

Rec'd 12/17/05
Kerr

SURFACE WATER SUPPLY STUDY
COORDINATED STATEWIDE PLANNING
WATER DEMAND STUDY
STUDY AREA 2
SAN JOAQUIN DISTRICT

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SUMMARY OF WATER SUPPLY STUDY

This study is an evaluation of the average annual water supply available to the Sub-areas of Study Area 2 excluding precipitation and withdrawals from ground water storage. Included are presently developed supplies and water to be supplied from the State Water Project. The following is a tabulation of the sources of supply and the average annual supply in acre-feet listed in decreasing order of magnitude.

<u>Source</u>	<u>Annual Supply in Acre-Feet</u>
Kings River	1,580,190
Central Valley Project	869,810
Kaweah River	395,300
State Water Project	179,200
Tule River	119,800
Minor Streams	72,470
Recharge to Ground water from the San Joaquin River	28,330
Transfer from Study Area 1	14,500
San Joaquin River Riparian Pumping	6,000
Kern River	6,000
Total Annual Supply	3,271,600

The water supplies from the Central Valley Project and the State Water Project were the easiest to evaluate because the contractual delivery amounts had been previously determined and only the seepage loss from the Friant Kern Canal, which constitutes a source of supply through ground water recharge, had to be estimated. The other sources of supply were more difficult to evaluate because of the necessity of estimating streamflow by correlation for periods without records, estimating channel seepage losses, riparian pumping, headgate deliveries, water transfers and reservoir evaporation losses.

The water supplies from the Kings, Kaweah and Tule Rivers were evaluated with due consideration given to recent water rights negotiations

between water agencies served from these sources. The evaluations include the effect of reservoir regulation for flood control and conservation purposes, reservoir evaporation losses and conveyance losses in estimating deliveries to the water agencies.

The water supply from the Kings River consists of headgate deliveries, riparian pumping, and ground water recharge through channel seepage losses to seven of the sub-areas in Study Area 2. The supply was evaluated through analysis of Kings River and Pine Flat Reservoir operation from 1955 through 1966.

The water supply from releases from Terminus Dam on the Kaweah River and Success Dam on the Tule River are used almost entirely in Sub-areas 10 and 11 respectively, with a minor amount of surface outflow to Sub-area 9. The water supply from the Kaweah and Tule Rivers to Sub-areas 10 and 11 are considered to be the difference between the reservoir releases and the surface outflow.

Almost all of the runoff from minor streams is unregulated and occurs during the winter and spring months. The supply from this source is derived by infiltration of the runoff in the stream channels, valley floor and canal distribution systems intercepting the runoff.

The water supply derived by recharge through seepage losses from the San Joaquin River was estimated from conveyance losses computed by the inflow-outflow method. These losses and the San Joaquin River riparian pumping are not considered as Central Valley Project supplies and had to be evaluated separately.

Water transfers occur when water is pumped from well fields located in one study area and transported to another. Transfers also occur between sub-areas. These transfers were estimated using available data.

A portion of the runoff of Kern River during extremely wet years flows into the Tulare Lake Basin where it is consumptively used. The supply from this source had been evaluated in the water demand study for Study Area 1.

Tabulated in Table 1 are the average annual amounts of water supply to each of the sub-areas in Study Area 2 from all sources.

TABLE 1
SUMMARY OF WATER SUPPLY TO STUDY AREA 2
(Tabulated Quantities are Average Annual Amounts in Acre-Feet)

Sub- area Number:	Name	Kings River										Central Valley Project										Transfer:					
		Diversion:	Gravity	Riparian:	Seepage:	Pumping:	Loss:	Total	River	Tule	Kaweah	Friant:	Mendota:	Canal:	Kern:	Seepage:	Total	State:	of	Study:	Riparian:	Seepage:	Loss:	Between:	Subareas:	San:	San:
1	Kings River Foothills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Fresno Irrigation District et al	446,400	700	0	447,100	0	447,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Consolidated Irrigation Dist.	262,200	1,300	0	263,500	0	263,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Kings Rv. Water District	56,400	4,400	0	60,800	0	60,800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Alta Irrigation District	184,000	2,100	0	186,100	0	186,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Laguna Irrigation Dist. et al	155,030	3,200	0	158,230	0	158,230	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Raisin City Water Dist. et al	0	800	0	800	0	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Lemoore Canal & Irrigation Co.	108,130	0	0	108,130	0	108,130	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Tulare Lake Basin WSD et al	301,430	4,000	0	305,430	0	305,430	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	Kaweah Delta WCD et al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Tule Rv. Assoc. et al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Tulare Foothills	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Sand Ridge et al	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS		1,513,590	16,500	50,100	1,580,190	395,300	119,800	6,000	72,470	760,140	91,400	18,270	869,810	179,200	+14,500	6,000	28,330	3,271,600									

KINGS RIVER

The Kings River with a mean annual natural runoff at the Piedra Gaging Station of 1,628,300 acre-feet for the 71-year period 1896-1966 constitutes the largest single source of surface water supply to Study Area 2. The supply is distributed to seven of the subareas in Study Area 2. For location of diversion points refer to Plate 1.

Gaging Stations and Periods of Record

The gaging station "Kings River at Piedra" was used to record the Kings River natural runoff and to allocate water to agencies diverting from Kings River prior to operation of Pine Flat Reservoir for conservation under an interim contract in February 1954.

Allocations of water to agencies diverting from the Kings River are based on the mean daily natural flows of Kings River at Piedra as will be explained later. Since Pine Flat Reservoir began operation in 1954, it has been necessary to reconstruct the natural flows that would have occurred at Piedra because the flows have been altered. Gaging stations on the main stem of the river and tributaries above Pine Flat Reservoir and on tributaries between Pine Flat Dam and Piedra are now used to compute the natural flow of the river at Piedra. In 1958, Pacific Gas and Electric Company's Courtwright and Wishon Reservoirs on the North Fork of the Kings River became operational and since that time it has been necessary to include the change in contents and evaporation of these reservoirs in computing the natural flow at Kings River at Piedra.

In addition to the stream gaging stations mentioned above which are used to compute the mean daily natural flow of Kings River at Piedra, the Kings River Water Association maintains numerous gaging stations below

diversion weirs downstream from Piedra and below canal diversion headworks for operational purposes. These latter stations are not listed in this report. Plate 1 shows the stream system and diversion points on the Kings River.

The stream gaging stations used in computing Kings River water supply are as follows:

Gaging Station Name	Drainage Area: : (sq. miles)	Source:	Period of Record
Kings River at Piedra	1,687	USGS	Sept. 1895-Sept. 1959
Kings River below North Fork	1,350	USGS	Oct. 1951-Present
Big Creek AB Pine Flat Reservoir	69.2	USGS	Oct. 1953-Present
Sycamore Creek AB Pine Flat Reservoir	56.5	USGS	April 1953-Present
Helms Creek below Courtwright Dam	39.7	USGS	Oct. 1958-Present
North Fork Kings River nr. Cliff Camp	181	USGS	Aug. 1921-Present
Kings River below Pine Flat Dam	1,542	USGS	Oct. 1953-Present
Mill Creek nr. Piedra	120	USGS	Nov. 1938-Present

In addition to the above stream gaging stations, water stage recorders maintained on Wishon and Courtwright Reservoirs are used to compute daily changes in storage. Other upstream storage at Pacific Gas and Electric's forebay reservoirs is too small to be of significance.

Allocations of Kings River Water

The Kings River Water Association (KRWA) membership is comprised of 28 water agencies which divert water from the Kings River and its distributaries. Under the terms of the Water Right and Administrative agreement dated May 3, 1927 and subsequently amended June 1, 1949 and September 10, 1963, all of the natural flows of Kings River at Piedra are allocated to the 28 member agencies

which include both public and private water agencies. A watermaster appointed by the Board of Directors of the KRWA is responsible for the administration of the original agreement and the subsequent amendments.

A diversion schedule adopted in the 1949 amendment to the 1927 agreement is the basis for water entitlements to the member agencies. The diversion schedule is applied to the mean daily computed natural flow of Kings River at Piedra in determining the water entitlements of each of the member agencies.

Pine Flat Reservoir and Kings River Operation

Operation of Pine Flat Reservoir for conservation purposes began in February 1954 under an interim contract between the KRWA and the USBR. The interim contracts were renewed each year until late 1963 when a permanent contract was negotiated. The KRWA has an agreement which allocates the total storage space in Pine Flat Reservoir to the member agencies. Each agency is allowed to store its schedule entitlement water within its allocated storage space and subsequently release it at a time when it would be operationally advantageous. The storage of water is subject to certain limitations imposed by minimum flow requirements below Pine Flat Dam and flood control reservations. In effect, each agency has its own water supply from the Kings River and storage space in Pine Flat Reservoir and can store or release water as it sees fit, subject to the limitations previously mentioned. The Kings River Water Master is responsible for keeping the water account records of the member agencies.

Under the terms of the agreements among the KRWA agencies, each agency must bear its prorata share of conveyance losses from Pine Flat Dam to its point of diversion from the river. For example, if 1000 second-feet were ordered released from Pine Flat Reservoir for delivery below Peoples Weir (see Plate 1) located just downstream from Highway 99, and 900 second-feet arrived at this point, agencies diverting at Peoples Weir would be allowed

to divert 90 percent ($900 + 1000 \times 100$) of their ordered release. If their ordered release were 500 second-feet they would be allowed to divert 450 second-feet. Additional losses to the remaining 450 second-feet flowing below the weir would have to be borne by downstream agencies which had ordered the remaining 500 second-feet.

From the foregoing description of Kings River operation, it is apparent that many factors reduce the amount of scheduled water an agency can divert from the river. These factors include flood control releases, reservoir evaporation losses, minimum flow requirements and conveyance losses. Furthermore, there is a wide variation in the percent of scheduled water diverted by the various agencies because of the position of each agency on the diversion schedule, the contracted storage space in Pine Flat Reservoir, the conveyance distance from Pine Flat Dam and each agency's operation methods.

The operation of Pine Flat Reservoir and Kings River for conservation purposes described above is very brief. Many conflicting claims and controversies over channel losses, riparian pumpers, schedule deficiencies, etc. have been compromised by the September 1963 amendment to the Agreement and Water Rights Indenture. These compromises have resulted in great many operational details which are too lengthy to be treated in this report.

Analysis of Water Supply from Kings River

In determining the water supply from the Kings River to the sub-areas which receive Kings River water, it was necessary to estimate the long-term average annual entitlement of each agency which diverts water from the Kings River and then to adjust these entitlements to compensate for losses incurred by channel losses, flood control spills, riparian pumpers, reservoir evaporation, operational spills, etc.

Long Term Period Used to Estimate Water Supply

A residual mass diagram was prepared to determine a suitable long term to be used in the water supply analysis (see Plate 2). The period of record of the natural flow of Kings River at Piedra is the 71-year period from 1896 through 1966.

Consideration was given to using the 50-year period 1917 through 1966, however, this period ranged from the extreme accumulated departure from the 71-year mean to zero departure and was only 92.2 percent of the 71-year mean. Thirty-two years were subnormal and only 18 were above normal in runoff.

The period 1935 through 1966 could have been used because the mean annual runoff is very nearly that of the 71-year mean period, however, this would have given a period of only 32 years for analysis and less than one-half of the runoff data would be utilized.

For the above reasons it was considered advisable to use the entire 71-year period from 1896 through 1966 in estimating water supplies from the Kings River.

Schedule Entitlements

The Kings River Water Association staff has computed the schedule entitlements (based on the currently used schedule) of each of member agencies for the period from 1910 to the present. The schedule entitlements for the period 1910 through 1966 were totaled and the averages determined. The average natural runoff of Kings River at Piedra for the period 1910 through 1966 was 95.70 percent of the 71-year period 1896-1966, therefore the average annual entitlement of each agency was multiplied by a factor of 1.0449 to derive the long term average.

Adjustment of Schedule Entitlements to
Estimate Headgate Diversions

Records of Pine Flat Reservoir and Kings River operation are available for the 12-year period 1955 through 1966. The storage space allocation in Pine Flat Reservoir to KRWA member agencies during the 9-year period 1955 through 1963 when the reservoir was operated under interim contracts was very nearly the same as under the 1963 permanent contract. During the 12-year period 1955 through 1966, only 304,000 acre-feet or 1.7 percent of the computed natural flow at Piedra was lost through surface outflow from the Kings River Service Area via Fresno Slough. For the above reasons, the actual operation of Pine Flat Reservoir and Kings River from 1955 through 1966 was used as a basis for estimating the percentage of Kings River schedule entitlement each KRWA agency can divert into its headgate.

The operation of Pine Flat Reservoir has been complicated by purchases of CVP water by KRWA agencies, loans and repayments of water to P. G. & E., interagency loans, transfers, and sales of water and other factors. All such transactions, however, were noted in the KRWA Water Master's Reports, and it was possible, although tedious, to allow for the transactions in estimating the percent of available water which was diverted. During the period 1955-63, James and Tranquillity Irrigation Districts, KRWA member agencies, sold most of their Kings River water to other KRWA agencies. In the September 1963 Amendment to the Administrative Agreement between the KRWA agencies, James and Tranquillity Irrigation Districts agreed to lease their Kings River scheduled water to the other KRWA agencies for a period of 40 years. The water from this source and water to be contributed by member agencies from their Kings River entitlements under the terms of the September 1963 amendment is to be placed in a so-called "storage operation pool". The purpose of the storage operation pool is primarily to supply

water to the Kings River Water District, riparian pumpers, and to recompense conveyance losses borne by the KRWA agencies. The September 1963 amendment is not expected to cause any substantial change in the percentage of entitlement capable of being diverted because: (1) contributions to the storage operation pool are based largely on historical losses of entitlement borne by the KRWA member agencies, and (2) the 24,100 acre-feet of average annual entitlement leased from James and Tranquillity Irrigation Districts which amounts to about 1.5 percent of Kings River mean annual runoff will alleviate the trend toward increasing channel losses and increasing riparian pumping.

Table 2 shows the Kings River surface water supply to KRWA member agencies for the period 1955 through 1966 and the estimated supply based upon the long-term historical runoff of Kings River at Piedra. An explanation of column headings follows:

Column 1: KRWA member agency. All the listed agencies are currently members of the KRWA.

Column 2: This is the average annual total of all surface water available to each agency for the period 1955 through 1966 at Pine Flat Reservoir and the Friant-Kern Canal outlet to Kings River. It includes Kings River schedule entitlement water, Central Valley Project water purchased under short-term contracts, water purchased from long-term Central Valley Project contractors, and sales, transfers and loans of water among KRWA agencies.

Column 3: This is the average annual amount of water diverted into each agency's headgate from the Kings River for the period 1955 through 1966.

Column 4: This is the percentage of total water available to each agency during the period 1955 through 1966 which was diverted from the Kings River and is computed by dividing Column (4) by Column (3) and multiplying by 100.

Column 5: This is the average annual long-term Kings River schedule entitlement and was computed as explained in the Section "Allocation of Kings River Water".

Column 6: This is the average annual amount of each agency's Kings River water which can be diverted from Kings River and is the product of Column (4) and Column (5).

Column 7: These are the sub-areas in which the listed KRWA agencies lie.

There are three points which may need clarification in order that Table 2 may not be misunderstood:

1. Kings River Water District did not become a member of the KRWA until September 1963 and therefore did not appear on the KRWA 1949 diversion schedule. The total Kings River entitlement of 1,670,357 acre-feet shown in Column (5) is greater than the 1,628,300 acre-feet of mean annual runoff. Contributions to the "storage operation pool" by other KRWA agencies provide the water for the Kings River Water District and such contributions are reflected in the percentage of available water which is diverted.

2. The schedule entitlements and diversions of James and Tranquillity Irrigation Districts are not shown because they have been leased to other KRWA agencies.

3. The schedule entitlement and diversions shown for Consolidated Irrigation District include those of the "Lone

TABLE 2

KINGS RIVER SURFACE WATER SUPPLY TO KRWA AGENCIES
(Tabulated Quantities are in Acre-feet Except as Noted)

Agency (1)	Average Available 1955-66 (2)	Average Diverted 1955-66 (3)	Diversion Percentage (4)	Kings River Entitlement 1896-1966 (5)	Headgate Delivery (6)	Study Sub-area (7)
Alta I. D.	173,191	166,602	96.2	191,227	184,000	5
Burrel Ditch Company	8,424	6,690	79.4	9,121	7,240	6
Circle L Farms	1,515	759	50.1	1,456	730	9
Clarks Fork R D	2,053	1,062	51.7	2,674	1,380	6
Consolidated I. D.	258,192	253,323	98.0	267,307	262,200	3
Crescent Canal Company	16,189	12,747	78.7	19,504	15,400	6
Stratford & Empire WS I. D.	16,672	10,349	62.7	17,799	11,200	8
Fresno I. D.	449,082	439,353	97.8	456,473	446,400	2
John Heinlen MWC	8,608	6,200	72.6	9,962	7,230	8
Laguna I. D.	60,944	53,275	87.4	66,169	57,800	6
Corcoran Irrigation Co.	20,380	18,036	88.5	19,096	16,900	9
Last Chance W. D. C.	73,035	65,462	89.6	77,199	69,200	9
Lemoore Canal Company	107,073	82,158	76.7	116,927	89,700	8
Liberty Canal Company	8,678	7,176	82.7	11,187	9,250	6
Riverdale I. D.	25,583	22,899	89.5	28,442	25,500	6
Liberty Mill Race Co.	17,054	15,264	89.5	18,961	17,000	6
Reed Ditch Company	8,530	7,634	89.5	9,480	8,480	6
People Ditch Company	162,130	148,256	91.5	173,981	159,000	9
Stinson Canal Company	15,588	9,123	58.5	17,607	10,300	6
Tulare Lake Basin W. S. D.	84,025	55,006	65.5	84,829	55,600	9
Upper San Jose Company	3,612	2,254	62.4	4,296	2,680	6
Kings River W. D.	66,660	56,370	84.6	66,660	56,400	4
Totals	1,587,218	1,439,998		1,670,351	1,513,590	

Supply to Sub-areas in Acre-feet Annually

Sub-area	Supply	Sub-area	Supply	Sub-area	Supply
2	446,400	5	184,000	9	301,430
3	262,000	6	155,030		
4	56,400	8	108,130		

"Tree Canal" which serves a portion of Consolidated Irrigation District; consequently, the schedule entitlement and diversion of "Lone Tree Canal" has been subtracted from that of the Fresno Irrigation District.

Kings River Riparian Pumpers

Records of pumping from the Kings River have been kept by the KRWA since 1955, however the quantities pumped during 1965 and 1966 are not available. Table 3 shows the amounts of water pumped as projected to 1968. Projections into the future beyond 1968 are probably not justified without a study which would show the amount of riparian lands which could be developed.

TABLE 3

KINGS RIVER SUPPLY BY RIPARIAN PUMPING

<u>Agency</u> ^{1/}	<u>Pumping Acre-feet</u>	<u>Sub-area</u>
Kings River W. D.	4,400	4
Fresno I. D.	700	2
Consolidated I. D.	1,300	3
Alta I. D.	2,100	5
Last Chance W. D. C ^{2/}	1,300	9
Murphy Slough Assn.	1,200	6 & 7
Peoples Ditch Company	1,500	9
Laguna I. D.	2,800	6 & 7
Lemoore Canal Company	1,200	9
Total	16,500	

Riparian Pumping by Sub-areas

<u>Sub-area</u>	<u>Pumping Acre-feet</u>
2	700
3	1,300
4	4,400
5	2,100
6	3,200
7	800
9	4,000

^{1/} Assigned to those agencies in KRWA 1955 Pump Report.

^{2/} Includes Riverdale I. D., Reed and Liberty Mill Race Canal Companies.

Hydrologic Balance of Kings River Supply

The items of supply to the Kings River and its distributaries include the flow at Piedra, Central Valley Project deliveries at the Kings River Wasteway, and sub-surface accretions in the portion of the river between Piedra and Highway 99.

The items of disposal from Kings River and its distributaries water include (1) Pine Flat Reservoir evaporation, (2) surface diversion by gravity, (3) surface diversion by pumps, (4) surface outflow via Fresno Slough, (5) Channel seepage losses, and (6) evaporation from the river water surface and evapotranspiration from channel vegetation.

The KRWA staff computes annual Kings River losses in various reaches of the Kings River and its distributaries by the inflow-outflow method, however the computed losses include riparian pumping and evapotranspiration within the Kings River Water District. In this study riparian pumping and Kings River Water District evapotranspiration were not treated as channel losses.

Historically, the Kings River Water District has diverted far in excess of its consumptive use of applied water requirement which has been estimated at 34,000 acre-feet annually in this study. The average annual surface and pump diversion for the 12-year period 1955 through 1966 was 59,300 acre-feet. The District, which lies in the upper Kings River Delta, has 18 surface diversions from the several channels of the Kings River in this area. Most of the canals and ditches spill back into the Kings River. For the above reasons, the consumptive use of applied water was used in the hydrologic balance equation. Other KRWA agencies do not return water to the river except on very rare occasions.

Tabulated in Table 4 are the hydrologic balance of Kings River for the period 1955 through 1966 and the channel losses in several reaches of the

river. Return flows from Kings River Water District diversion were computed by subtracting consumptive use of applied water from the amount diverted.

TABLE 4

HYDROLOGIC BALANCE AND CHANNEL LOSSES IN THE
KINGS RIVER FOR THE PERIOD 1955 THROUGH 1966
(Tabulated Quantities are Annual Averages in Acre-feet)

Item	Quantity in Acre-feet
(1) Kings River at Piedra plus CVP Water	1,530,986
(2) Pine Flat Reservoir Evaporation Loss	16,400
(3) Kings River Water District Return Flows	26,139
(4) Total Available Water (1) + (3) - (2)	1,540,725
(5) Gravity Diversions: 1. KRWA	1,438,485
(5a) 2. Short Term CVP to Kings Co. W.D.	8,926
(5b) Total Gravity	1,447,411
(6) Pump Diversions	13,860
(7) Total Surface Diversions (5b) + (6)	1,461,271
(8) Fresno Slough Outflow	25,334
(9) Total Surface Diversions plus Outflow	1,486,600
(10) Net Channel Losses (4) - (9)	54,120
(11) Channel Gains	24,659
(12) Gross Channel Losses (10) + (11)	78,779

Losses (-) and Gains (+) by Channel Reach

		<u>% of Gross Loss</u>
Piedra to Peoples Weir	+24,659	
Peoples Weir to Lemoore Weir	-51,591	65.49
Lemoore Weir to Island Weir	- 6,436	8.17
Island Weir to Crescent Weir	- 1,506	1.91
Crescent Weir to Stinson Weir	- 8,712	11.06
Stinson Weir to James Weir	- 1,495	1.90
South Fork	- 9,039	11.47
Total		100.00

Tabulated in Table 5 are the hydrologic balance of Kings River based on a return of the runoff that occurred during the 71-year period 1896 through 1966 and the estimated channel losses in several reaches of the river.

TABLE 5

HYDROLOGIC BALANCE AND CHANNEL LOSSES IN THE
KINGS RIVER BASED UPON THE 71-YEAR PERIOD 1896
THROUGH 1966 RUNOFF OF THE KINGS RIVER AT PIEDRA
(Tabulated Quantities are Annual Averages in Acre-Feet)

1931-60
avg

Item	Quantity
(1) Computed Natural Flow Kings River at Piedra	1,628,000
(2) Pine Flat Evaporation Losses	16,400
(3) Kings River Water District Return Flows	26,800
(4) Total Available (1) + (3) - (2)	1,638,400
(5) Gravity Diversions by KRWA Agencies	1,513,590
(6) Pump Diversions	16,500
(7) Total Surface Diversions (5) + (6)	1,530,090
(8) Fresno Slough Outflow	46,000
(9) Total Surface Diversions plus Outflow (7) + (8)	1,576,090
(10) Net Channel Losses (4) - (9)	62,310
(11) Channel Gains	21,400
(12) Gross Channel Losses	83,710

1571

35,205

Losses (-) and Gains (+) by Channel Reach

Piedra to Peoples Weir	+21,400
Peoples Weir to Lemoore Weir	-54,820
Lemoore Weir to Island Weir	-6,840
Island Weir to Crescent Weir	-1,600
Crescent Weir to Stinson Weir	-9,260
Stinson Weir to James Weir	-1,590
South Fork	-9,600

Supply from Kings River Seepage Losses

Tabulated in Table 5 are the channel losses and gains in the Kings River by various reaches. In general, the river is effluent from Piedra to a point near the City of Reedley and influent in the channels below that point. The gains and loss estimates were based upon inflow-outflow measurements made by the KRWA.

The channel losses can be considered as consisting at two components:

(1) seepage losses and (2) evaporation from the water surface and evapotranspiration from phreatophytes along the river channel. The amount of water which is recharged to Study Area 2 is the total channel loss as given in

Table 5 less the sum of evaporation from the water surface and evapotranspiration from the phreatophytes.

The evaporation was computed from the estimated water surface area of each reach using $7\frac{1}{2}$ minute USGS quadrangle maps and the pan evaporation at Friant Government camp multiplied by a factor of 0.70.

Aerial photographs of the stream channels were observed to estimate the area covered by the phreatophytes. Based upon those observations it was estimated that the evapotranspiration from the phreatophytes was equal to the water surface evaporation for reaches of the channel between Reedley Narrows and the Island Weir (see Plate 1). In the Kings River Water District the river divides into numerous channels, sloughs, and ponds and the evapotranspiration was considered as part of the evapotranspiration of the Kings River Water District; therefore only the evaporation from the water surface was considered for this reach. In the channel reaches below Island Weir on both the North and South Forks, the U. S. Army Corps of Engineers is clearing the channels for flood control purposes and the channels will be maintained in the future by the Kings River Conservation District. Evapotranspiration losses in these channels is assumed to be only one-half as great as evaporation losses.

In estimating the distribution of seepage losses to the sub-areas, the spring of 1967 ground water map was used along with considerable judgement. Based upon available information it was assumed that the losses or gains occurred uniformly in the designated reaches and that equal amounts accrued to areas on the right and left of the river channel and its distributaries. This assumption is supported by the relatively symmetrical ground water mounds and troughs under the river channels.

Table 6 presents the seepage losses and channel gains in each reach of the river and the distribution of the losses and gains to the sub-areas.

Channel gains are from sub-surface outflows from Sub-areas 3 and 5 and therefore represent a loss in supply to these sub-areas.

TABLE 6

KINGS RIVER WATER SUPPLY FROM CHANNEL SEEPAGE LOSSES
(Tabulated Quantities are Average Annual Amounts in Acre-feet)

Channel Reach	: Total Channel : Loss (-) : or : Gain (+)	: Evaporation : and : Evapotrans- : piration	: Seepage : Loss
Piedra to Peoples Weir	+21,400	5,590	+26,990
Peoples Weir to Lemoore Weir	-54,820	3,270	-51,550
Lemoore Weir to Island Weir	- 6,840	750	- 6,090
Island Weir to Crescent Weir	- 1,600	590	- 1,010
Crescent Weir to Stinson Weir	- 9,260	670	- 8,590
Stinson Weir to James Weir	- 1,590	120	- 1,470
South Fork	- 9,600	1,260	- 8,340
Totals	-62,310	12,250	-50,060

Supply by Recharge to Sub-areas

Sub-area	Recharge	Round-off
3	- 4,310	- 4,300
5	-13,500	-13,500
6	+27,730	+27,700
7	+ 9,020	+ 9,000
8	+ 3,340	+ 3,400
9	+27,780	+27,800
	50,060	50,100

Future Developments on Kings River

Pacific Gas and Electric Company's power development on the North Fork of the Kings River was the last project constructed on the Kings River. Courtright and Wishon Reservoirs became operational in 1958. Since Pacific Gas and Electric had no water rights on the Kings River, it was necessary to purchase water from the U. S. Bureau of Reclamation and transfer it, by exchange, to Courtright and Wishon Reservoirs. As the project is currently operated,

P. G. and E. has water stored in Pine Flat Reservoir as well as the upstream Courtright and Wishon Reservoirs. In general, storage is depleted in the upstream reservoirs in the late summer and autumn when power releases exceed inflow and P. G. and E.'s storage in Pine Flat Reservoir increases. Conversely, in the spring and early summer, storage increases in the upstream reservoirs when inflow exceeds power releases and P. G. and E.'s storage in Pine Flat Reservoir decreases. The above operation may be considered as "paper" transfers of water between Pine Flat Reservoir and the upstream reservoirs.

There are operational and economic disadvantages to P. G. and E. owning water to fill its reservoirs. Because P. G. and E. owns water in an amount nearly equal to the upstream storage, the upstream storage can be considered as "dead" storage and offers no benefit for flood control or conservation purposes. In the 1967 water year, almost 485,000 acre-feet were lost to the Kings River service area through surface outflow via Fresno Slough. This could have been substantially reduced if P. G. and E.'s storage space could have been utilized.

Pacific Gas and Electric and the KRWA are negotiating to remedy this problem. If an agreement can be reached whereby the upstream storage can be used for conserving water, additional water will be made available to the Kings River service area. In computing Kings River water to the sub-areas, this factor was not considered because it cannot be evaluated until an agreement is reached.

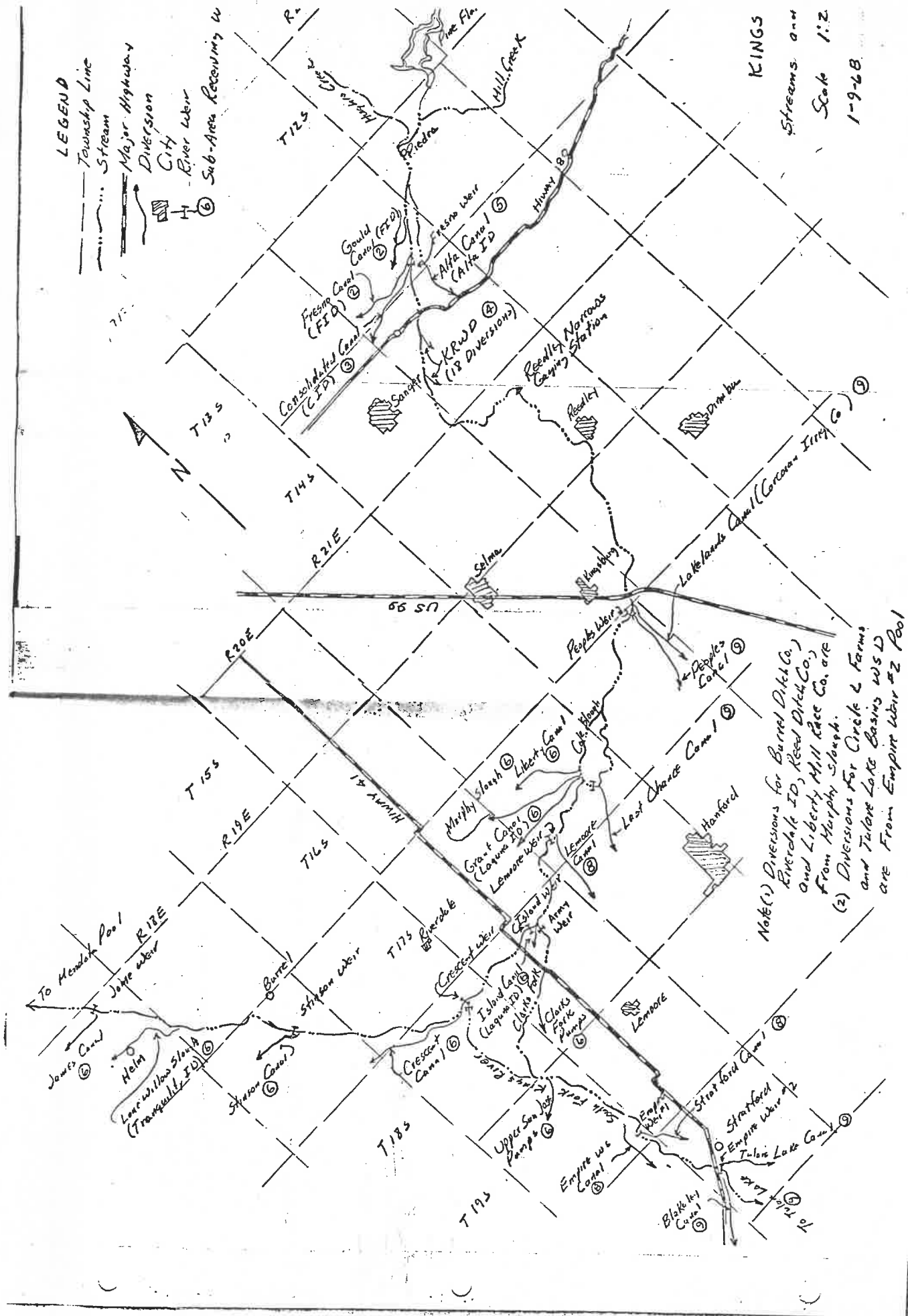
The KRWA and other agencies for many years have considered development of the Middle and South Forks of the Kings River for power. Nearly all the plans for development included reservoirs at Tehipite Valley and Cedar Grove, the two most favorable storage sites. The plans met with strong opposition from conservation groups and were subsequently abandoned; the Cedar Grove and Tehipite reservoir sites were later annexed to the Kings Canyon National Park and thus were eliminated for development.

The only reservoir site on the Kings River that appears to offer possibilities for additional storage is at Rodgers Crossing, located on the main stream of the Kings River just upstream from its confluence with the North Fork. About two-thirds of the natural runoff of Kings River occur above this point. The writer discussed the possibility of this development with the Kings River Water Master, Robert E. Leake, in August of 1967. He stated that the project appeared marginal at this time, however with future imports to the Kings River Service Area by the East Side Division of the Central Valley Project, additional storage at Rodgers Crossing may become economically justified. His reason for this statement was that at present not too much Kings River water is lost to the service area (estimated in this report to average 46,000 acre-feet annually) and that a great deal of additional storage would have to be provided to conserve the major portion of this loss. For instance, 485,000 acre-feet of live storage would have had to be provided in 1967 to eliminate the loss that occurred that year. With the advent of imports, however, water lost through surface outflow would occur much more frequently and in greater amounts, therefore additional storage, which would result in a significant increase in yield, may become justified.

A quantitative evaluation of the justification of additional storage considering imports of water has not yet been made by the KRWA. The statements made by Robert Leake appear reasonable. If the Kings River Service Area, which is a water-deficient area, contracted for an import of 150,000 acre-feet annually (a rough estimate of the present deficiency) much more water would be lost during wet years unless additional storage is provided.

1-9-68

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CENTRAL VALLEY PROJECT

The U. S. Bureau of Reclamation's Central Valley Project water deliveries are the second largest source of supply to Study Area 2. Deliveries from the Friant-Kern Canal began in 1949 and have increased since that time as the water agencies have constructed or expanded their distribution systems.

The source of supply of Central Valley Project water to Study Area 2 is the San Joaquin River. The water rights to most of the flows of the San Joaquin River were acquired by the U. S. Bureau of Reclamation by an exchange agreement negotiated between the U. S. Bureau of Reclamation and water agencies diverting from the Mendota Pool. Under the agreement, the water agencies are supplied water from the Delta-Mendota Canal in exchange for the water they formerly diverted from the San Joaquin River, thus making it possible to export most of the San Joaquin River flows to water-deficient areas. Since the initiation of deliveries from the Friant-Kern Canal, the ground water storage in the service area has increased slightly; without the deliveries the ground water storage would have been reduced drastically.

The U. S. Bureau of Reclamation publications, "Water Supply, Fresno Field Division", report on the operation of Millerton Lake. Included in the reports are the Friant-Kern Canal deliveries to contracting water agencies, contractual amounts for Class 1 and Class 2 water deliveries, ground water conditions, etc.

The U. S. Bureau of Reclamation has run hypothetical storage operations of the Friant Division of the Central Valley Project and has estimated the annual average of Class 1 and Class 2 water which will be available to the long-term contracting agencies in the future. The amounts of these anticipated deliveries are based on estimates of runoff of the

San Joaquin River and the ability of the agencies to divert their contractual amounts of water.

Since the time deliveries from the Friant-Kern Canal were initiated, many deliveries have been made under short-term temporary contracts. This water has been available largely because the long-term water contractors have not been able to accept their full contractual amounts of water. It is anticipated that in the future, the long-term contractors will be able to accept their full contractual water deliveries and little, if any, water will be available for temporary contracts; therefore, the dependable supply to Study Area 2 is assumed to be derived entirely from long-term contracts.

In 1964, a contract was executed between the U. S. Bureau of Reclamation and James and Tranquillity Irrigation Districts. Under the terms of the contract, James and Tranquillity Districts will receive a combined total annual supply of 29,900 acre-feet of "Water Rights Water" and 49,100 acre-feet of Class 1 water. The water is diverted by pumping from the Mendota Pool.

There are other diversions of San Joaquin River water by public agencies and private individuals from Mendota Pool for use in Subarea 7. The rights to this water are pending a formal determination and in lieu of such a formal determination, the quantities of water diverted in 1964 are used in this report as the supply to these entities.

Plate 3 shows the water agencies receiving long-term contracted water deliveries from the Friant-Kern Canal.

The last U. S. Bureau of Reclamation water supply report received by the Department of Water Resources is the 1964 report. Tabulated in Table 7 of this report is pertinent data on Friant-Kern Canal and San Joaquin River Supply as taken from the 1964 U. S. Bureau of Reclamation water supply report.

TABLE 7

CENTRAL VALLEY PROJECT WATER SUPPLY
(Supply and Contractual Amounts in Average Annual Acre-feet)

Subarea	Water Agency	Contractual Maximums		Average Delivery
		Class 1	Class 2	
1	Garfield W. D.	3,500	0	3,500
	International W. D.	1,200	0	1,200
	City of Orange Cove	1,400	0	1,400
	Orange Cove I. D.	39,200	0	39,200
	Round Mountain Ranch	90	0	90
	Totals Subarea 1	45,390	0	45,390
2	Fresno I. D.	0	75,000	36,000
	City of Fresno	60,000	0	60,000
	Totals Subarea 2	60,000	75,000	96,000
6	James I. D.	35,300	9,700 ^{1/}	45,000
	Tranquillity I. D.	13,800	20,200 ^{1/}	34,000
	Totals Subarea 6	49,100	29,900	79,000
7	Fresno Slough W. D.		900 ^{2/}	900
	Reclamation District 1606		300 ^{2/}	300
	State of California (MWMA)		1,100 ^{2/}	1,100
	Private Individuals	7,100 ^{3/}	3,000	10,100
	Totals Subarea 7	7,100	5,300	12,400
10	Exeter I. D.	11,500	19,000	20,500
	Ivanhoe I. D.	7,700	7,900	11,600
	Lewis Creek W. D.	1,450	0	1,450
	Lindmore I. D.	33,000	22,000	44,000
	Lindsay-Strathmore I. D.	30,000	0	30,000
	Stone Corral I. D.	10,000	0	10,000
	Tulare I. D.	30,000	141,000	97,700
	Totals Subarea 10	123,650	189,900	215,250

TABLE 7 (Continued)

CENTRAL VALLEY PROJECT WATER SUPPLY
(Supply and Contractual Amounts in Average Annual Acre-feet)

Subarea	Water Agency	Contractual Maximums		Average Delivery
		Class 1	Class 2	
11	Delano-Earlimart I. D.	92,800	63,500 ^{4/}	123,300 ^{4/}
	Lower Tule River I. D.	61,200	238,000	175,400
	Porterville I. D.	16,000	30,000	31,400
	Saucelito I. D.	21,200	32,800	36,900
	Teapot Dome W. D.	7,500	0	7,500
	Terra Bella I. D.	29,000	0	29,000
Totals Sub-area 11		227,700	364,300	403,500
<u>1/</u> Schedule II or "Water Rights Water". (No cost for delivery.)				
<u>2/</u> "Water Rights" deliveries made in 1964 pending formal determination of rights.				
<u>3/</u> 1964 deliveries pending settlement of water rights.				
<u>4/</u> Prorated on the basis of the percentage of the total area of the district that is included in Sub-area 11.				

Friant-Kern Canal Seepage Losses

Friant-Kern Canal seepage losses constitute a minor source of supply to Study Area 2 amounting to an estimated average annual 18,270 acre-feet.

The U. S. Bureau of Reclamation conducted seepage loss studies of the Friant-Kern Canal in October of 1950; the results of the study are presented in the U. S. Bureau of Reclamation Technical Memorandum No. 644 dated January 1953. The studies were conducted by the "ponding" method in which dikes were constructed at each end of approximately an 0.6-mile reach of canal; the reach was filled with water to the normal operating water level and the subsequent water level lowering over a period of 24 days was noted. Both lined and unlined sections of the canal were tested. The unlined reach was from Mile 52.8 to Mile 53.4 and the lined reach was from Mile 69.0 to Mile 69.6. These reaches are at approximately the mid-point of the canal in Study Area 2

and can be considered as representative of the canal capacity and cross-section area in Study Area 2.

The test results indicated that 0.98 and 0.75 acre-feet per day per mile were lost through seepage in the unlined and lined sections of the canal respectively; in other words, the rate of loss in the unlined section is 1.31 times as great as the rate of loss in the lined section. It is recognized that the loss rates from other reaches of the canal may be different from those of the test reaches, however, no information is available on other reaches of the canal.

The Fresno Field Division of the U. S. Bureau of Reclamation reports the annual diversions into the Friant-Kern Canal from Millerton Lake and the deliveries, including operational spill, to the contracting agencies. The difference between the diversion and deliveries is indicative of the conveyance losses, which consist of seepage and evaporation. The average annual loss for the 6-year period 1959 through 1964 was 29,800 acre-feet and the losses ranged from a maximum of 35,064 acre-feet in 1960 to a minimum of 25,595 acre-feet in 1963, indicating a good degree of consistency.

From a previous Department of Water Resources study, "Water Requirements and Project Staging", the average annual evaporation losses from the Friant-Kern were estimated from evaporation loss rates, canal water surface area, etc. The study indicated that the average annual amount of water lost by evaporation was 4,700 acre-feet per year. Subtracting this loss from the total loss gives an average annual seepage loss of 25,100 acre-feet.

From the relative seepage loss rates of the lined and unlined sections of the canal as estimated in the U. S. Bureau of Reclamation study and the total seepage losses as estimated in this study, the water supply to the subareas derived from Friant-Kern Canal seepage losses was estimated.

The estimated loss rate from the lined section of the canal is 154 acre-feet per mile per year and from the unlined section is 202 acre-feet per mile per year.

Table 8 presents the estimated Friant-Kern seepage losses in each of the subareas. The total canal length is 155 miles of which 112.1 miles lies in Study Area 2. Of the estimated total average annual seepage loss of 25,100 acre-feet, 18,270 acre-feet are estimated to be lost in Study Area 2.

TABLE 8
FRIANT-KERN CANAL SEEPAGE LOSSES TO SUBAREAS

Subarea	Canal Reach			Type Canal	Seepage Loss (Ave. Annual in Acre-Feet)	Round-off Totals
	From Mile	To Mile	Length Miles			
1	6.9	25.2	18.3	Lined	2,818	
	36.6	54.8	18.2	Unlined	3,676	
	54.8	59.0	4.2	Lined	<u>647</u>	
					7,141	7,140
2	25.2	30.2	5.0	Lined	770	770
5	30.8	36.6	5.8	Lined	893	890
10	59.0	63.8	4.8	Unlined	970	
	63.8	92.9	29.1	Lined	<u>4,481</u>	
					5,451	5,450
11	92.9	119.0	26.1	Lined	4,019	<u>4,020</u>
TOTAL SEEPAGE LOSS IN STUDY AREA 2						18,270

Note: No seepage loss assumed in the 0.6 mile Kings River Siphon.

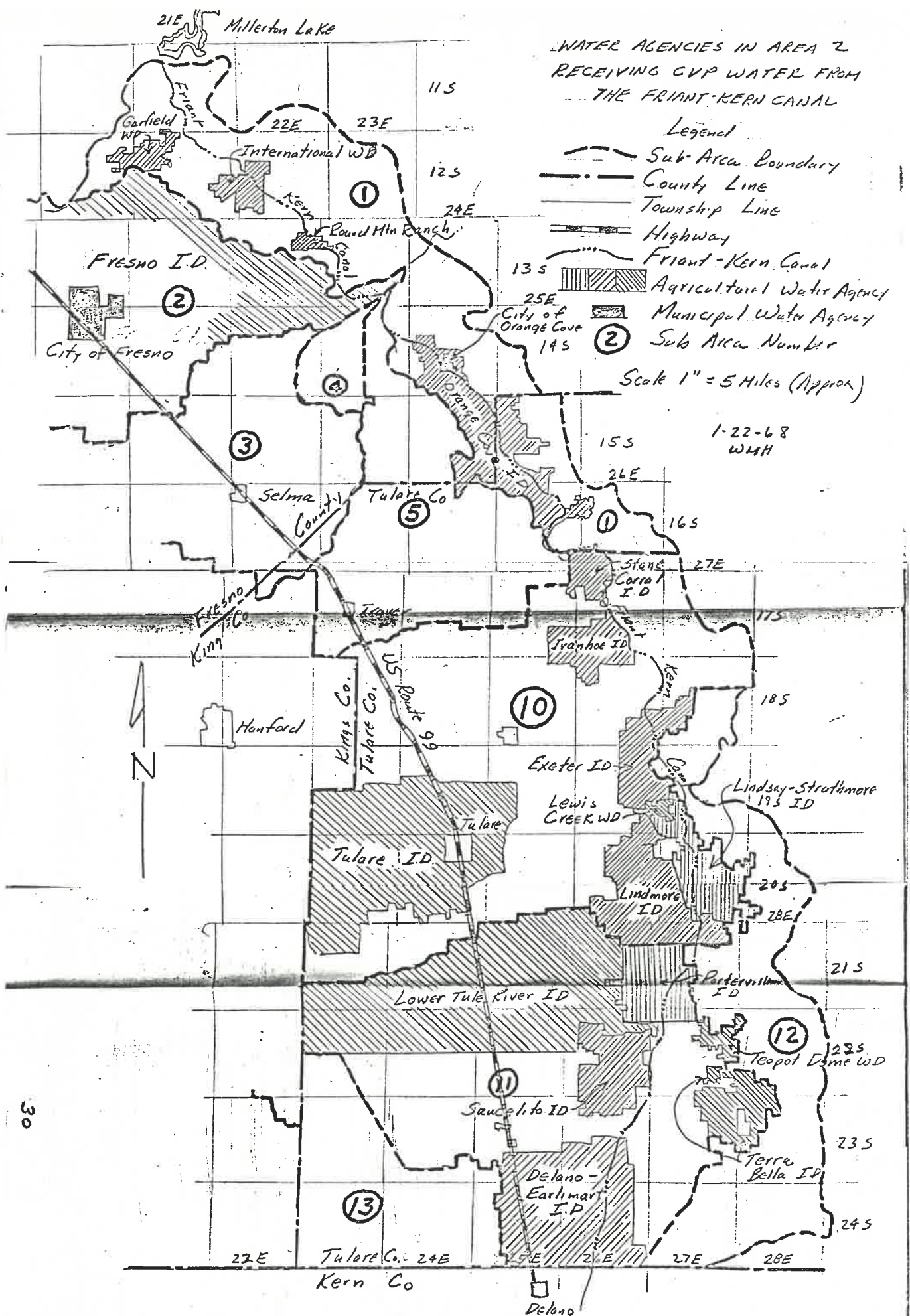
WATER AGENCIES IN AREA 2 RECEIVING CVP WATER FROM THE FRIANT-KERN CANAL

Legend

- Sub-Area Boundary
- County Line
- Township Line
- Highway
- Friant-Kern Canal
- Agricultural Water Agency
- Municipal Water Agency
- Sub Area Number

Scale 1" = 5 Miles (Approx)

1-22-68
WJH



KAWEAH RIVER

The Kaweah River, with an average annual natural runoff below Terminus Dam of 399,000 acre-feet, constitutes the third largest single source of water supply to Study Area 2, ranked behind the Kings River and the Friant Kern Canal. Unlike the Kings River, which supplies water to seven subareas of Study Area 2, almost all Kaweah River water is used in Subarea 10, with only a small percentage outflowing to Subarea 9. It was not necessary, therefore, to estimate water entitlements of individual agencies as was necessary for the Kings River.

Gaging Stations and Periods of Records

The gaging station "Kaweah River ^Near Three Rivers" located in the SW¹/₄ of Section 33, Township 17 South, Range 28 East, was used for the historical Kaweah River runoff from 1904 through 1961. After the operation of Terminus Reservoir began in the water year 1961-62, the above gaging station was inundated and the gaging stations "Kaweah River at Three Rivers" and "South Fork Kaweah River at Three Rivers" were used to compute the natural flow of the Kaweah River.

The gaging stations used to compute Kaweah River water supply are as follows:

Gaging Station Name	: Drainage : : Area : : Sq. Miles:	Source	: Period of Record
Kaweah River near Three Rivers	520	USGS	Apr. 1903-Sept. 1961
Kaweah River at Three Rivers	418	USGS	Oct. 1958-Present
South Fork Kaweah River at Three Rivers	867	USGS	Oct. 1958-Present
Lakeside Ditch near Head		DWR & KDWCD ¹ /	Oct. 1917-Present
Corcoran I.D. Diversion Below Lakeside #2 Canal		DWR & KDWCD	Oct. 1917-Present
Cross Creek Below Lakeland #2 Canal		DWR	Oct. 1921-Present
<u>1/Kaweah Delta Water Conservation District</u>			

The first three stations were used to estimate water supply available from the Kaweah River and the last three were used to estimate outflow from Sub-area 10 to Subarea 9.

Determination of Period to be Used for Study

A residual mass was drawn for the entire 63-year period, 1904 through 1966 for which records of the natural flow of the Kaweah River were available. The accumulative departures from the mean followed the same pattern as did the Kings River at Piedra because there is a good correlation between the runoff for the two streams. As in the case of Kings River, it was not considered advisable to use only the last 50 years of record because the Kaweah River runoff averaged only 93.5 percent of the long-term mean for that period and only 18 of the 50 years were above normal in runoff (see Plate 4). The average annual runoff of the Kings River for the period 1904 through 1966 was 99.97 percent of the period from 1896-1966, therefore the two rivers can be considered as being analysed on comparable hydrologic periods.

Diversions from Kaweah River and its Tributaries

There are 29 agencies owning and operating physical works for the surface diversion and distribution of Kaweah River water, consisting of 20 mutual water companies, three irrigation districts, one public utility company and five privately owned enterprises. Of the 29 agencies only two lie partially or entirely outside Sub-area 10. These are the Corcoran Irrigation Company and the Lakeside Irrigation Water District. In addition to water supplied to these agencies, water flows out of Sub-area 10 to the Tulare Lake area during some years of above normal runoff. The Kaweah River Service Area and water agencies, canal systems and diversion entitlements are presented in the Department of Water Resources Bulletin No. 49 series.

Recent Water Rights Changes on the Kaweah River

With the beginning of operation of Terminus Reservoir for flood control and conservation purposes in 1962, it became apparent to Kaweah River water users that it would be impractical to allocate water in the same manner as prior to river regulation. Diversion entitlements historically were based on the quantity of flow in the river channels at the points of diversion. To make effective use of conservation storage in Terminus it was necessary to alter the natural flow of the river which in turn changed the flow at the points of diversion. From 1962 to the present time, the Kaweah River water users have been operating under a temporary agreement pending permanent agreement on the allocation of Kaweah River water.

With regulation provided by Terminus Reservoir, the quantity of water flowing to the Tulare Lake area, which occurred sporadically and was difficult to utilize as an agricultural water supply, could be substantially reduced. In January of 1965 an agreement was made whereby the Kaweah Delta Water Conservation District purchased the claimed water rights of the Tulare Lake interests. The agreement purports to be mutually advantageous. The average annual amount of such claimed water rights was determined by an engineering committee which represented both parties to the agreement^{1/}. Terminus Reservoir cannot eliminate entirely flows to the Tulare Lake area. The average annual flow to the lake area under the agreement is estimated to be 1,220 acre-feet by the engineering committee. The U. S. Corps of Engineers in their hypothetical storage operation of Terminus Reservoir estimates this flow to be 2,300 acre-feet. The estimate by the Corps of Engineers is used in this study because of possible bias by the engineering committee in negotiating water rights.

^{1/} "Kaweah Water Rights Settlement by Purchase" by Stanley M. Barnes, Journal of the Irrigation and Drainage Division, ASCE, Vo. 92, No. IR1, March 1966.

Kaweah River Supply to Sub-areas 9 and 10

The Kaweah River water supply to Sub-area 9 is the surface inflow from Cross Creek and Elk Bayou. The supply goes to the Corcoran Irrigation Company, a portion of Lakeside Irrigation Water District, and the Tulare Lake area.

As explained in the previous section title, "Recent Water Rights Changes on the Kaweah River", no permanent agreement has been established for the allocation of Kaweah River water to the 29 agencies of the Kaweah River Service Area; therefore the water entitlements of Corcoran Irrigation Company and Lakeside Irrigation Water District have not been agreed to as yet. In negotiations of this type, however, it is customary to use historical diversions in establishing entitlements. The 17-year period 1950 through 1966 was analysed to determine the recent diversions by the two agencies. The following is a tabulation of the average amount of water diverted during this period by the agencies:

<u>Agency</u>	<u>Average Diversion 1950-1966 in Acre-feet</u>
Corcoran Irrigation Company	5,662
Lakeside Irrigation Water District	28,983

An estimated 21.7 percent (based on water stock purchases by Lakeside Irrigation Water District) of the Lakeside Irrigation Water District entitlement goes to lands inside Sub-area 9, therefore the Kaweah River water supply to this area for 17-year period was 6,289 acre-feet.

The above average diversions for the 17-year period 1950-1966 were corrected to the long-term period in estimating water entitlements. In addition to these diversions, Sub-area 9 receives 2,300 acre-feet annually to the Tulare Lake area as estimated by the U. S. Army Corps of Engineers.

The Kaweah River water supply to Sub-area 10 consists of the entire natural flow of Kaweah River at Terminus less the evaporation from Terminus Reservoir and the outflow to Sub-area 9. Table 9 shows the distribution of Kaweah River water for the long-term period 1904 through 1966.

TABLE 9
KAWEAH RIVER WATER SUPPLY TO SUB-AREAS 9 and 10

	Quantity in Acre-feet	
	Mean Annual	Round-off
Kaweah River at Terminus Dam	399,057	399,100
Terminus Reservoir Evaporation	3,782	3,800
Net Available	395,275	395,300
Outflow to Sub-area 9		
1. Lakeside Irrigation Water District	6,633	6,630
2. Corcoran Irrigation Company	5,971	5,970
3. Tulare Lake Area	2,300	2,300
Total Outflow to Sub-area 9	14,904	14,900
Retained in Sub-area 10		380,400

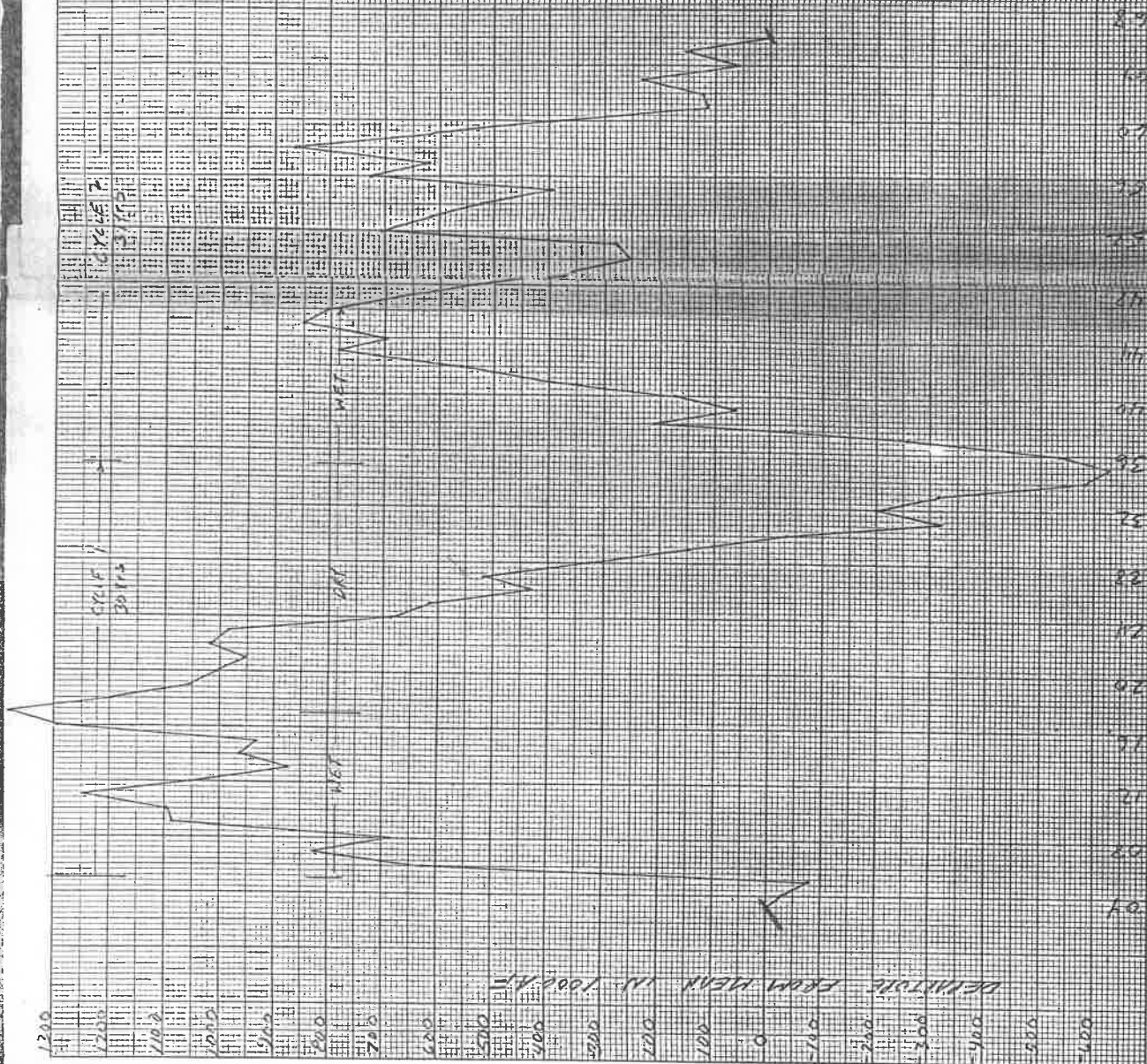
Future Development on Kaweah River

There appears to be little advantage to be gained from additional storage on the Kaweah River for conservation purposes. Under the U. S. Army Corps of Engineers' hypothetical storage operation the average annual outflow to the Tulare Lake area is only 2,300 acre-feet or about 0.6 percent of the natural flow of the Kaweah River at Terminus Dam. It is doubtful that this flow would be beneficial to the Tulare Lake area because it would occur very infrequently (estimated by the U. S. Army Corps of Engineers at three years out of 57), during the extremely wet years.

Future imports of water to the area may change conservation aspects however, and additional storage could become justified.

PLATE 4

CAVEAU TAPER
RESIDUAL MASS DIMINISH
12-5-67
MURDER ROAD



TULE RIVER

The Tule River has an estimated average annual natural runoff of 125,800 acre-feet. Unlike the Kings River, which supplies water to seven subareas in Study Area 2, most of the Tule-River runoff is used in Subarea 11, with only a small percentage outflowing to Subarea 9.

Gaging Stations and Periods of Records

The gaging stations "Tule River near Porterville" located in the NW $\frac{1}{4}$ of Section 25, Township 21 South, Range 28 East, and "South Fork Tule River near Success" located in the SW $\frac{1}{4}$ of Section 4, Township 22 South, Range 29 East, were used to estimate the historical natural runoff of the Tule River prior to September 1960. The total runoff was considered to be the sum of the runoff of the two stations. The minor amount of runoff from the watershed between the gaging stations and Success Reservoir, estimated at 0.23 percent of the total runoff, was considered to be insignificant. The natural runoff of Tule River after September 1960 reported by the U. S. Geological Survey is the flow at the gaging station "Tule River Below Success Dam" as adjusted for Success Reservoir evaporation, change in reservoir contents, and Pioneer Ditch Diversions.

The gaging station "Tule River near Porterville" has a continuous record from May 1901 through September 1960. The gaging station "South Fork Tule River near Success" has records from June 1930 through December 1954 and January 1956 to the present. In estimating the long-term average annual natural runoff of the Tule River, it was necessary to estimate the runoff of the South Fork for the period prior to June 1930 and from January 1955 through December 1955 by correlation with the runoff at the gaging station "Tule River near Porterville".

The gaging stations used to compute Tule River water supply are as follows:

	: Drainage :	:	:
	: Area in :	Source :	Period of Record
	: Square Miles :	:	:
Tule River near Porterville	261	USGS	May 1901-Sept. 1960
South Fork Tule River near Success	109	USGS	June 1930-Dec. 1954
Tule River below Success Dam	393	USGS	Oct. 1960-Present
Tule River at Worth Bridge near Porterville	395	USGS	Oct. 1953-Sept. 1960
Tule River at Turnbull Station	---	USBR & DWR	Oct. 1942-Sept. 1958
Elk Bayou one mile east of Elk Bayou Avenue	---	USBR	Oct. 1943-Sept. 1953

The first four stations listed were used to determine historical natural runoff and the last two were used in estimating the outflow to Subarea 9.

Determination of Period to be Used for Study

A residual mass diagram was drawn for the 65-year period, 1902 through 1966, for which records of the natural runoff were available. The accumulative departures from the mean followed the same pattern as the Kings and Kaweah Rivers, indicating a good correlation. As in the case of the Kings and Kaweah Rivers, it was not considered advisable to use only the last 50 years of record because the Tule River averaged only 87.5 percent of the 65-year mean and only 17 of the 50 years were above normal in runoff (see Plate 5). The average annual runoff of the Kings River at Piedra for the period 1902 through 1966 was 99.86 percent of the average annual runoff for the period 1896 through 1966. Therefore, the two rivers can be considered as being analyzed on comparable hydrologic periods.

TULE RIVER
PERSONAL CALLS DAILY
12-15-17



Outflow to Subarea 9

If Success Reservoir could be operated to conserve water for Subarea 11 only, very little Tule River water, if any, would be lost through surface outflow to Subarea 9. Tule River water has flowed into the Tulare Lake area historically, however, and the right to such flows are claimed by the Tulare Lake interests. According to the ASCE Paper, "Kaweah Water Rights by Purchase" (see "Kaweah River Water Supply"), the Tulare Lake interests do not plan to sell their claimed right to Tule River water.

The gaging station "Tule River at Turnbull Station" was used to estimate Tule River flows to the Tulare Lake area. There is an inflow of Kaweah River water to the Tule River via Elk Bayou and this inflow must be subtracted from the flow at Turnbull Station to derive the amount of Tule River water entering Subarea 9. The average annual flow of Elk Bayou into the Tule River was estimated at 9,500 acre-feet in the aforementioned ASCE paper; in this study it was estimated at 10,200 acre-feet, a fairly close agreement. The estimated average annual flow at Turnbull Station is 29,100 acre-feet of which 10,200 acre-feet is Kaweah River water (this water was purchased by the Kaweah Delta Water Conservation District). The difference, 18,900 acre-feet, is the average annual outflow of Tule River water to Subarea 9.

Although the historical Tule River outflow to the Tulare Lake area is not an adjudicated right, it is undoubtedly the basis for a claimed right. The 18,900 acre-feet average annual outflow is considered as a source of supply to Subarea 9 for the above reason.

The average annual water supply from the Tule River to Subareas 9 and 11 is tabulated in Table 10.

TABLE 10

TULE RIVER WATER SUPPLY TO SUBAREAS 9 AND 11

Area	Average Annual Quantity in Acre-Feet
Tule River at Success Dam	125,800
Success Reservoir Evaporation	6,000
Net Available	119,000
Outflow to Subarea 9	18,900
Retained in Subarea 11	100,900

Future Development on the Tule River

There are no known plans for additional conservation storage on the Tule River and it appears that little advantage could be gained from additional storage under present conditions of developments. Future imports of water may change conservation aspects, however, and additional storage could become justified.

MINOR STREAMS

In analyzing the supply from minor streams originating in the western slopes of the Sierra Nevada, the drainage basins of the streams were grouped to facilitate estimating the supply available to the Sub-areas delineated in this study. The groupings, which are illustrated in Plates 6 through 9, are as follows:

<u>Drainage Basin</u>	<u>Sub-areas Supplied</u>
<u>Dry Creek Group</u>	
Dry Creek (Fresno County)	1 and 2
Dog Creek	2
Fancher Creek	2
Redbanks Creek	2
Intermediate Drainage	2
<u>Sand Creek Group</u>	
Wahtoke Creek	1 and 5
Sand Creek	1 and 5
Intermediate Drainage	1 and 5
<u>Cottonwood Creek Group</u>	
Cottonwood Creek	10
Dry Creek (Tulare County)	10
Yokohl Creek	10 and 12
Lewis Creek	10 and 12
Greasy Creek	10
Intermediate Drainage	10 and 12
<u>Deer Creek Group</u>	
Deer Creek	11
White River	11
Intermediate Drainage	11 and 12

Gaging Stations and Periods of Record

Many gaging stations have been installed on the minor streams supplying water to the foothill and valley floor portion of the San Joaquin Valley. Generally the stations were installed to obtain data to be used for

specific investigations and studies and were subsequently abandoned. Some of the stations have been reestablished.

Table 11 presents a list of gaging stations used in this report for estimating water supply from minor streams. The stations are listed geographically from north to south.

TABLE 11

GAGING STATIONS USED TO ESTIMATE MINOR STREAM SUPPLY

Station Name	: Drainage : Source ^{1/} :	: Area : of : Period of Record :	: (Sq. mi.): Record :
Little Dry Creek near Friant	58	USGS & DWR	Oct. 1936-Sep. 1956
Dry Creek near Academy	45.3	USGS & DWR	Oct. 1940-Sep. 1948
Dog Creek near Academy	14.63	USGS & DWR	Oct. 1940-Sep. 1948
Dry Creek Diversion to Little Dry Creek	--	FID	Oct. 1949-Present
Dry Creek below Dry Creek Reservoir	68.6	FID	Oct. 1949-Present
Dog Creek Diversion to Dry Creek	--	FID	Oct. 1949-Present
Wahtoke Creek near Campbell Mtn.	19.2	USBR	Oct. 1945-Sep. 1953
Sand Creek near Orange Cove	31.7	USGS & DWR	
Cottonwood Creek above Highway 69	59.5	USBR	Oct. 1945-Sep. 1951 Oct. 1962-Present
Dry Creek near Lemon Cove	80.4	USGS & USBR	Oct. 1943-Sep. 1951 Oct. 1959-Present
Yokohl Creek east of Exeter	57.8	USBR	Oct. 1962-Present
Deer Creek at Terra Bella I.D.	86.0	TBID	Oct. 1919-Present
White River near Ducor	92.9	USBR	Oct. 1942-Sep. 1954 Oct. 1959-Present

^{1/} USGS United States Geological Survey
 USBR United States Bureau of Reclamation
 FID Fresno Irrigation District
 TBID Terra Bella Irrigation District

In addition to the records listed in Table 11, the Fresno Irrigation District has estimates of flow of Dry Creek and Dog Creek near Academy by months for the period October 1949 through September 1967, however, these estimates are based upon staff gage observations. The Fresno Irrigation District streamflow estimates were not used in estimating the long-term runoff of Dry Creek and Dog Creeks. They were used, however, in estimating the inflow to Dry Creek Reservoir during the period 1949 through 1967 because no other records were available (see sub-section on Dry Creek Group).

Estimates of Streamflow

The periods for which records are available for minor streams are much shorter than for the major streams (Kings, Kaweah and Tulare Rivers) and some are discontinuous.

In this study, correlations were established between minor streams for various periods when records were available and estimates of streamflow for periods ranging from 23 to 24 years were made. The annual estimates of streamflow for the 23- and 24-year periods were then averaged and adjusted to the long-term average based upon the runoff of the closest major stream. The Dry Creek and Sand Creek Group were adjusted to Kings River, Cottonwood Creek Group was adjusted to Kaweah River and the Deer Creek Group was adjusted to the Tule River.

Consideration was given to extending the annual runoff estimates of the minor streams to the entire period of record of the closest major streams, however, such an extension would have to be based upon a linear correlation between the streams and would not yield results any more accurate than an algebraic adjustment. The adjustments were made as in the following example:

- a. Estimated average annual runoff of Cottonwood Creek above Highway 69 for the period 1944 through 1966 = 3060 acre-feet.

b. Estimated average annual runoff of Kaweah River near Three Rivers for the period 1944 through 1966 = 365,235 acre-feet or 91.5 percent of long-term average.

c. Estimated long term average annual runoff of Cottonwood Creek above Highway 69 = $3060 \div .915 = 3344$ acre-feet.

Drainage Basin Boundaries

The drainage basin boundaries were determined from 15 and 7½ minute U. S. Geographical Survey topographic maps, and the areas were planimetered in cases where they had not previously been determined.

The geologic contact line between water bearing and nonwater bearing rocks or soils was traced on the topographic maps. This contact line was established during a prior study by the Geology Unit. In general, the contact line follows the base of the foothill line except where alluvial fans were formed in stream valleys. For the purposes of this study, it was considered that a negligible amount of surface runoff occurred below the geologic contact line because (1) average annual rainfall ranges from only 9 to 14 inches, (2) the slope of the land is relatively gentle, and (3) soil depths are great enough to allow most of the precipitation to infiltrate.

Some of the stream gaging stations were located a short distance downstream from the geologic contact line. In this study, no channel seepage losses were assumed to occur between the stream gaging stations and the geologic contact line because of the brief and flashy nature of the runoff of these streams which occurs only during periods of heavy rainfall. In instances where the stream gaging stations were located a significant distance above the geologic contact lines, the estimated runoff from the drainage area below the gaging station was added to that at the gaging station to derive the total runoff.

Dry Creek Group

Estimates of the annual runoff for the period 1934 through 1957 for Dry Creek near Academy and Dog Creek near Academy were made by correlation with Little Dry Creek near Friant. The Little Dry Creek Station was abandoned in 1957 hence more recent runoff records are not available. The correlations indicate that the unit runoff (expressed in acre-feet per square mile) increases with the altitude of the watershed. The Dog Creek watershed, which rises to an altitude of 2,200 feet, had an average unit runoff of 67.4 acre-feet per square mile compared with 178.0 acre-feet per square mile for the Dry Creek watershed which rises to an elevation of 4,500 feet.

The Dog Creek watershed was considered to be typical of the low elevation drainage areas of the foothills between the San Joaquin and Kings River, therefore the same unit runoff was estimated for this drainage area which includes Redbanks Creek, Fancher Creek and intermediate unnamed streams.

The Dry Creek Reservoir, which was constructed by the U. S. Army Corps of Engineers in 1948 to prevent flooding of Fresno residential areas, has been operated since 1949 by the Fresno Irrigation District under the supervision of the U. S. Army Corps of Engineers. The reservoir regulates the runoff of Dog Creek, which can be diverted into the reservoir, as well as the runoff of Dry Creek. Water can be released from the reservoir either into the Dry Creek channel below the dam or into a bypass channel which conveys water to Little Dry Creek and thence into the San Joaquin River.

An analysis was made of the operation of the reservoir for the period October 1949 through September 1967. The following table shows how the water was distributed. Tabulated quantities are average annual amounts.

	<u>Quantity in Acre-feet</u>
1. Inflow to Reservoir	7,700
2. Release to Dry Creek	2,870
3. Release to Little Dry Creek	1,930
4. Reservoir Loss (1)-(2)-(3)	2,900

The releases to Little Dry Creek are lost as a supply to Study Area No. 2 but the releases to Dry Creek constitute a source of supply. The reservoir loss can be considered as a source of supply because essentially the entire loss is from seepage. The reservoir contains water only during wet periods occurring during the winter and early spring when evaporation losses are a minimum.

In computing the long term supply to Study Area No. 2 the estimated inflow to Dry Creek Reservoir was given the same distribution as above. The average annual long term amounts are tabulated below.

	<u>Amount in Acre-feet</u>
1. Inflow to Reservoir	9,350
2. Release to Dry Creek	3,480
3. Release to Little Dry Creek	2,350
4. Reservoir Loss	3,520

Sand Creek Group

Estimates of the annual runoff for Sand Creek and Wahtoke Creek were made by correlation of Sand Creek with Little Dry Creek near Friant. The intermediate drainage areas were assumed to have the same unit runoff as Wahtoke Creek. The 24-year period 1934 through 1947 was used in determining streamflow by correlation because of lack of more recent streamflow records on these streams.

The long-term mean annual runoff was estimated by an adjustment based on the long-term mean annual runoff of Kings River at Piedra.

Cottonwood Creek Group

The period 1944 through 1966 was used to estimate the streamflow of this group. During this 23-year period, Dry Creek and Cottonwood Creek had discontinuous records of 15 and 10 years respectively. Estimates of annual Dry Creek flows for the 8-year period 1953 through 1959 were made by correlation with Kaweah River near Three Rivers. Estimates of the annual runoff of other streams in this group for the 23-year period were made by correlation with Dry Creek. Yokohl Creek, with four years of record, was considered to be representative of the intermediate drainage.

area, therefore the unit runoff of the intermediate drainage areas was considered to be the same as Yokohl Creek.

The long-term mean annual runoff was estimated by an adjustment based on the long-term mean annual runoff of Kaweah River near Three Rivers.

Deer Creek Group

The period 1943 through 1966 was used to estimate the streamflow of this group. Although Terra Bella Irrigation District has maintained a gaging station on Deer Creek since 1919, the Department of Water Resources San Joaquin District Hydraulics Unit stated that the gaging station is not up to Department of Water Resources, U. S. Geological Survey, or U. S. Bureau of Reclamation standards and that there is some question as to the accuracy of reported runoff. White River near Ducor has streamflow records from 1943 through 1954 and 1959 through 1966 or for 20 of the 24 years used in this study. Annual runoff of White River near Ducor for the period without records from 1955 through 1958 was estimated by correlation with Deer Creek at Terra Bella Irrigation District.

The drainage basins of Deer Creek and White River extend to altitudes of over 7,000 feet, consequently the runoff of these streams is not typical of the runoff of the lower altitude intermediate drainage areas in this stream group. Furthermore, there are no streams in this group with low altitude drainage areas that have streamflow records. For these reasons the intermediate drainage areas were assumed to have the same unit runoff as Yokohl Creek in the Dry Creek Group.

The long-term mean annual runoff was estimated by an adjustment based upon the long-term mean annual runoff of the Tule River at Success Dam.

Minor Streams as a Source of Supply to the Subareas

At the present time, only two of the minor streams, Dry Creek and Dog Creek are regulated by a reservoir. Furthermore, no diversion structures, except for a minor one on Deer Creek, have been constructed for diversion of streamflows for agricultural or other use.

Almost all of the streamflow is derived from rainfall runoff which occurs during the winter and early spring months when agricultural water requirements are at a minimum. The uncontrolled streamflow traverses the alluvial fans of the streams and a portion of the valley floor or are intercepted by the canal systems of water agencies. The stream channels in the alluvial fans and on the valley floor are generally pervious and almost all of the runoff is lost by seepage. On relatively rare occasions, some runoff from the Dry Creek Group which enters Fresno Irrigation District's canal system is returned to the San Joaquin River. The runoff of the Cottonwood and Deer Creek Groups is always consumptively used in Study Area 2 because there is no surface outflow from the Tulare Lake Basin.

In the Dry Creek Group, releases to Dry Creek channel from Dry Creek Reservoir which is in Sub-area 1 flow about two miles to the Enterprise Canal, the northern boundary of Sub-area 2. The entire flow from such releases can be considered as a supply to Sub-area 2, however, seepage losses from Dry Creek Reservoir can be considered as a supply to Sub-area 1. Fancher and Redbank Creeks and the intermediate drainage area flow a short distance from the geologic contact line to Sub-area 2 therefore the runoff from these streams can be considered as a supply to Sub-area 2.

In the Sand Creek Group, runoff from Wahtoke and Sand Creeks and the intermediate drainage traverse their alluvial fans and a considerable distance on the valley floor before entering Sub-area 5, therefore substantial channel seepage losses occur in Sub-area 1. In this study, it was assumed that 50 percent of the runoff of this group percolated to the underground in Sub-area 1 and 50 percent entered Sub-area 5. The actual seepage loss distribution could not be determined within the scope of this study. The supply from this stream group is small compared with the total supply to Sub-area 5, so an error in the estimate of seepage loss would have a minor effect on the total surface water supply to Sub-area 5. The flows of Wahtoke and Sand Creek that enter Sub-area 5 are introduced into the Alta Irrigation District Canal System. It is assumed that these flows are lost by seepage in the canal system.

Cottonwood Creek flows through about two and one-half miles in Sub-area 17 between the geologic contact line and the upper boundary of Sub-area 10. There are channel losses in this reach of the alluvial fan occupying Woodlake Valley. Substantially all the runoff of Cottonwood Creek can be considered as a source of supply to Sub-area 10, however, because little of the water lost through seepage in Sub-area 17 is consumptively used, it enters the ground water basins and results in subsurface inflow to Sub-area 10. In this study the entire runoff of Cottonwood Creek is assumed to be a supply to Sub-area 10. At times during winter floods, Cottonwood Creek flows into Cross Creek and its flows are intermingled with Kaweah River flows, a portion of which are lost to Sub-area 10. This loss to Sub-area 10 has been made by an appropriate reduction to the combined flows (see Kaweah River Water Supply).

The flows of Greasy and Dry Creeks enter the Kaweah River a short distance downstream from the geologic contact line and are considered to accrue entirely to Sub-area 10. The flow of Yokohl Creek and the intermediate drainage area flow a considerable distance across alluvial fans and the valley floor before reaching Sub-area 10. Of these flows, 50 percent is considered to remain in the Tulare foothill Sub-area 12 and the remaining 50 percent runs off to Sub-area 10.

In the Deer Creek Group, both Deer Creek and White River have seepage losses in the channel reaches between the geologic contact line and the upper boundary of Sub-area 11, however, such losses can be considered as eventually accruing to Sub-area 11 through subsurface inflow. A significant portion of the runoff from the intermediate drainage areas infiltrates to the ground water in Sub-area 12. In this study, 50 percent of the intermediate drainage area runoff is considered to accrue to Sub-area 12 and 50 percent to Sub-area 11.

Tabulated in Table 12 is the mean annual long-term runoff of minor streams and in Table 13 the supply from minor streams that accrue to the sub-areas.

TABLE 12

RUNOFF OF MINOR STREAMS

Drainage Basin	Drainage Area in Sq. Miles	Mean Annual Runoff Acre-feet
<u>Dry Creek Group</u>		
Dry Creek (Fresno County)	68.6	9,350
Dog Creek	14.6	960
Fancher Creek	21.5	1,410
Redbanks Creek	14.9	970
Intermediate Drainage	<u>20.7</u>	<u>1,350</u>
Totals	140.3	14,040
<u>Sand Creek Group</u>		
Wahtoke Creek	19.2	970
Sand Creek	31.7	2,470
Intermediate Drainage	<u>50.6</u>	<u>2,540</u>
Totals	101.5	5,980
<u>Cottonwood Creek Group</u>		
Cottonwood Creek	59.5	3,340
Dry Creek (Tulare County)	80.4	9,930
Greasy Creek	8.8	160
Yokohl Creek	57.8	1,050
Lewis Creek	28.4	520
Intermediate Drainage	<u>110.7</u>	<u>2,020</u>
Totals	345.6	17,020
<u>Deer Creek Group</u>		
Deer Creek	86.0	30,100
White River	92.7	5,880
Intermediate Drainage	<u>98.3</u>	<u>1,800</u>
Totals	277.0	37,780
TOTAL RUNOFF MINOR STREAMS	864.4	74,820

TABLE 13
SUPPLY FROM MINOR STREAMS

Sub-area Number	Minor Stream Group	Average Annual Supply in Acre-feet
1	Dry Creek Group	3,520
	Sand Creek Group	2,990
	Total	<u>6,510</u>
2	Dry Creek Group	8,170 ^{1/}
5	Sand Creek Group	2,990
10	Cottonwood Creek Group	15,220
11	Deer Creek Group	36,880
12	Cottonwood Creek Group	1,800
	Deer Creek Group	900
	Total	<u>2,700</u>
TOTAL MINOR STREAM SUPPLY		72,470

^{1/} An annual average of 2,350 acre-feet is diverted from Dry Creek Reservoir into Little Dry Creek. This is the difference between Table 12 and Table 13 totals.

Future Developments on Minor Streams

It appears doubtful if storage on minor streams for conservation purposes could be economically justified. Of the total average annual runoff of 74,820 acre-feet from minor streams, only 2,530 acre-feet are lost by outflow from Study Area 2. Some of the minor streams do cause flood damage, however, and this damage can be expected to increase in the future with urban growth. Flood control projects on some of the minor streams is anticipated.

In the Dry Creek Group, there is a flood control reservoir--Dry Creek, built by the U. S. Army Corps of Engineers, and one on Redbanks Creek built by the Fresno Metropolitan Flood Control District. The only

other significant stream which could be controlled is Fancher Creek, which flows into the Fresno Irrigation District canal system. Under present conditions of development, Fancher Creek flood flows can be discharged through the canal system without causing damage.

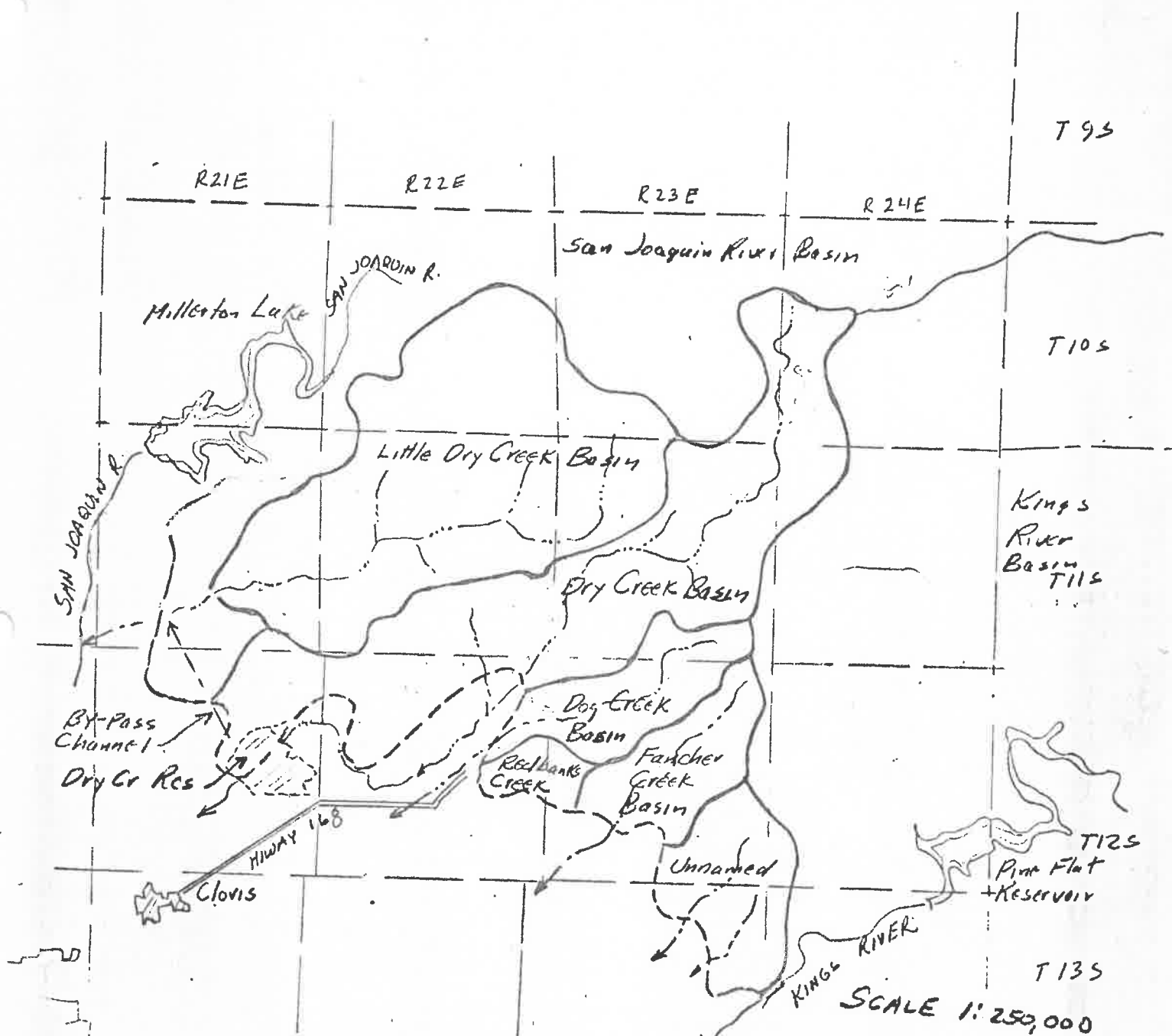
In the Sand Creek Group, Wahtoke Creek flows in a relative large, steep channel and discharges into the Alta Canal and the Kings River, therefore flooding is not a problem. Sand Creek, on the other hand, discharges onto the valley floor and causes problems at times of heavy rainfall. At this time no known plans have been developed to eliminate flooding caused by Sand Creek. In the future, with increased development it may become justified to construct flood control facilities.

In the Cottonwood Creek Group, Cottonwood, Yokohl and Lewis Creek and the intermediate drainage areas are sources of flooding of agricultural lands. The only known investigation conducted was in the Stone Corral Soil Conservation District Area. The District has filed an application for assistance under the U. S. Public Law 566 to eliminate flooding and high ground water tables in the vicinity east of Colvin Mountain. There is no known plan to eliminate flooding caused by Cottonwood, Yokohl or Lewis Creek, however with future development flood control facilities may become justified.

In the Deer Creek Group the U. S. Army Corps of Engineers studied possible flood control and recreation projects on Deer Creek and White River as part of their Poso Stream Group study. There was no project on White River that was economically justified at the time of the study in 1966, however, a note was made that with future developments, a project involving storage reservoirs, levee systems or both may become justified. On Deer Creek the U. S. Bureau of Reclamation is proposing an 800,000 acre-foot reservoir at Hungry Hollow as part of its initial phase of the Eastside

Divison of Central Valley Project. The reservoir as planned would provide storage for flood control.

DRY CREEK GROUP



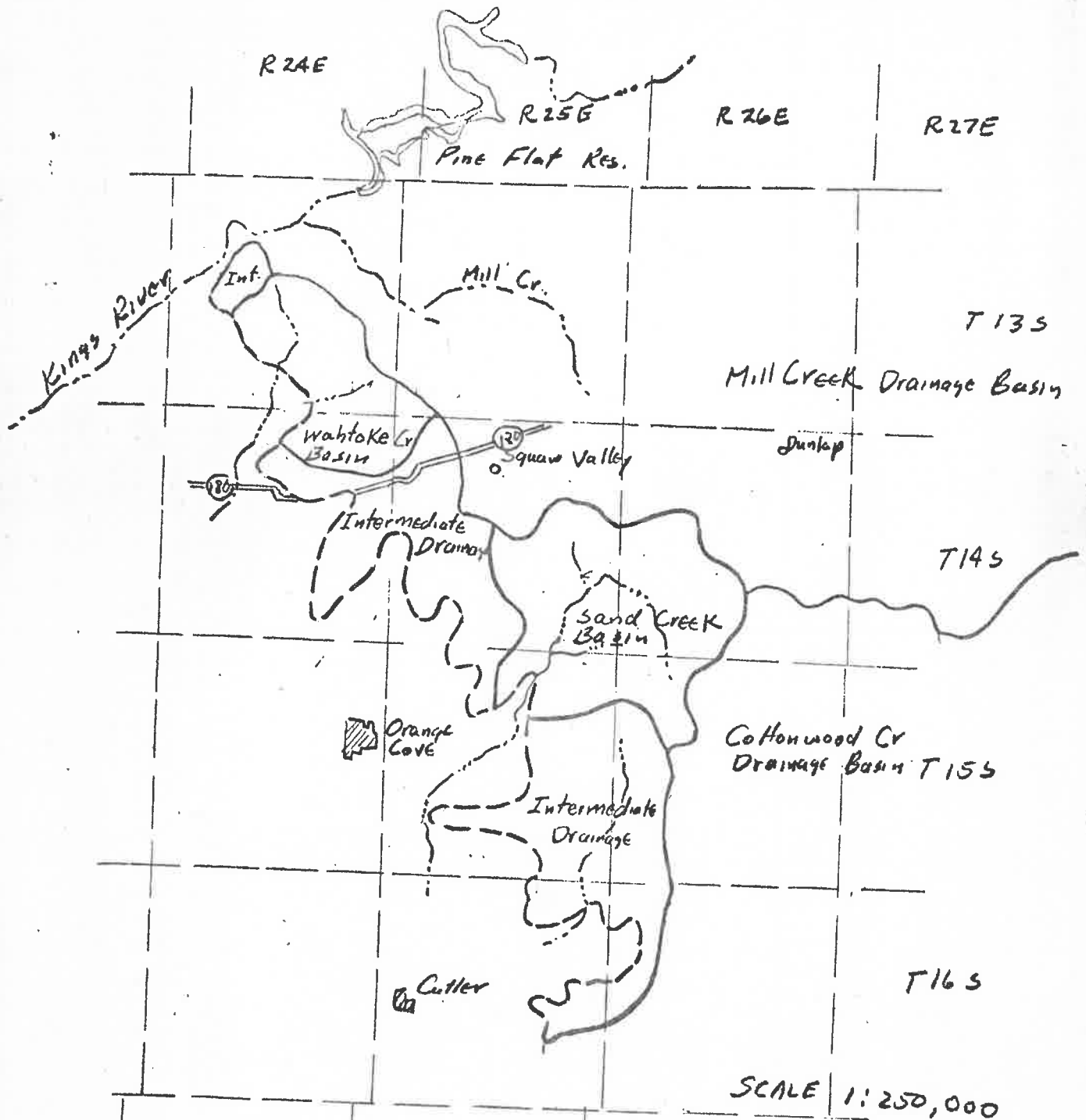
Note: Little Dry Creek is not included in the Dry Creek Group, however, it was used to estimate runoff of other streams and its relative position is shown on this map.

LEGEND

- Drainage Boundary
- - - Geologic Contact Line
- ~ ~ ~ Stream Channel
- - - Township Line

1-4-68

WMH



- Legend
- Drainage Boundary
 - - - Geologic Contact Line
 - Stream Channel
 - Township Line

1-8-68
WMH

COTTONWOOD CREEK GROUP

PLATE 8

R26E

R27E

R28E

R29E
T14S

T15S SCALE 1:250,000

Legend

- Drainage Boundary
- - - Geologic Contact Line
- T16S — Stream Channel
- Township Line

1-8-68
WMH

o Kaweah

o Three Rivers
T17S

Kaweah River
Drainage Area

Terminus Res

Intermediate
Drainage Area

T18S

Exeter

Yokohi
Creek Basin T19S

Lindsay

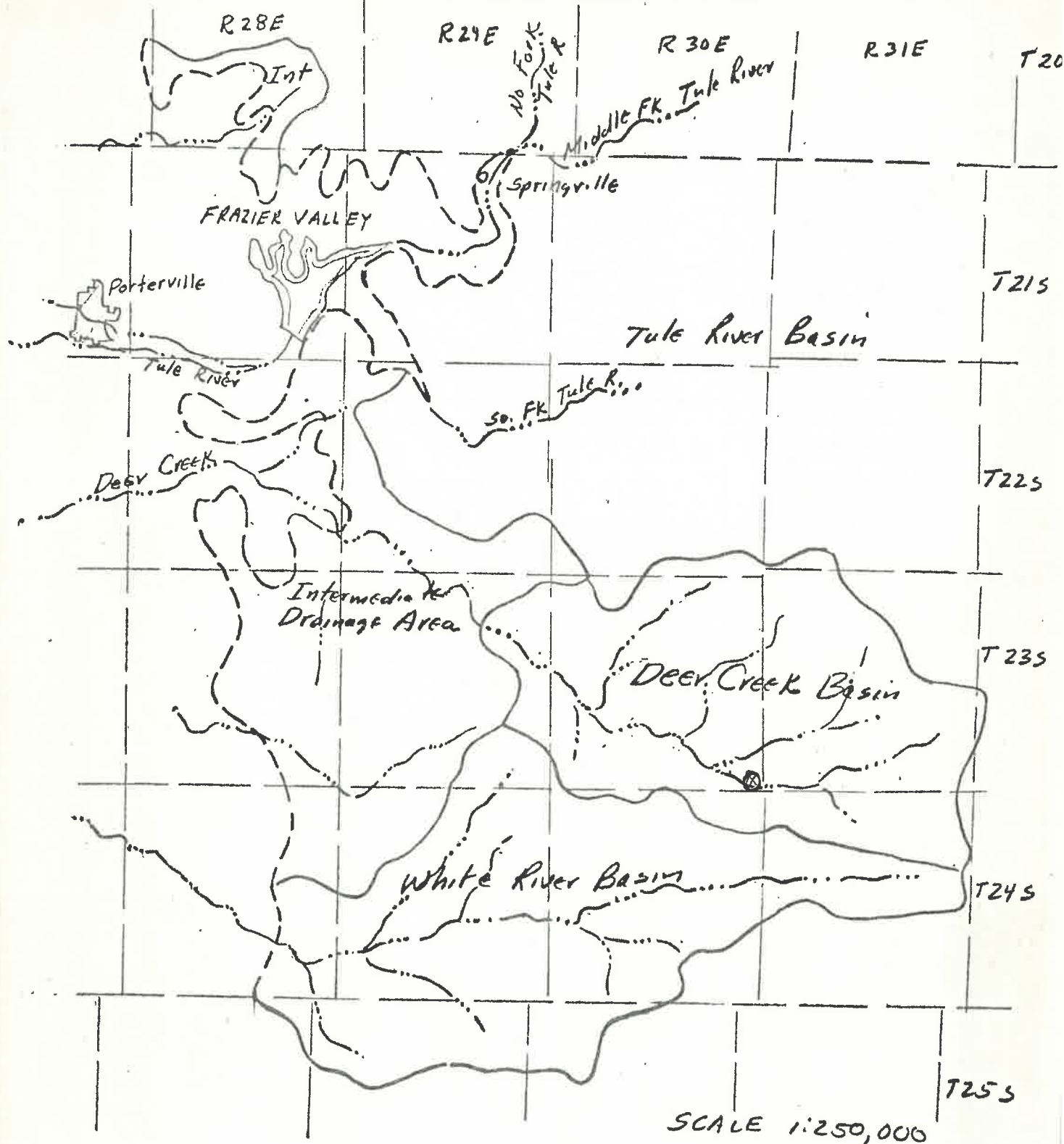
Lewis
Creek Basin

T20S



DEER CREEK GROUP

PLATE 9



SCALE 1:250,000

LEGEND

- Drainage Boundary
- - - - Geologic Contact Line
- ... Stream Channel
- Township Line

OTHER SOURCES

In addition to the water supply from the sources previously enumerated, Study Area 2 receives water from the State Water Project, transfers of water from Study Area 1 to Study Area 2 and between sub-areas in Study Area 2, San Joaquin River riparian pumping and San Joaquin River seepage losses.

A total of 179,200 acre-feet of State Water Project water to be delivered by year 1990 has been contracted for by four water agencies in Study Area 2. Tabulated below are the water agencies, the sub-area in which they are located and the contractual amounts of water.

Sub-area No.	Contracting Agency	Year 1990 Annual Entitlement in Acre-feet
8	Empire Westside I. D.	3,000
9	Tulare Lake Basin W.S.D.	110,000
13	Hacienda Water District	8,500
13	Dudley Ridge Water District	57,700

The riparian pumping from the San Joaquin River is reported in the Department of Water Resources Bulletin No. 23 and Bulletin No. 130 series. The annual pumping to Subareas 1 and 2 were totaled for the ten-year period 1956 through 1965 and the average annual amounts were computed. The pumping to the subareas was as follows:

Subarea	Average Annual Pumping in Acre-Feet
1	4,900
2	1,100

Pumping from the San Joaquin River below Gravelly Ford to Subarea 7 is a Central Valley Project delivery and is tabulated with the other Central Valley Project deliveries.

Seepage losses from the San Joaquin River constitute a source of supply to Subareas 1, 2 and 7, through ground water recharge. Channel losses between the gaging station "San Joaquin River Below Friant" and Mendota Dam have been computed for the Lower San Joaquin River Water Quality Investigation for the period 1951 through 1960. In several years the computed losses exceeded the flow below Friant. The reason for this may be that the accuracy of recorded flows into and from the Mendota Pool, which averages over one million acre-feet annually, is not sufficient to determine losses reliably. A four percent error in measuring inflow or outflow, for example, would result in a miscalculation of losses by 40,000 acre-feet.

For the above reasons, the U. S. Bureau of Reclamation's gaging station "San Joaquin River at Gravelly Ford" which is located upstream from Mendota Pool was used to compute channel losses for the ten-year period 1956 through 1965. In seven of the ten years the flow below Friant was less than 100,000 acre-feet, ranging from 63,000 acre-feet to 99,000 acre-feet. In the same seven years the flow at Gravelly Ford ranged from 14,000 acre-feet to 45,000 acre-feet. An error of four percent in the recorded flow below Friant would result in miscalculation of average annual losses by approximately 3,200 acre-feet for the seven years. By using the recorded flows at the Gravelly Ford gaging station, a reliable estimate of channel losses is possible, whereas by using the inflow to and outflow from the Mendota Pool, estimated channel losses would be of doubtful accuracy.

In the inflow-outflow equation for computing losses between the gaging station below Friant and Gravelly Ford, the inflow consists of the river below Friant and the discharge of Little Dry Creek, the only

significant tributary to the river below the gaging station below Friant; the outflow consists of the flow at Gravelly Ford and the riparian pumping.

The loss rate was assumed to be constant throughout the river channel reach between the Highway 41 Bridge and Gravelly Ford, furthermore the loss rate in the channel reach between Gravelly Ford and Mendota Dam was assumed to be the same as for the upstream reach. These assumptions were necessary because no intermediate gaging station was available to compute variations in loss rates. Observation of the spring 1967 ground-water map indicates that no losses occur above the Highway 41 Bridge.

The average annual loss for the ten-year period 1956 through 1965 between the gaging station below Friant and Gravelly Ford was estimated at 34,864 acre-feet. Of this total loss, 5,748 acre-feet was estimated to be from evaporation from the water surface and evapotranspiration from the phraetophytes along the channel. The resulting average annual seepage loss, which results in ground water recharge, accrued equally to the areas north and south of the river. This assumption was substantiated by observation of the spring of 1967 ground water map which indicates a relatively symmetrical ground water mound under the San Joaquin River in this channel reach.

The 28,330 acre-feet of recharge from the San Joaquin River to Study Area 2 was ratably apportioned to Subareas 1, 2 and 7 based upon the length of boundary of each subarea along the river. The estimated recharge to Study Area 2 from the San Joaquin River is as follows:

: Average Annual Recharge	
Subarea :	from the San Joaquin
: River in Acre-Feet	
1	1,470
2	12,090
7	14,770
Total	28,330

Another source of supply or depletion to sub-areas in Study Area 2 is water transfers whereby water from well fields in one study area or sub-area is transported for use in another study area or sub-area.

The Alpaugh Irrigation District, located in Study Area 2 receives water pumped from Study Area No. 1 (Kern County). The average annual amount of this supply is estimated at 14,500 acre-feet.

There are three transfers of water between sub-areas in Study Area 2. Water from James Irrigation District's well field in Sub-area 7 is transported to Sub-area 6. The average annual transfer is estimated at 12,200 acre-feet based upon pumpage reported in the U. S. Bureau of Reclamation's "Water Supply, Fresno Field Division" for 1964. The second transfer is from the well field of the Angiola Water District, located in Sub-area 11, to Sub-area 9. The average annual amount of this transfer is estimated at 6,500 acre-feet. The third transfer is from Lower Tule River Irrigation District in Sub-area 11 to Sub-area 9. From the U. S. Bureau of Reclamation Field Division Water Supply Report, this transfer averages 15,500 acre-feet annually for the period 1948 through 1965.