Figure 4- Tule River	Success Reservoir unimpaired inflow and actual outflow	1988 (dry) 1998 (wet) 2000 (median)[1]	USACOE	data compiled by Sacramento district and sent on CD
Figure 6- Kern River	Isabella Reservoir unimpaired inflow and actual outflow	1988 (dry) 1998 (wet) 2000 (median)	USACOE	data compiled by Sacramento district and sent on CD

Figure or Table	**Data Displayed**	**Years Chosen**	**Data source**	**Notes**
Table 5- Kings River Water Distribution	Annual Volume and seasonal flow amounts	1979 (average) 1988 (dry) 1995 (wet)	Kings River Water Association Watermaster Reports	From University of California Water Resources Archives
Table 6- Kaweah River Water Distribution	Annual Volume and seasonal flow amounts	1977 (dry) 1978 (wet) 1979 (average)	Kaweah River Flows, diversions, and Storage, 1975-80. CADWR Bulletin 49-F	From University of California Water Resources Archives
Table 7- Tule River Water Distribution	Annual Volume and seasonal flow amounts	1996 (average) 1998 (wet) 2000 (dry)[1]	Tule River Water Association Watermaster Reports	From EPA San Francisco office

[1] The water year 2000 runoff was close to a median year (54% exceedance value) but it was only 69% of the average runoff from 1962-2006. It was the driest year of the watermaster reports available from the EPA although it is not nearly as dry as the years chosen for the Kings (1988) or Kaweah (1977) Rivers.

APPENDIX 2

Site Visit Log of Trip to Tulare Lake Basin (June 29 and 30, 2006)

Site Visit Log of Trip to Tulare Lake Basin

Date: June 29, 2006

Stop 1 **Gould Canal and Friant-Kern Canal**

- Observed turn-out structure that discharges water from Friant-Kern Canal (FKC) into the Gould Canal and Enterprise Canals.

Stop 2 **Fresno Canal, Kings River, and Friant-Kern Canal** (Photo 1)

- Observed turn-out structure on FKC that moves water into Fresno Canal and Kings River.
- Observed weir diversion from Fresno Canal into the Kings River.

Stop 3 **Kings River pump-in into the Friant-Kern Canal**

- Observed pump-in location from Kings River (Alta Slough/76 Channel) into the Friant-Kern Canal.

Stop 4 **Alta Slough**

- Observed the cobble Weir that diverts water into Alta Slough (aka 76 Channel).

Stop 5 **Alta Canal and Frankwood Avenue** (Photo 2)

- Observed Alta Irrigation District head gate

Stop 6 **Wutchumna Ditch and Friant-Kern Canal**

- Observed pump location from Wutchumna Ditch into FKC.

Stop 7 **St. John's River and Friant-Kern Canal**

- St. John's River at pump-in to FKC.
- FKC siphon under St. John's River
- Observed FKC turn-out structure that discharges water into St. John's River.

Stop 8 **FKC Discharge to Tulare Irrigation District Canals**

Stop 9 **Tule River and Friant-Kern Canal** (Photo 3)

- Observed permanent pumps in Tule River Wasteway used to pump water from Tule River into FKC.
- Turn out from FKC to Tule River.

Stop 10 **Deer Creek and Friant-Kern Canal at County Road 208**

- FKC turn-out into Deer Creek west of County Road 208 (downstream side).

Stop 11 **White River and County Road 208**

Stop 12 **Poso Creek and County Road 208**

Stop 13 **Terminus of Friant-Kern Canal at Coffee Road** (Photos 4 and 5)

- Terminus gates at end of FKC, channel connecting FKC to Kern River, and Kern River.
- FKC turn out into Arvin-Edison Canal.
- Connection from FKC to Cross Valley Canal (CVC).

Date: June 30, 2006

Stop 14 **St. John's River at Alta Avenue Bridge**

Stop 15 **Cottonwood Creek at Alta Avenue Bridge**

Stop 16 **Banks Ditch near intersection of Alta Avenue and Avenue 360**

- Observed drop structures in canal

Stop 17 **Banks Ditch before Rd. 52** (Photo 6)

- Observed drop structure in canal

Stop 18 **Lakeland Canal and Denver Avenue**

Stop 19 **Unnamed Canal near People's Ditch** (Photo 7)

- Observed flume on unnamed ditch near People's Ditch

Stop 20 **People's Ditch** (Photo 8)

- Observed drop structure in canal

Stop 21 **People's Ditch and Riverside Ditch**

- Observed drop structure in canal

Stop 22 **Kings River and People's Ditch**

- Observed drop structure in canal

Stop 23 **Lakeland Canal and unpaved road**

- Observed drop structure in canal

Stop 24 **Lakeland Canal and Corcoran Ponds** (Photo 9)

- Water level in Corcoran Ponds

Stop 25 **Empire Weir Number 2 on Kings River near Highway 41 Bridge** (Photos 10 and 11)

- Observe three-way division of water at Empire weir: Tulare Lake Canal, Kings River Canal, and Blakely Canal.

- Observed drop structures

Stop 26 **Kings River at Empire Weir Number One**

Stop 27 **Fresno Slough at Mt. Whitney Road Crossing** (Photo 12)

- Water level in Fresno Slough

Stop 28 **Fresno Slough at Elkhorn Grade Road Crossing**

- Water level in Fresno Slough

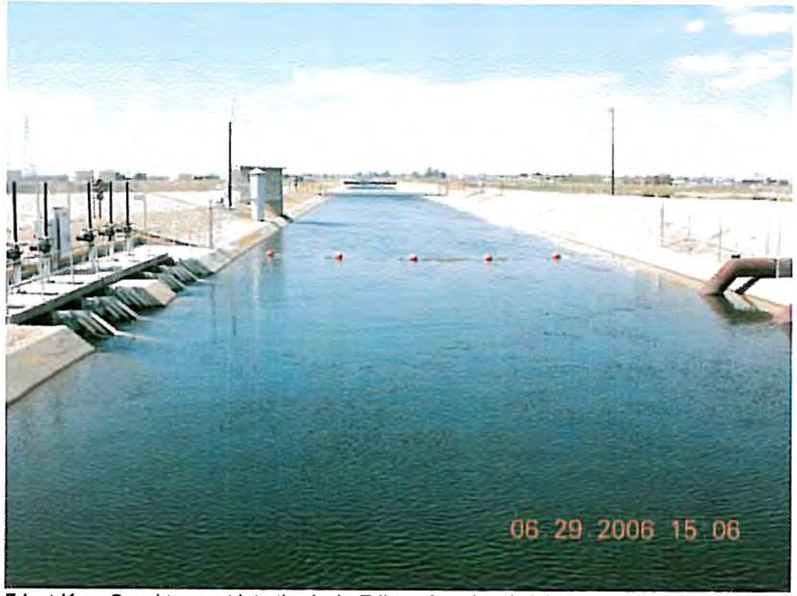
Friant-Kern Canal gate that moves water into Fresno Canal and the Kings River.

Alta Canal head gate.

Permanent pumps in the Tule River Wasteway used to move water from the Tule River into the Friant-Kern Canal.

Channel connecting the Friant-Kern Canal to the Kern River.

Selected Site Visit Photos



Friant-Kern Canal turn out into the Arvin-Edison Canal and siphon connection to the Cross Valley Canal.

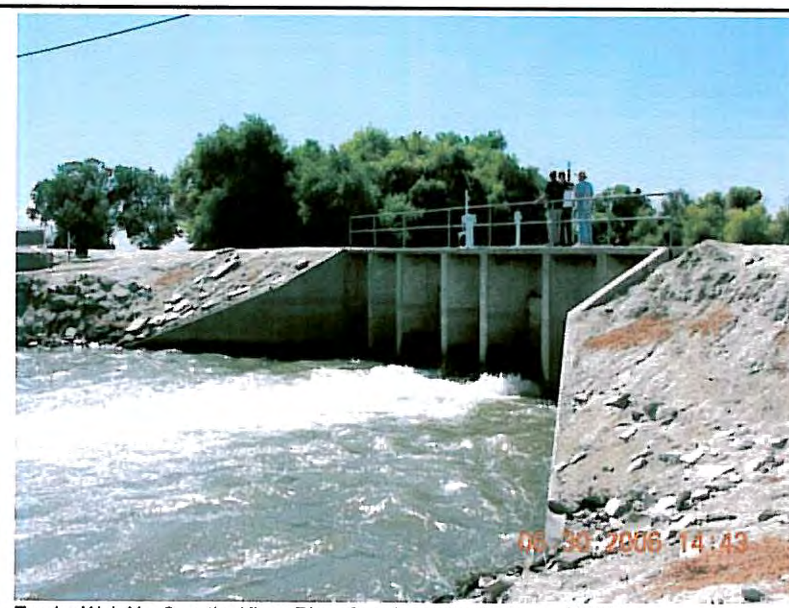

Drop structure in Banks Ditch.

Flume on unnamed canal near People's Ditch.


Drop structure in People's Ditch.

Selected Site Visit Photos

Corcoran Ponds.



Empire Weir No. 2 on the Kings River Canal near the Highway 41 Bridge.

Kings River Canal south of structure on Kings River at Empire Weir No. 2.

Fresno Slough at Mt. Whitney Road Crossing.

Selected Site Visit Photos