SACRAMENTO RIVER TOXIC CHEMICAL RISK ASSESSMENT PROJECT
FINAL PROJECT REPORT

90-11WQ
OCTOBER 1990

APPENDIX H, I, J, K, L, M, N

PREPARED BY:

DIVISION OF WATER QUALITY
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARD,
CENTRAL VALLEY REGION

WATER RESOURCES CONTROL BOARD
STATE OF CALIFORNIA

LIST OF APPENDICES - CONTINUED

APPENDIX H

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Northern District

DRAFT

SACRAMENTO VALLEY RICE IRRIGATION HYDROLOGY STUDY

for the

California Regional Water Quality Control Board
Central Valley Region

December 1984

Water Resources Control Board Contract 2-128-150-0

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Northern District

Donald J. Finlayson . . . Chief
Philip J. Lorens . . . Chief, Water Management and Data Branch

This report was prepared by

Robert R. McGill . . . Senior Land and Water Use Analyst

Assisted by

<u>Northern District</u>

W. D. McIntyre . . . Water Resources Engineering Associate
Donald E. Werner . . . Water Resources Technician II
Karen Liptak . . . Graduate Student Assistant

<u>Central District</u>

George K. Sato . . . Senior Land and Water Use Analyst
Milton D. Jones . . . Water Resources Engineering Associate

Special services were provided by

<u>Drafting</u>

Clifford Maxwell . . . Senior Delineator

<u>Reports Review and Typing</u>

Mitchell Clogg . . . Research Writer
Helen Chew . . . Office Technician
June Daniels . . . Office Technidian
Diane McGill . . . Secretary

This report was prepared under contract with the Regional Water Quality Control Board, Central Valley Region.

TABLE OF CONTENTS

APPENDICES

FIGURES

TABLES

PART ONE

INTRODUCTION AND SUMMARY

PART ONE

INTRODUCTION AND SUMMARY

The discharge of residues from the weed herbicides Ordram and Bolero (both registered trademarks) into farm drains that flow into prime Sacramento and Feather River water supplies caused serious concern during the 1982 and 1983 rice-growing seasons. The City of Sacramento complained that the herbicides imparted a bitter taste to the city drinking water, and large fish kills in drainage sloughs were blamed on the chemicals.

In response, the Regional Water Quality Control Board, Central Valley Region, working with the State Resources Control Board, the Departments of Fish and Game, Health Services, and Food and Agriculture, the Agricultural Commissioners of the Sacramento Valley counties, and the University of California Cooperative Extension, are developing a comprehensive plan to reduce off-site movement of herbicides from Sacramento Valley rice fields.

As part of this effort, the State Department of Food and Agriculture increased controls on the use of rice weed herbicides for the 1984 irrigation season. No-spill holding times were set for six and eight days, respectively, for Bolero and Ordram. (Ordram is the much more heavily used of the two.) Growers were required to hold water either within rice fields or spill only onto adjacent idle or fallow lands--no water could be spilled to agricultural drains. Water recycling systems, where rice irrigation water that spills from paddies is recovered and reused, were also allowed if approved by the county agricultural commissioner. In addition, after holding water treated with Ordram for six days, growers could appeal to the county agricultural commissioner for permission to spill it if a serious agronomic condition could be documented.

Farmers had to file notice of intent and notice of application with local county agricultural commissioners in order to use Ordram or Bolero. The county agricultural commissioners' offices intensified surveillance for violators. The Stauffer Chemical Company, manufacturer of Ordram, working through its valley-wide sales staff, held many advisory meetings with rice farmers before the growing season, explaining the need for strict adherence to label instructions with special emphasis on good water management. An intensified water sampling program was done by the California Department of Fish and Game, Central Valley Regional Water Quality Control Board staff, State Water Resources Control Board and others.

Study Activities and Funding

As part of the plan to halt herbicide contamination of water supplies, the Regional Board contracted with the Department of Water Resources to examine valley-wide rice irrigation and drainage water movement to see if changes to the drainage system might help. The Department was also asked to inspect on-farm irrigation practices and farm or irrigation district water recycling and drain recapture as possible management techniques for reducing contamination. For this study the Sacramento Valley was divided into seven major hydrologic study areas (see Figure 2, Part One).

Organization of this Report

Part One of this report is the "Introduction and Summary", which includes this page. It ends with Findings of the study and Recommendations that additional studies be made to provide information needed to plan effective water management in the rice-growing areas. Part Two analyzes the circulation of rice irrigation water, dividing the analysis into seven study areas created for this investigation. Table 10 summarizes the irrigation water balance for the different areas.

Part Three compares different methods of irrigation and discusses their implications in terms of water quality, drain flows, and downstream water use.

Appendix A is a proposal for a study of water recycling. Now only a fraction of the total rice acreage recycles irrigation water, but the method has significant advantages, not the least of which is near-total control of herbicide residues. Appendices B and C have data on 1982 land use and evapotranspiration of applied water.

Separately bound for this study is a series of 1:24,000-scale U. S. Geological Survey quadrangle maps showing irrigation or water district boundaries. These maps are being transmitted separately.

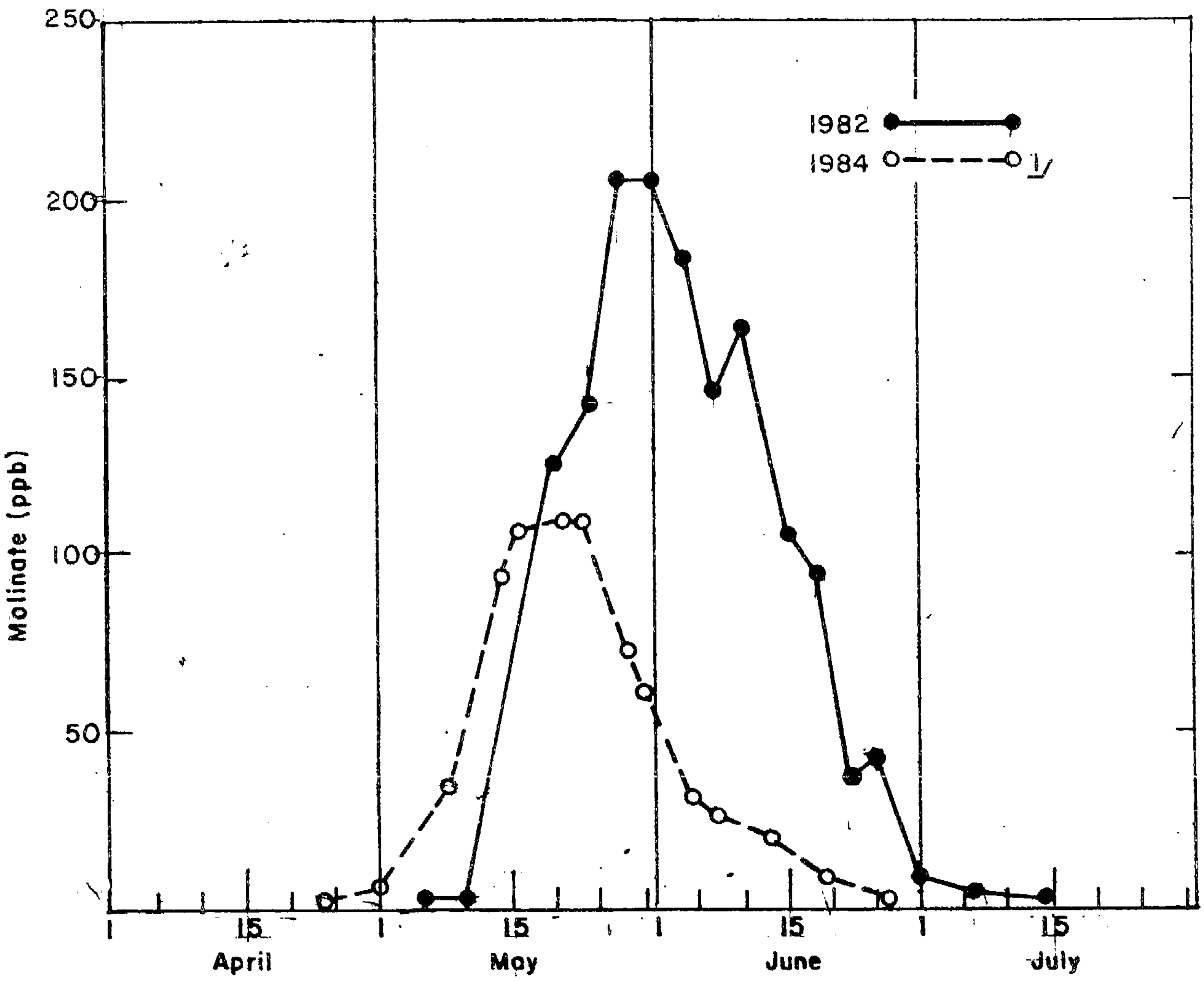
(Note: Superscript numbers--(3)--direct the reader to texts listed in "References" at the end of Part Three.)

Results of the 1984 Regulations

Laboratory tests of water samples taken at widely spaced intervals from Sacramento Valley waterways show marked reduction in overall rice herbicide levels during the 1984 growing season[1]. This was mainly due to improved on-farm water management. Farmers held herbicides on-farm, with no

Pesticide Concentrations Lowered

This graph, with the comments quoted, appeared in a report of the California Department of Food and Agriculture issued in August, 1984. More data are needed before the reasons for these reductions in molinate can be identified. (Molinate is the active ingredient in Ordram.) Still, the dramatic drop in the substance's concentrations in the Colusa Basin Drain, one of the largest in the region, shows the effectiveness of 1984's combined efforts.



1/ Preliminary 1984 data reported by Stauffer Chemical Company.
Source: CDFA Rice Herbicide Program Update № 9, July 13, 1984.

"Figure 1 compares levels of Ordram in the Colusa Basin Drain during 1984 and 1982. The amount of Ordram used during the two rice seasons was very similar. Although a final analysis of the two seasons is not complete, there was apparently a significant decrease in residues of Ordram in 1984. This can be considered a significant accomplishment of this year's program."

significant water spill, for the required period, and water levels in the major drains were more than adequate to provide dilution for what minor spilling there was. The Conway Ranch in Yolo County was permitted to operate on a district-wide basis. Their recycling system allowed individual fields to spill, but the spill was recycled within the area. In total, permission was granted to recycle paddy water on 43,990 acres (1) in May and June 1984. This was slightly less than 10 percent of the rice planted in the valley.

Most farmers observed herbicide holding regulations. A few were permitted to dump rice paddies after holding Ordram only six days. Most of these were for rice-seed planting, occasioned by cool weather and poor seed germination.

Despite increased rice acres in 1984 over 1983, herbicide levels in the drains stayed generally within Department of Fish and Game recommendations. No 1984 fish kills were attributed to rice weed herbicides.

Study Findings and Recommendations

Valley rice farmers made a concerted effort to comply with State regulation. Assisted by the precise laser levelling of fields, they kept May-June paddy water levels lower than they have ever been. To do otherwise would have risked significant economic losses through reduced yields, in the event that riceweed herbicides were banned. Responsibility for keeping residues out of drains and out of prime water supplies rested with the individual farmer or manager, as did the program's success.

Drain outflows to the Sacramento River were normally high in May and June 1984. Water was abundant in both the Feather and Sacramento River watersheds and diverters took water at capacity. Areas 3 and 5, which rely heavily on ground water, had no outflow until fields were drained for harvest in September.

It is likely that current on-farm water management practices will improve even further as farmers better realize the need for longer holding periods. Increased drain recapture at the district level would help maintain water quality by increasing the time of travel of drain water back to the Sacramento River.

The Department of Water Resources acknowledges the need for further herbicide monitoring in the drains and other key locations throughout the Sacramento Valley.

Findings

- Drain outflow from agriculture, mainly rice, totalled more than a million acre-feet in 1982. Totals for 1984 will probably be slightly less.
- In 1982 and 1984, during the months of May and June, the rice herbicide application period, about 25 percent of the total summer irrigation season drainage entered the Sacramento River. This amounted to about 250,000 acre-feet.
- Rice farmers improved irrigation management practices in 1984 to better control herbicide contamination. Continued emphasis on improved irrigation management is the key to further reducing contamination levels.
- No-spill irrigation management is necessary during the rice herbicide application period but becomes less important for the rest of the season. Some spill is desirable to maintain flow and water temperature, oxygen levels, and other water quality characteristics in the drains to sustain aquatic life and riparian vegetation.
- Increased drainage recaptured by water districts and individual farmers could reduce rice herbicide levels returning to prime supplies by increasing the time water is kept on-farm.
- Drainage recycling systems for better water management will probably not expand voluntarily, because they use more energy, have a high capital cost and may actually prove to be beneficial only during the short herbicide holding period.
- There was no summer outflow until September harvest period from Study Areas 3 and 5. These depend on expensive pumped ground water and practice strict conservation.
- It is expected that low applied water irrigation will increase in popularity as a way to keep herbicides from moving off-farm. This practice could be accompanied by increased flows in major drains from water purveyors to maintain water quality in the drains.
- Two major drains—the Colusa and Sutter Basin Drains—contribute 70 percent of the May-to-September irrigation return flows to the Sacramento River.
- Seventy-five percent of the prime water delivered within the study area is used to meet evapotranspiration (ET).

Recommendations

. Further studies should be made on the advisability of reducing TDS and turbidity levels in the Sacramento River by eliminating or reducing spills from the Colusa and Sutter Basin Drains.

. Additional studies should be made to see if these large quantities of agricultural drainage can be used to meet present and future water demands in Yolo and Lake Counties.

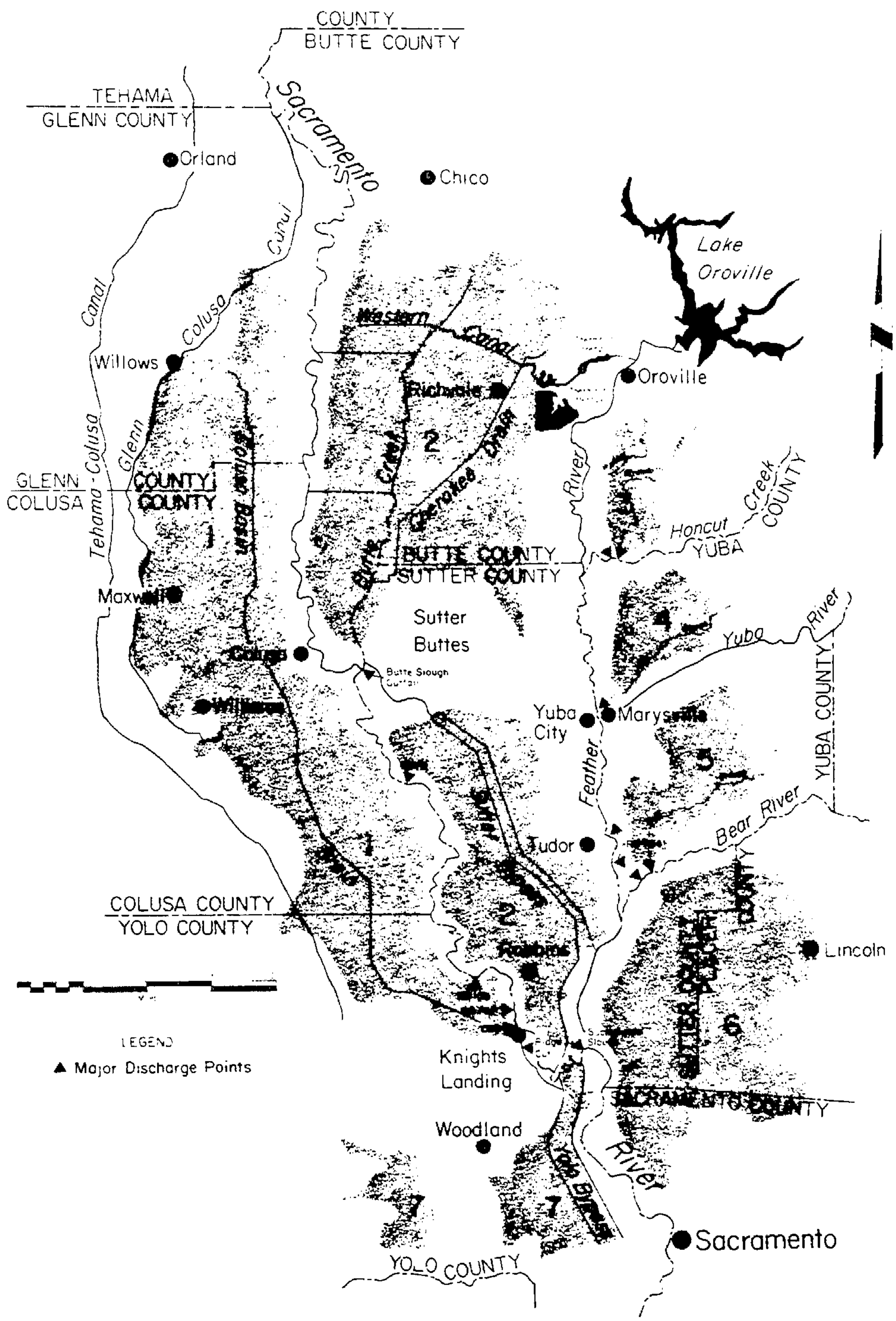
PART TWO

SUMMER IRRIGATION SEASON WATER CIRCULATION BY STUDY AREA

PART TWO

SUMMER IRRIGATION SEASON WATER CIRCULATION BY STUDY AREA

Figure 2



Selected Hydrologic and Rice-Growing Areas

PART TWO

SUMMER IRRIGATION SEASON WATER CIRCULATION BY STUDY AREAS

For purposes of this study, the rice-growing lands of the Sacramento Valley are divided into seven study areas (Figure 2). These are crossed by the Sacramento River and several of its major tributaries, the American, Bear, Feather and Yuba Rivers. These streams, and a network of sloughs, ditches, canals, creeks, and manmade bypasses, both supply the irrigation water to rice paddies and drain them eventually back into the Sacramento. Interstate 80, Interstate 5, the coastal mountain ranges and Sierra Nevada foothills (and the increasingly dry lands as you approach them), and Sutter Buttes are other prominent features that help define the separate study areas.

The method of this study was to restrict the analysis to the summer irrigation season, May through September, so that flood season flows would not be confused with summer irrigation return flows. For each study area a hydrologic balance was calculated for the summer of 1982. Outflow, which is mostly rice irrigation return flow[2,3], is a function of surface and pumped water supplies, less evapotranspiration of applied irrigation water (ETAW) and any other irrecoverable losses, such as deep percolation, that might occur. Outflows from Study Areas 1, 2 and 6 were generally gauged measurements while Areas 3, 4, 5 and 7 are careful estimates based largely on crop water-use data.

The 1982 crop acres for each of the counties within the seven study areas were used to calculate ETAW. Rice acreages were taken from the U. S. Crop and Livestock Reporting Service. County crop acres for all other crops were developed from the Department of Water Resources (DWR) crop surveys. DWR surveys also identify the source of water to all land parcels. Ground water pumpage and surface water use were computed by the land-use method, where crop acres are multiplied by quantities of applied water known to be used by each crop.

TABLE 1

1982 RICE ACREAGE, SACRAMENTO VALLEY1/
(1000s of Acres)

County	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6	Area 7	Total
Glenn	71.0	10.0	0	0	0	0	0	81.0
Colusa	106.0	14.0	0	0	0	0	0	120.0
Butte	0	102.3	3.7	0	0	0	0	106.0
Yuba	0	0	0	21.4	11.1	0	0	32.5
Sutter	0	58.7	0	0	0	32.3	0	91.0
Placer	0	0	0	0	0	10.0	0	10.0
Sacramento	0	0	0	0	0	18.5	0	18.5
Yolo	18.9	0	0	0	0	0	17.6	36.5
Total	195.9	185.0	3.7	21.4	11.1	60.8	17.6	495.5
% Valley Total	39	37	1	5	2	12	4	100
% Statewide Total2/	36.2	34.3	0.7	4.0	2.0	11.3	3.3	91.8

1/ Crop and Livestock Reporting Service
2/ Based on 540,000 acres in 1982

Tabulations of surface water supplies in 1982 came from diversion measurements made by the U. S. Bureau of Reclamation, DWR, and various irrigation and reclamation districts throughout the valley. The hydrology was available on a monthly basis, but it is generally summarized on an irrigation season basis for this analysis. Each of the seven study areas is discussed in detail below.

Study Area 1

This rich rice-growing area lies west of the Sacramento River, with Hamilton City and Knights Landing marking its approximate northern and southern extremities. Interstate 5 passes through, in a north-south direction, and the area is served on its west side by the communities of Willows, Maxwell, and Williams. It had more than 450,000 irrigated acres in 1982.

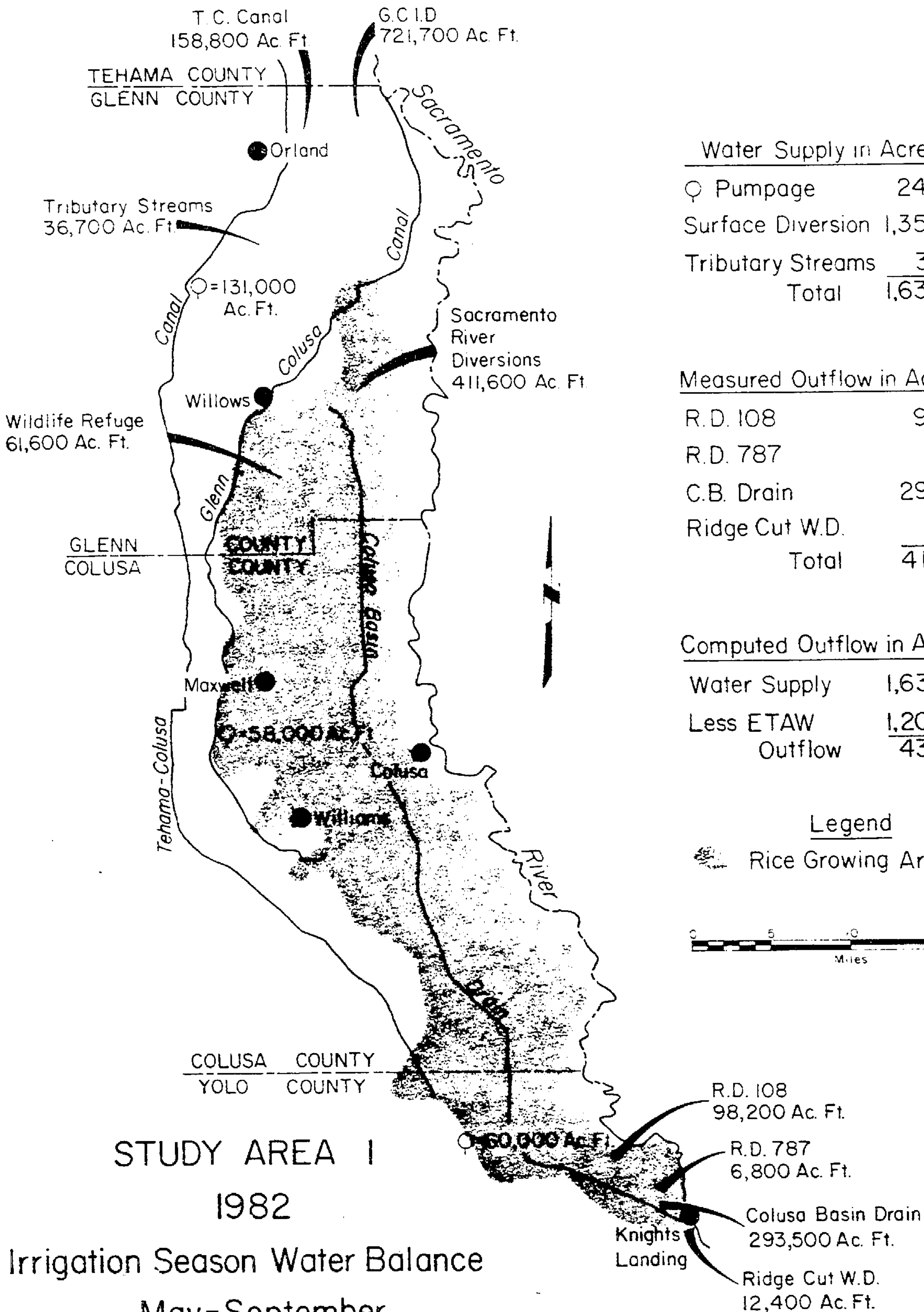
Water for this area comes from the U. S. Bureau of Reclamation's (USBR) Tehama-Colusa Canal, and from more than 100 right-bank diversions on the Sacramento River. The Glenn-Colusa Irrigation District is one of the largest diverters, taking between 700,000 and 800,000 acre-feet annually. Small westside streams and ground water augmented the water supply in 1982.

Rice irrigation-flows from this large area return to the Sacramento River mainly from three closely spaced drains--a large bank of pumps operated by Reclamation District 108, a small drain from the Reclamation District 787, and a very large Colusa Basin Drain that enters the river near Knights Landing. A small amount of drainage also passes through the Knights Landing Ridge Cut into the Yolo Bypass for irrigation during the summer months.

In the summer of 1982 there was a measured outflow from Study Area 1 of around 411,000 acre-feet, nearly all of it from rice irrigation [2]. During the application of Bolero and Ordram, almost 80,000 acre-feet of water containing the herbicides entered the Sacramento River from the Colusa Basin Drain at Knights Landing. Residue concentrations peaked in the Colusa Basin Drain about June 15[(4)]. They were measured in samples taken during an intensive multi-agency sampling program. Concentrations dropped to low levels by July 5.

This 80,000 acre-feet was a much larger volume of water than had been measured during the critical May-June herbicide period in the four previous growing seasons. Those volumes were 47,000, 42,200, 64,800, and 61,600 acre-feet.

The acreage planted to rice, rainfall patterns, water depth in rice paddies, Sacramento River flow stages, district management, and water retention regulations will all affect the quantity and quality of these spills. Nevertheless, it is clear from these observations of Area 1 that a very large volume of water, approximately 80,000 acre-feet, must receive improved management in order to reduce or eliminate rice herbicide contamination in the Sacramento River.



Water Supply in Acre Feet	
Pumpage	249,000
Surface Diversion	1,353,700
Tributary Streams	36,700
Total	1,639,400

Measured Outflow in Acre Feet	
R.D. 108	98,200
R.D. 787	6,800
C.B. Drain	293,500
Ridge Cut W.D.	12,400
Total	410,900

Computed Outflow in Acre Feet	
Water Supply	1,639,400
Less ETAW	1,206,300
Outflow	433,100

STUDY AREA I

1982

Irrigation Season Water Balance

May-September

NOTE: Arrows pointing in show source of water supply to service areas.
Arrows pointing out show location of drainage from service areas.

TABLE 2

STUDY AREA 1

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982
(Acre-Feet)

<u>Surface Water Supply</u>

USBR Tehama-Colusa Canal		158,800
Tehama-Colusa Canal Wildlife Reguge		61,600
Westside Tributary Streams		36,700
Glenn-Colusa Irrigation District		721,700
River Diversions Right Bank		411,600
	Subtotal	1,390,400

<u>Ground Water Pumpage</u>

Private Wells		249,000
	Subtotal	249,000
	Total Supply	1,639,400

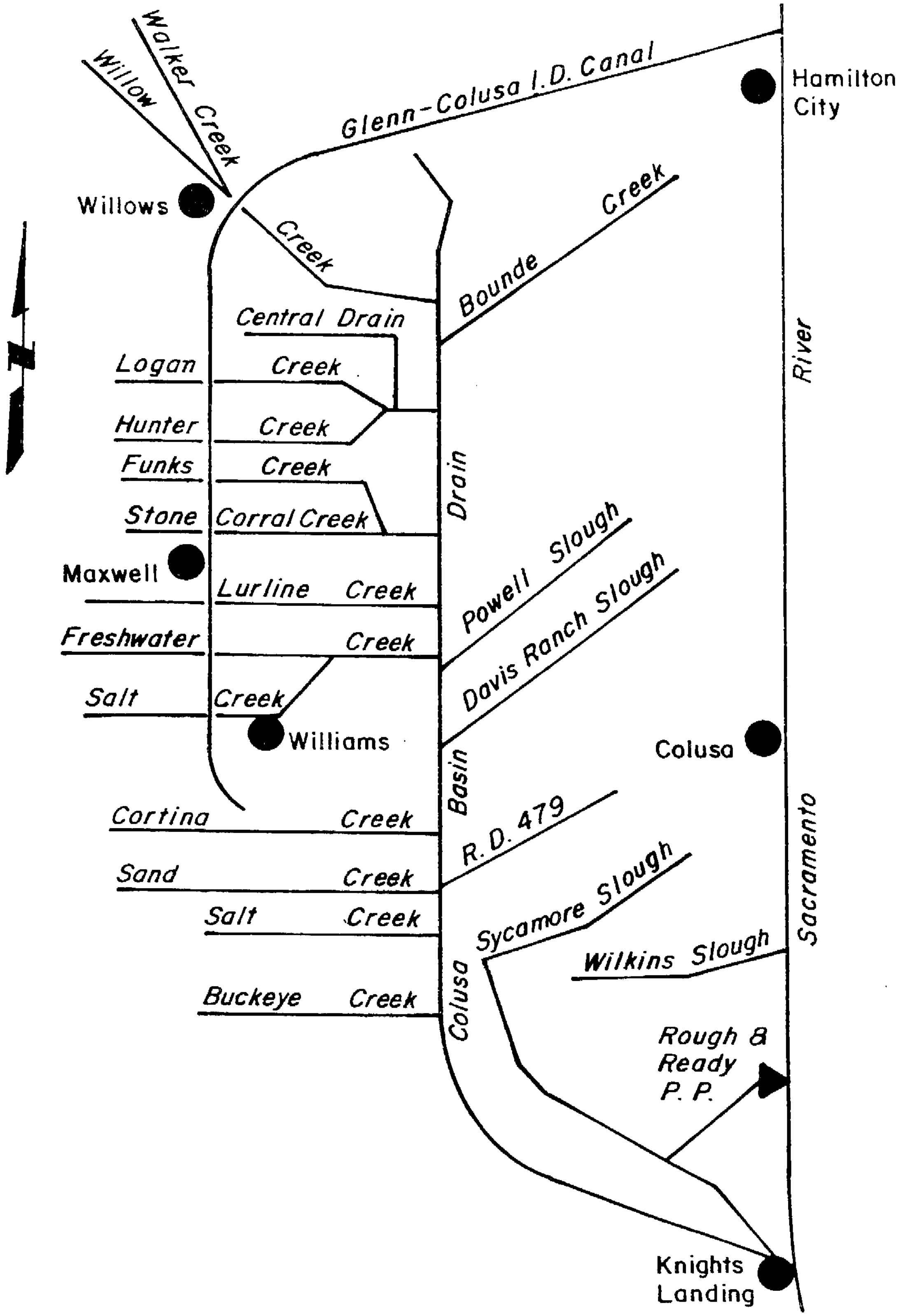
<u>Computed Outflow</u>

Water Supply - ETAW = Outflow
1,639,400 - 1,200,300 = 433,100 (computed)

<u>Measured Outflow</u>

Reclamation District 108		98,200
Colusa Basin Drain		293,500
Reclamation District 787		6,800
Ridge Cut to Yolo Bypass		12,400
	Total	410,900 (measured)

Figure 4



Schematic Diagram of Major Drains

Study Area I

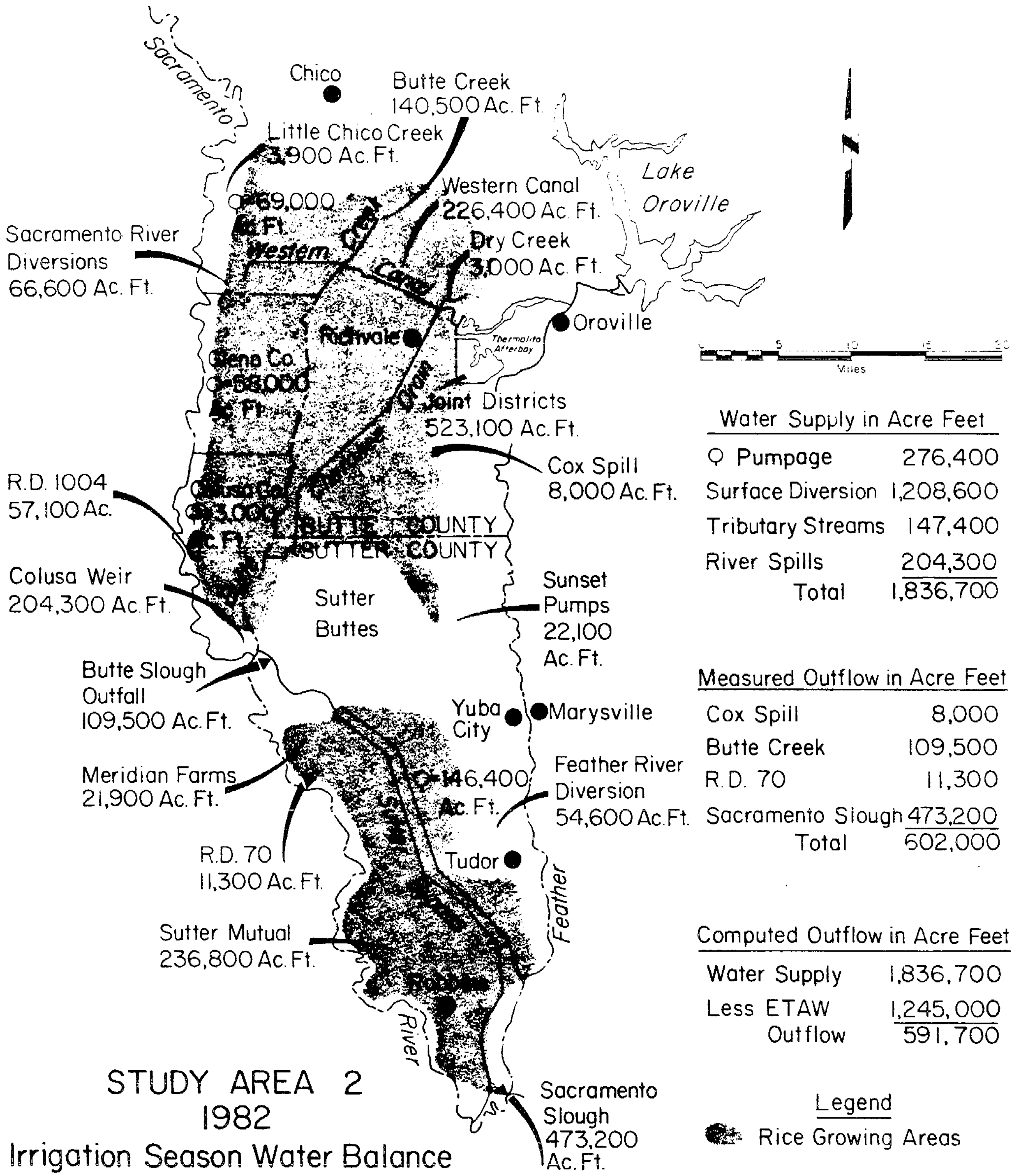
Study Area 2

This area is west of the Feather River and east of the Sacramento. Sutter Buttes is at its center. Yuba City is its principal community, on the eastern border. Of its nearly 485,000 irrigated acres in 1982, 185,000 were rice.

Area 2's water comes from the Sacramento River and the Feather and its tributaries, more than half-a-million acre-feet from the former and about a million from the latter.

The low-lying drainage channels collect water that moves east from east-bank Sacramento River diversions--the drain for this water is Butte Creek and its tributaries--and west from the Feather. This water is also collected by Butte Creek or moves around Sutter Buttes and ultimately to the Sutter Basin Drain. All these waters flow to the Sacramento River near Verona via Sacramento Slough.

There was a very large measured outflow during the critical herbicide-application period in 1982. (The critical period is the part of the growing season when herbicides are heavily used. It varies according to weather and other factors. In 1982, the period was about fifty days from about May 10 to July 5.) The large outflow of 1982 was due partially to floodflows that passed through the area in May and to very large early spring river diversions. These 200,000 acre-feet of outflow represent a very difficult water management problem because of sheer magnitude.



Water Supply in Acre Feet

Pumpage	276,400
Surface Diversion	1,208,600
Tributary Streams	147,400
River Spills	204,300
Total	1,836,700

Measured Outflow in Acre Feet

Cox Spill	8,000
Butte Creek	109,500
R.D. 70	11,300
Sacramento Slough	473,200
Total	602,000

Computed Outflow in Acre Feet

Water Supply	1,836,700
Less ETAW	1,245,000
Outflow	591,700

Legend
Rice Growing Areas

STUDY AREA 2
1982
Irrigation Season Water Balance
May–September

NOTE: Arrows pointing in show source of water supply to service area.
Arrows pointing out show location of drainage from service areas.

TABLE 3

STUDY AREA 2

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982
(Acre-Feet)

Surface Diversions from Feather and Other Tributaries

Little Chico Creek	3,900
Butte Creek	140,500
Dry Creek	3,000
Western Canal	226,400
Joint Water Districts	523,100
Sunset Pumps (JWD)	22,100
Other Feather Diversions	54,600
Total	973,600

Surface Water Diversions from Sacramento River
(May through September 1982)

R.D. 1004	57,100
Colusa Weir Spills (May)	204,300
Meridian Farms	21,900
Sutter Mutual Water Company	236,800
Minor Diversions	66,600
Total	586,700

Ground Water Extraction

Private Wells	276,400
Total Water Supply	1,836,700

Computed Outflow

Water Supply - ETAW = Outflow
1,836,700 - 1,245,000 = 591,700

Measured Outflow

R.D. 70 Spill to Sacramento River	11,300
Butte Slough Outfall to Sacramento River	109,500
Sacramento Slough to Sacramento River	473,200
Cox Spill to Feather River	8,000
Total	602,000

The Impact of Drought on Agricultural Drainage

Table 4 compares outflow at Colusa Basin Drain near Knights Landing for drought year 1977 with 1982. Low out-flow in June and July 1977 suggests that drain flows would be deficient for serving agriculture in southern Colusa or northern Yolo Counties. Noteworthy, however, is that since 1977 the Tehama Colusa Canal has brought an additional 200,000 acre-feet of agricultural supply to the westside Sacramento Valley. This supply should create additional return flows to the Colusa Basin Drain that are not reflected in the 1977 values(5). One might speculate that if a 1977 water year happened with a 1982 or 1984 rice crop pattern, rice herbicide and TDS levels in the drain would be high. This would probably be true valley-wide.

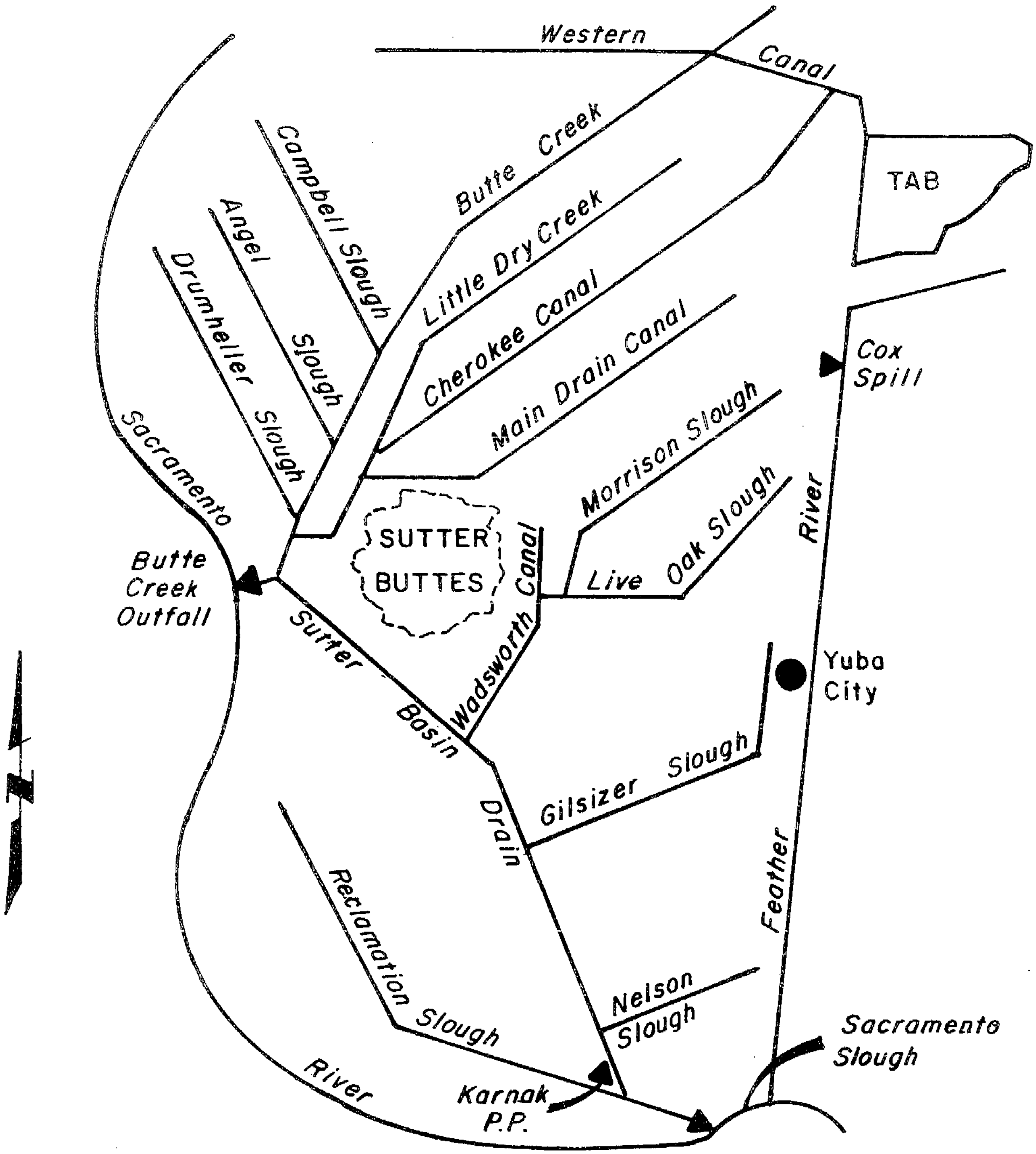
TABLE 4

MONTHLY OUTFLOW
COLUSA BASIN DRAIN AT KNIGHTS LANDING
(Acre-Feet)

Month	Drought Year 1977	Wet Year 1982
May	30,000	18,300 1/
June	80	47,200
July	150	63,500
August	18,700	83,300
September	28,200	83,700
Total	77,130	296,000

1/ No spills entered Sacramento River for the first 13 days in May due to high river stage. The May value represents only the period May 14 through 31.

Figure 6



Schematic Diagram of Major Drains
Study Area 2

Study Area 3

This area is bounded north and west by the Feather River and by the Sierra foothills to the east. Honcut Creek forms the southern border; the area is called Honcut Valley. The City of Oroville is at the north end.

Eighty percent of the water supply is ground water. Nearly 30,000 acre-feet are pumped. Small amounts of surface water are taken from return flows of the Oroville Wyandotte Irrigation District and from Honcut Creek. A little comes from the Feather River. About 11,500 acres are irrigated.

All irrigation drainage flows south through Wyman Ravine or Wyandotte Creek, eventually spilling into Honcut Creek just east of Highway 70. Return flows are not measured but were estimated using the formula: Prime Water Supply - ETAW = Outflow.

TABLE 5

STUDY AREA 3

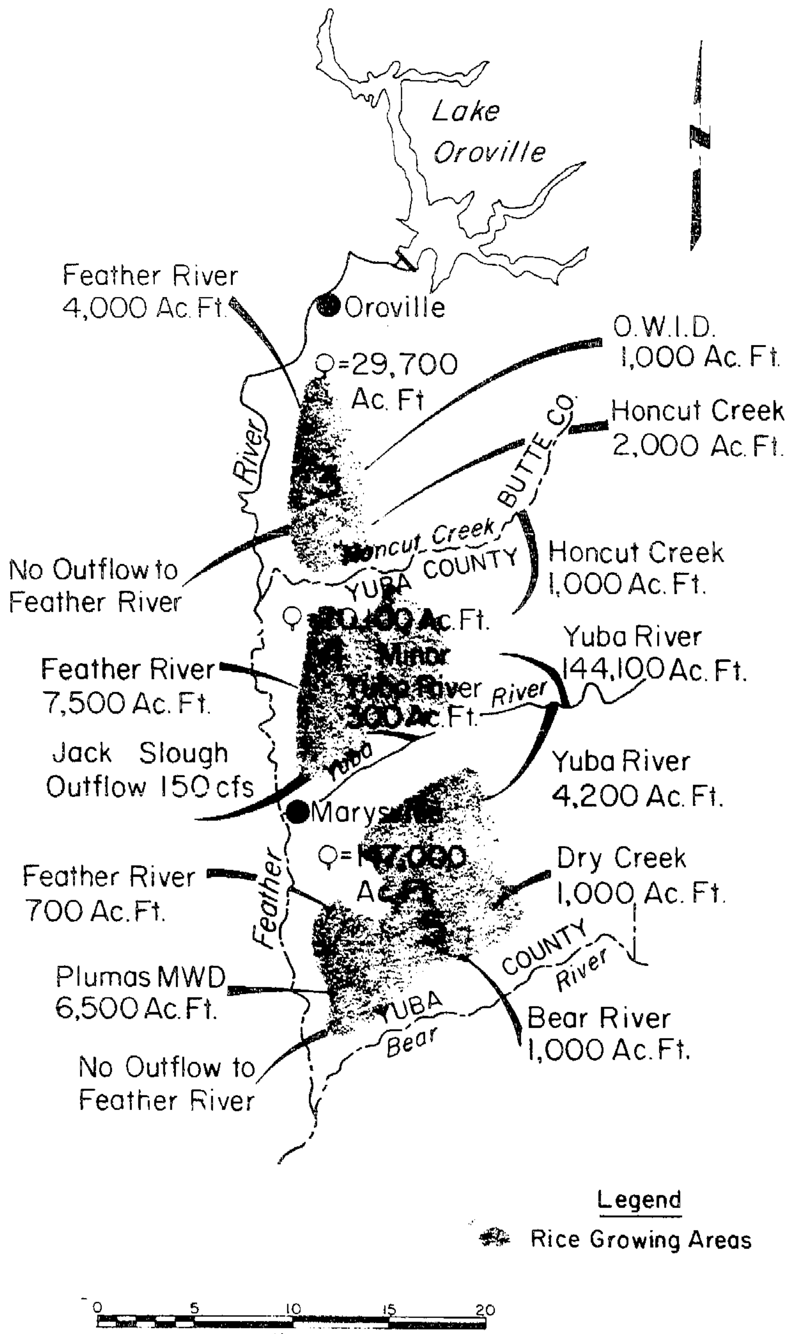
IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982

Prime Water Supply	Acre-Feet
Return Flows from OWID	1,000
Feather River Diversions	4,000
Honcut Creek Diversions	2,000
Ground Water Pumpage	29,700
Total	36,700

Computed Outflow

Prime Supply - ETAW = Outflow, or
36,700 - 33,600 = 3,100 September Outflow

Figure 7



STUDY AREAS 3, 4 and 5
1982
Irrigation Season Water Balance
May-September

Area 3

Water Supply in Acre Feet	
Pumpage	29,700
Return Flow O.W.I.D.	1,000
Honcut Creek	2,000
Feather River	4,000
Total	36,700

Computed Outflow in Acre Feet	
Water Supply	36,700
Less ETAW	33,600
Deep Percolation	3,100

No Summer Outflow

Area 4

Water Supply in Acre Feet	
Pumpage	20,100
Yuba River Diversion	144,100
Yuba River, (Minor)	300
Feather River	7,500
Honcut Creek	1,000
Total	173,000

Computed Outflow in Acre Feet	
Water Supply	173,000
Less ETAW	121,000
Deep Percolation	11,000
Outflow	41,000

Average 150 cfs Outflow at Jack Slough.

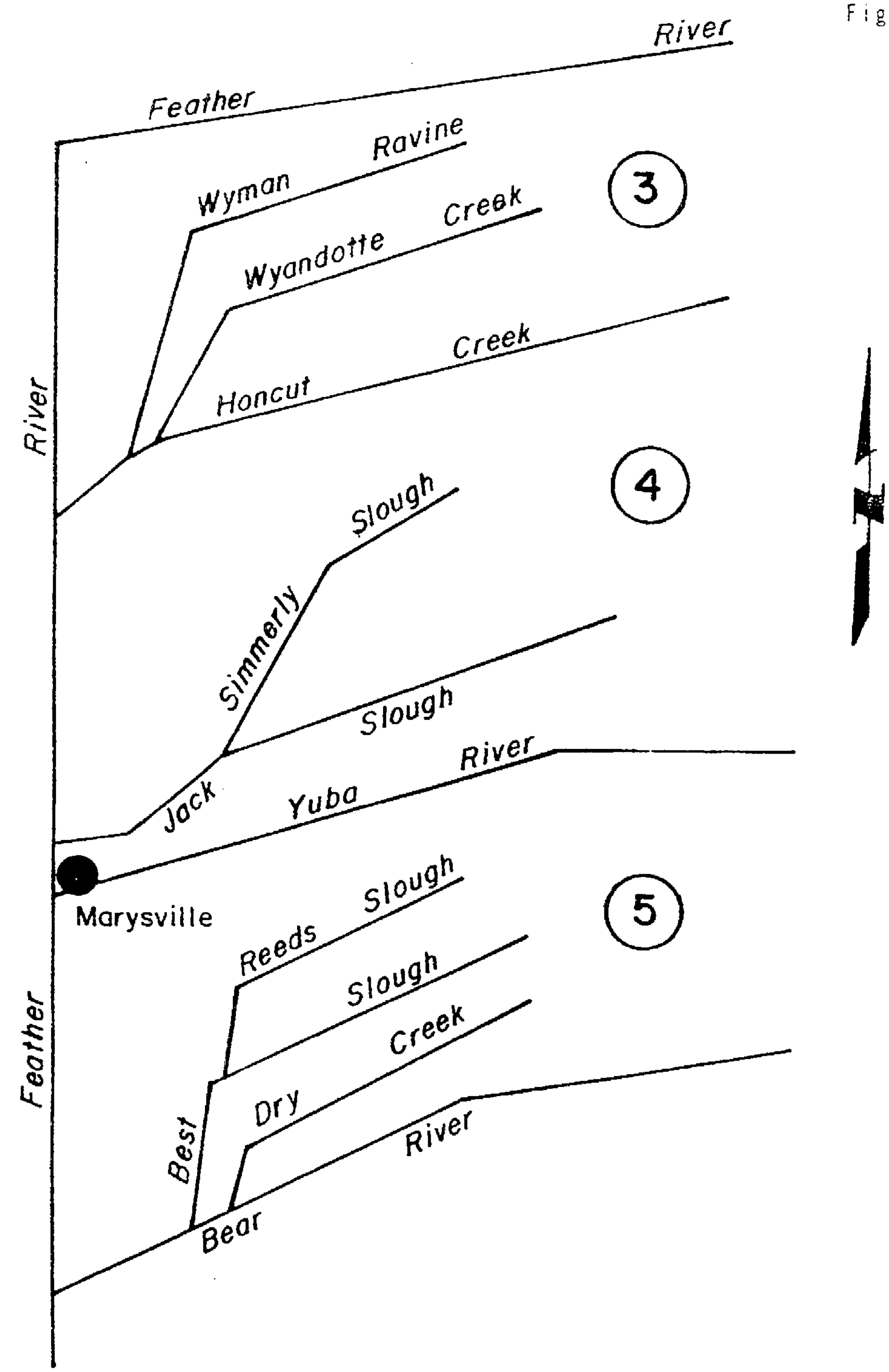
Area 5

Water Supply in Acre Feet	
Pumpage	147,000
Feather River	4,200
Yuba River	700
Plumas MWD	6,500
Dry Creek, Other Tribs.	1,000
Bear River	1,000
Total	160,400

Computed Outflow in Acre Feet	
Water Supply	160,400
Less ETAW	133,400
Deep Percolation	27,000

No Summer Outflow

NOTE: Arrows pointing in show source of water supply to service areas.
Arrows pointing out show location of drainage from service areas.



Schematic Diagram of Major Drains
Study Areas 3, 4 and 5

Study Area 4

This land lies directly south of Area 3, south of Honcut Creek, north of the Yuba River, and east of the Feather. It is entirely within Yuba County. Marysville is at its southwest corner. It has about 43,000 acres of irrigated farmland using nearly 213,000 acre-feet of water.

The main sources for this water are Reclamation District 10, Hallwood Irrigation District, Cordua Irrigation District, and Ramirez Water District. Irrigated water is generally inexpensive.

All irrigation return flow from this area drains via Jack Slough, which is ungaged. The computed outflow is 41,000 acre-feet.

TABLE 6

STUDY AREA 4

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982

Prime Water Supply	Acre-Feet
Yuba River Diversion	144,100
Feather River Diversion	7,500
Honcut Creek Left Bank	1,000
Minor Yuba	300
Ground Water Pumpage	20,100
Total	173,000

Computed Outflow

Prime Supply - (ETAW + Deep Percolation) = Outflow
173,000 - (121,000 + 11,000 1/) = 41,000 Computed Outflow
41,000 AF - 2   150 cfs Average Outflow at Jack Slough
138 days

1/ Estimated at 0.5 foot per acre of crops other than rice

Study Area 5

This is south of Area 4, bounded by the Yuba, Feather, and Bear rivers on the north, west, and south and the Sierra foothills on the east. Wheatland is at the southeast edge. Less than a fifth of its 51,000 irrigated acres is planted in rice.

The Plumas Mutual, Wheatland, and Brophy Water Districts are the principal water suppliers of surface water in the area. Most irrigation is done with ground water, expensive because of pumping costs.

Irrigation water is tightly managed, and there is little outflow during the rice-growing season. At the edge of the area, Plumas Mutual Water District runs several pumping stations that help drain the area and adjacent lands in winter. This discharge has no implications for this study. Any summer discharge must leave via Best Slough to the Bear River near Highway 70.

TABLE 7

STUDY AREA 5

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982

Prime Water Supply	Acre-Feet
Pumpage	147,000
Minor Feather River	700
Minor Yuba River	4,200
Plumas Municipal Water District	6,500
Dry Creek, Other Tributaries	1,000
Bear River	1,000
Total	160,400

Prime Supply - (ETAW) + Deep Percolation1/ = Outflow
160,400 - (133,400 + 27,000) = 0

No summer outflow

1/ Assumed difference was due to percolation on coarse alluvial soils along Feather River since no outflow was observed.

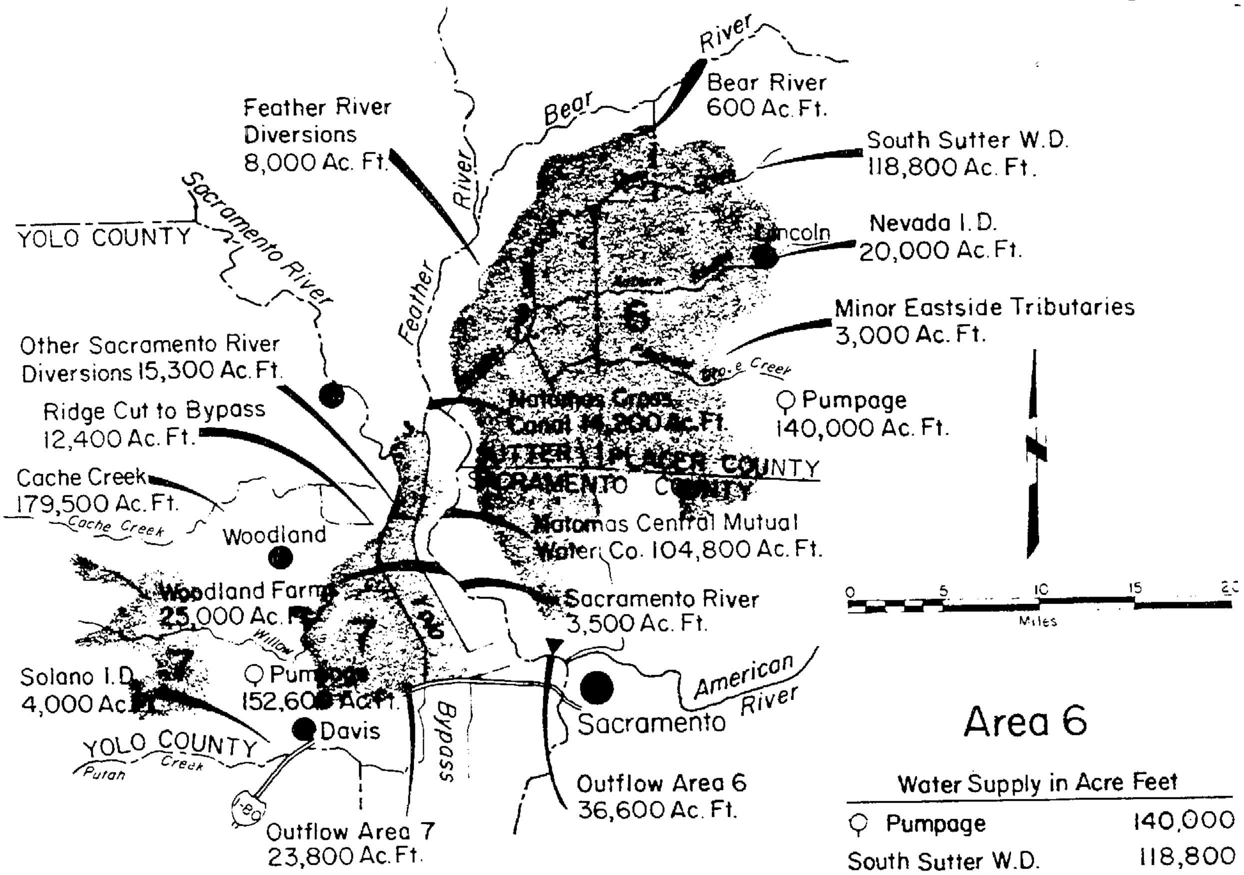
Study Area 6

This is east of the Sacramento and Feather Rivers between the Bear River on the north and the American on the south. It is bounded on the east by Highway 99E. It has parts of Sacramento, Placer, and Sutter Counties. In 1982 about 60,000 acres, some 40 percent of the area, were planted to rice.

Water comes from Camp Far West Reservoir via the South Sutter Water District conveyance system, from ground water and diversions from the Sacramento and Feather Rivers. The Nevada Irrigation District provides some surface water. Farmers also pick up small quantities of inexpensive return flow in Auburn Ravine, Coon, and Pleasant Grove Creeks, flowing from the eastern foothills. The Natomas Central Mutual Water Company is typical of the agricultural operation in Area 6 in that a great deal of reuse of drainage water is practiced in order to meet irrigation needs. Area water use efficiency is very high.

Only about 37,000 acre-feet leave the area during the May-through-September growing season. The main outflow is through a bank of pumps operated by RD 1000, a few miles upstream from the mouth of the American River. Outflow measured at these pumps was 34,000 acre-feet during 1982. (Computed by the land-use method for 1982, it was 29,700 acre-feet.)

Minor amounts of drain return flow are dumped into the American River in North Sacramento. Little of this is agricultural return flow; most of it comes from urban areas.



Area 6

Water Supply in Acre Feet	
♀ Pumpage	140,000
South Sutter W.D.	118,800
Nevada I.D.	20,000
Bear River	600
Feather River	8,000
Sacramento River	3,500
Natomas Cross Canal	14,200
Natomas Central Mutual Water Company	104,800
Minor Eastside Tribs.	3,000
Total	412,900

Measured Outflow in Acre Feet	
R.D. 1000	36,600

Computed Outflow in Acre Feet	
Water Supply	412,900
Less ETAW	383,200
Outfow	29,700

Area 7

Water Supply in Acre Feet	
♀ Pumpage	152,600
Cache Creek	179,500
Solano I.D. to U.C. Davis	4,000
Ridge Cut to Bypass	12,400
Woodland Farms	25,000
Other Sacramento River Diversions	15,300
Total	388,800

Computed Outflow in Acre Feet	
Water Supply	388,800
Less ETAW	365,000
Outflow	23,800

Legend

Rice Growing Areas

STUDY AREAS 6 and 7
1982
Irrigation Season Water Balance
May-September

NOTE: Arrows pointing in show source of water supply to service areas
Arrows pointing out show location of drainage from service areas.

TABLE 8

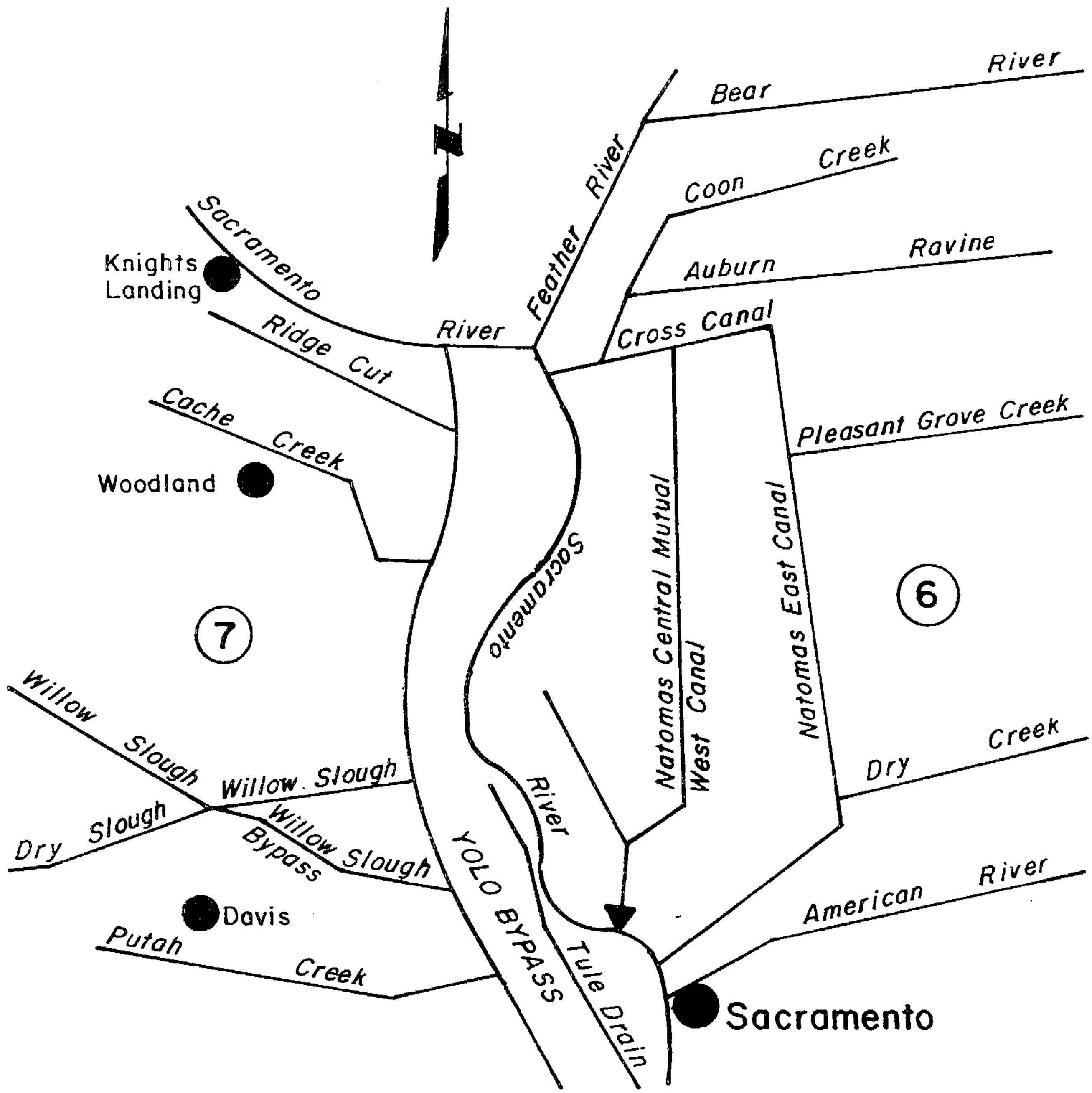
STUDY AREA 6

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982
(Acre-Feet)

Surface Water Supply	Acre-Feet
South Sutter Water District (from Bear River)	118,800
Auburn Ravine (from NID)	20,000
Bear River - left bank	600
Feather River - left bank	8,000
Sacramento River - left bank	3,500
Natomas Cross Canal (from Feather)	14,200
Natomas Central Mutual Water Company	104,800
Minor streams (Coon Creek, etc.)	3,000
Total Surface	272,900
Ground Water Pumpage	
Private Wells	140,000
Total Water Supply	412,900

Computed Outflow

Water Supply - ETAW = Outflow
412,900 - 383,200 = 29,700



Schematic Diagram of Major Drains
Study Areas 6 and 7

Study Area 7

This is within Yolo County. Its northern boundary is the drainage boundary of the Colusa Basin Drain. It is bounded on the south by Putah Creek and Interstate 80, on the east by the Sacramento River, and by the dry land beyond the reach of irrigation on the west.

The largest source of water to Area 7 is from Clear Lake and Indian Valley Reservoir via Cache Creek and Capay Valley. The Yolo County Flood Control and Water Conservation District is the major purveyor, delivering nearly 180,000 acre-feet for irrigation in 1982. Additional surface water comes from the Colusa Basin Drain via the Knights Landing Ridge Cut and right bank Sacramento diversions, and about 4,000 acre-feet per year are delivered to the University of California in Davis by the Solano Irrigation District. This water comes from Lake Berryessa via Putah Creek.

Ground water pumpage for Area 7 was estimated by the land use method. The 1981 land use survey for Yolo County included identification of crops by water source. It amounted to about 153,000 acre-feet.

This area is very water-efficient. Of its prime water supply of nearly 400,000 acre-feet, only about 25,000 acre-feet left the area during the growing season. This exited to the Delta by way of the Yolo Bypass.

During the 1984 rice irrigation season the Conway Ranch petitioned the Regional Water Quality Control Board and the Department of Fish and Game to allow recycling of rice irrigation spills, and the entire ranch was allowed to operate as a closed system. Managers were able to dump paddy water during the eight-day herbicide holding period without violating existing statutes.

Area 7 is somewhat water-short and has traditionally done much recycling of drain flows to meet applied water demands. Recycling of rice water is usually attempted when prime water supplies have been exhausted and no other supply except possibly expensive ground water is available. Over nearly all of the Sacramento Valley, gravity-fed surface supplies to rice growing areas are much less expensive for farmers to use than any other source. For these and other reasons recapture and recycling of prime supplies for water conservation or to prevent herbicide spill have not been popular.

TABLE 9

STUDY AREA 7

IRRIGATION SEASON WATER BALANCE
MAY-SEPTEMBER 1982
(Acre-Feet)

Surface Water Supply	Acre-Feet
Cache Creek	179,500
Solano Irrigation District to UCD	4,000
Ridge Cut to Yolo Bypass	12,400
Woodland Farms	25,000
Other - right bank Sacramento River	15,300
Subtotal	236,200
Ground Water Pumpage	
Private Wells	152,600
Subtotal	152,600
Total Water Supply	388,800

Computed Outflow

Water Supply - ETAW = Outflow
388,800 - 365,000 = 23,800 AF (May-September)

TABLE 10

SACRAMENTO VALLEY IRRIGATION SEASON WATER BALANCE SUMMARY
MAY-SEPTEMBER 1982
(Acre-Feet)

	Study Areas								
	1	2	3	4	5	6	7	Total	Percent of Prime Supply
Ground Water Pumpage	249,000	276,400	29,700	20,100	147,000	140,000	152,600	1,014,800	22
Surface Water	1,390,400	1,560,300	7,000	152,900	13,400	272,900	236,200	3,633,100	78
Total Supply	1,639,400	1,836,700	36,700	173,000	160,400	412,900	388,800	4,647,900	100
Less ETAW	1,206,300	1,245,000	33,600	121,000	133,400	383,200	365,000	3,487,500	75
Less Deep Percolation	0	0	3,100	11,000	27,000	0	0	41,100	1
Predicted Outflow	433,100	591,700	0	41,000	0	29,700	23,800	1,119,300	24
Measured Outflow	410,900	602,000	Not Measured	Not Measured	Not Measured	34,000	Not Measured	--	--

PART THREE

COMPARISON OF IRRIGATION METHODS

PART THREE

COMPARISON OF IRRIGATION METHODS

This third part of this report compares the main rice irrigation methods in the Sacramento Valley. There are three, one far more common than the others. (See Table 11, page 36.)

The Prevailing Practice--and we will label it that--uses more water than the others to irrigate rice paddies. This method is preferred by about seventy percent of the rice growers in the valley because it is generally cheaper than the others.

Area Recycling is a capital-intensive method of irrigation that recycles the same water on the farm or among cooperating farms, not returning it to drains and rivers until fields are drained for harvest. This method offers the best chance for controlling water quality, but farmers object to the high cost of adapting farms to a closed system--expensive grading, irrigation canals, pumping equipment[6]. Above all, the method needs large sumps to store water when paddy levels must be lowered during the growing season. Excavating these is expensive and ties up land that might otherwise be productive.

Before expanding our discussion of these three irrigation methods, a brief note on terms to head off confusion: Area Recycling is also called "drainage recycling"--the terms are interchangeable. "Drainage recapture", or "relifting" water is not an irrigation method; it is simply a way to stretch water supplies by pumping from drains back into irrigation canals and reusing the water. It is done when the distribution system cannot bring water to the user in the quantities needed.

Low Applied Water involves closer monitoring of weather and daily growing cycles so that no more water is applied to paddies than necessary to produce the crop. About twenty percent of the valley rice growers are using low applied water, but opinions differ on how much run-through water is needed to best promote the healthy growth of the crop. There are off-farm implications of reduced water use that we will discuss.

Table 11

COMPARISON OF RICE IRRIGATION PRACTICES

	PREVAILING PRACTICE 6- or 8-day herbicide holding period, then generous spill, balance of season.	AREA RECYCLING Some within-area paddy spill during herbicide period, but no spill beyond area.	LOW APPLIED WATER 6- or 8-day herbicide holding period, then no spill during balance of season.
Estimated acres now under this practice.	355,000 (70%)	45,000 (10%)	95,000 (20%)
Effects of different practices on:			
Water Charges	No Change (Usually flat rate)	Significant saving if water is expensive. (i.e. ground water)	Significant saving if water is expensive. (i.e. ground water)
Labor Requirements	No Change	Increased labor.	Increased labor.
Energy Use	No Change	Substantial increase.	Could reduce district costs for relifting.
New Equipment	No Change	Purchase, install, maintain relift pumps, other hardware.	No Change
Water Consumption	No Change	Could save expensive water.	Could save expensive water.
Flows in Drains	Maintain flows for fish, wildlife and riparian vegetation.	Eliminates fish and wildlife flows, reduced riparian vegetation.	Eliminates or reduces fish and wildlife flows, reduces riparian vegetation.
Downstream Water Supply to Other Users	No Change	Could be eliminated.	Could be eliminated or greatly reduced.
Instream Use	No Change	Could increase flows in Sacramento and Feather Rivers.	Could increase flows in Sacramento and Feather Rivers.
Drain Water Quality			
Turbidity	Same - currently high.	Reduced due to low flows in drains.	Reduced due to lower flows in drains.
Temperature	No Change	Increased in drains.	Increased in drains.
TDS	No Change	Could be lower in drains.	Could be lower in drains.
Nutrients	No Change	Reduced	Reduced
Sacramento River Water Quality	No Change	Reduced turbidity could increase algae in river and Delta.	Reduced turbidity could increase algae in river and Delta.

Prevailing Practice

With the commonest form of rice irrigation, water is applied to fields from around April 15 to May 1, followed by aerial seeding. About the tenth day after seeding, water levels are lowered by spilling water to the drains, and herbicides for the control of water grass are aerially applied. After the holding period, water is spilled to the drains to get rid of the remaining herbicide. Then, about 25 days after seeding, paddy water levels are again lowered to apply broadleaf herbicide, if needed. After the no-spill holding period, water levels are raised and remain generally high for the rest of the season. Spills are common, though. High winds can generate waves that wash over the paddy checks, and levels are often lowered when applying other substances.

This liberal spill custom is beneficial to fish and wildlife because it creates the drainflow necessary for their survival. Higher flows assure sufficient water to downstream users. Turbidity, however, may be higher in the main drains and thus in the Sacramento River.

Current liberal water rights and inexpensive water tend to favor the Prevailing Practice. There is no reason to suppose that farmers will shift to more water-efficient irrigation methods if they increase production costs.

Area Recycling

On-farm or Area Recycling is the only system that permits farmers to disregard herbicide holding times, because spilled water is collected in ditches or sumps and pumped back onto fields. With this system, used where water is scarce or where local regulations require it, water is replenished only as it is used by evapotranspiration or percolation, and irrigation water is not allowed to finally flow back to river sources until harvest time.

In addition to permitting the farmer to drain fields at will because the water is held on-farm or within the closed system of the cooperating farms, area recycling keeps applied chemicals on the paddies or in the recycling system. They are not spilled to drains and rivers where they cannot do their work of nourishing crops or controlling pests. The system has the potential for the strictest water quality management of any of the irrigation methods.

The drawbacks to Area Recycling can be considerable, however. Preparing a farm or the cooperating farms for closed recycling is costly. Ditches, traps, or sumps big enough to hold large volumes of water must be dug, and pumps and pipes to return the collected water to fields must be bought and installed. The system needs more hands-on management than any other, and labor costs reflect this.

Obviously, where fish and wildlife habitat now flourishes in and around well-watered drains, this would be disastrously changed if entire areas converted to Area Recycling.

Low Applied Water

This method of irrigation relies on close observation to minimize spill to drains. Inflow to paddies is adjusted according to crop needs. As with the Prevailing Practice, water is lowered after seeding to apply herbicides and the treated water held the required time. For the rest of the season, however, when typical rice paddies spill irrigation water freely at night and in cool weather when evapotranspiration is down, farmers using Low Applied Water cut down on inflow and permit the water level to drop slightly, on a warm summer day, and recover at night. Flows are adjusted so that spill is reduced to a fraction of the usual volume.

Low Applied Water offers a reduction in volume of water diverted for rice irrigation. It needs no special equipment and uses no pumping energy. It may save dollars by keeping applied plant nutrients and pest control materials on-farm longer. Despite opinions to the contrary, low water-use seems to have no bad effect on health or growth-rate of the crop (see box).

To the individual farmer, there are several possible drawbacks to using the Low Applied Water method of irrigation. The added man-hours for adjusting gates and weirs and simply checking the water circulation represent added bother or expense. Occasionally farmers use ground applications instead of aerial application of agricultural chemicals. Water movement needed to disperse these, and the reduced flows from Low Applied Water would probably be insufficient. Farmers in some areas rely heavily on drain flow for their irrigation water. If the Low Applied Water method were widely adopted, drain flows would drop, and this arrangement would be disrupted. Not only would drain flows drop, but the quality of the water would probably decline and with it the populations of wildlife that thrive along these quiet waterways.

A Low Applied Water Study

The Department of Water Resources studied low application of water on rice in 1981, 1982, and 1983 at the Wylie Ranch in Southern Glenn County(7). The study showed that the cumulative depths of applied water for the rice test plots averaged 5.8 feet, 4.4 feet, and 4.4 feet, respectively, for those three years. These figures contrasted with valley-wide averages of more than 7 feet per acre.

Strictly speaking, no water was "saved". The same amount of water was consumed by evapotranspiration and by percolation of Wylie's Ranch as at his neighbors', but 2 feet less per acre of rice were diverted from the Sacramento River, run through Wylie's rice fields, and then returned, with water quality reduced and temperature raised, to the river.

Preliminary data from this research are published in the Northern District report "Low Applied Water on Rice", 1982.

Some 46,000 acres of rice, less than 10 percent of the total acreage, was irrigated by ground water in 1984. Most of this was on farms that practiced no-spill irrigation because of the high energy cost associated with pumped water. These farms that use ground water must be considered a sub-group of the Low Applied Water farms, because careful water management is characteristic of all of these.

REFERENCES

1. Brunetti, Kathy. "Reducing Off-Site Movement of Molinate and Thiobencarb from California Rice Fields". State Department of Food and Agriculture, September 1984.

2. Scardaci, Steve. Personal Communication, May 1984.

3. Wick, Carl. Personal Communication, May 1984.

4. Finlayson, Brian. State Department of Fish and Game, Personal Communication, January 20, 1984.

5. State Department of Water Resources. Bulletin 184, "Ten Counties Investigation", December 1971.

6. Carlson, Warren. Glenn-Colusa Irrigation District, Personal Communication, August 1984.

7. State Department of Water Resources, Northern District. "Low Applied Water on Rice", April 1982.

APPENDICES

APPENDIX A

STUDY PROPOSAL TO THE REGIONAL WATER QUALITY CONTROL BOARD CENTRAL VALLEY REGION

SUBJECT: Recycling of Drainage from Rice Irrigation

STUDY OBJECTIVE: To Evaluate the Impacts of Drainage Recycling on Prime Sacramento Valley Water Supplies and Farm Income

Discussion

Off-site movement of farm pesticides and nutrients from rice production in the Sacramento Valley has caused concern because of the impact of these substances on aquatic life (mainly fish), on the taste of drinking water and on the appearance, mainly in regard to turbidity, of prime valley water supplies. Recycling irrigation waste water could reduce or eliminate the off-site movement of agricultural chemicals.

During the 1984 growing season, only 44,000 acres of 495,000 acres in the Sacramento Valley that are planted to rice were irrigated using on-farm recycling systems. Little is known about the impacts of recycling systems on the valley water regime or their effects on farm income.

Proposal

The contractor will examine for two irrigation seasons the financial feasibility and environmental impact of on-farm or in-area recycling of excess applied irrigation water on rice fields in the Sacramento Valley. The contractor will work with the Sacramento Valley Water Quality Advisory Committee. The contractor will evaluate costs of plumbing, maintenance, and operation (particularly energy costs) to see how these affect farm income. The contractor will study the impacts of recycling on downstream drain flows and water quality in those drains. The contractor will assess how reductions in downstream flow may create institutional and water rights problems.

Work Outline

The contractor proposes to begin work in January 1985 and end in December 1986. Field observations from two irrigation seasons would provide data for a draft report to be prepared by October 1986, with a final report due December 31, 1986.

The contractor will establish several test paddies where water-recycling systems will be tested for effects on water quality. These paddies will be compared with areas where no recycling or other flow-reducing measures are used (the current prevailing practice in the Sacramento Valley). Water sampling for herbicides will be done valley-wide during the summer of 1985. Sampling and testing for turbidity, electrical conductivity, and dissolved oxygen levels will be made by the Department of Water Resources, Northern District.

The contractor will evaluate the impact of large-scale recycling on water qualilty and drain flows by applying data collected at the test paddies to the entire rice-growing region in the Sacramento Valley.

Manpower Requirements

	Person Months	$	Charge
Senior Land and Water Use Analyst	3.0	7,000	$ 21,000
Senior Economist	3.0	7,000	21,000
Agricultural Engineering Consultant	2.5	4,000	10,000
Environmental Specialists	3.0	5,700	17,000
Graduate Student	6.0	1,500	9,000
Research Writer	1.0	5,000	5,000
Drafting Services	1.0	4,000	4,000
Typing	1.0	3,000	3,000
Lab Costs, Northern District	-	-	10,000
		Total Contract	$100,000

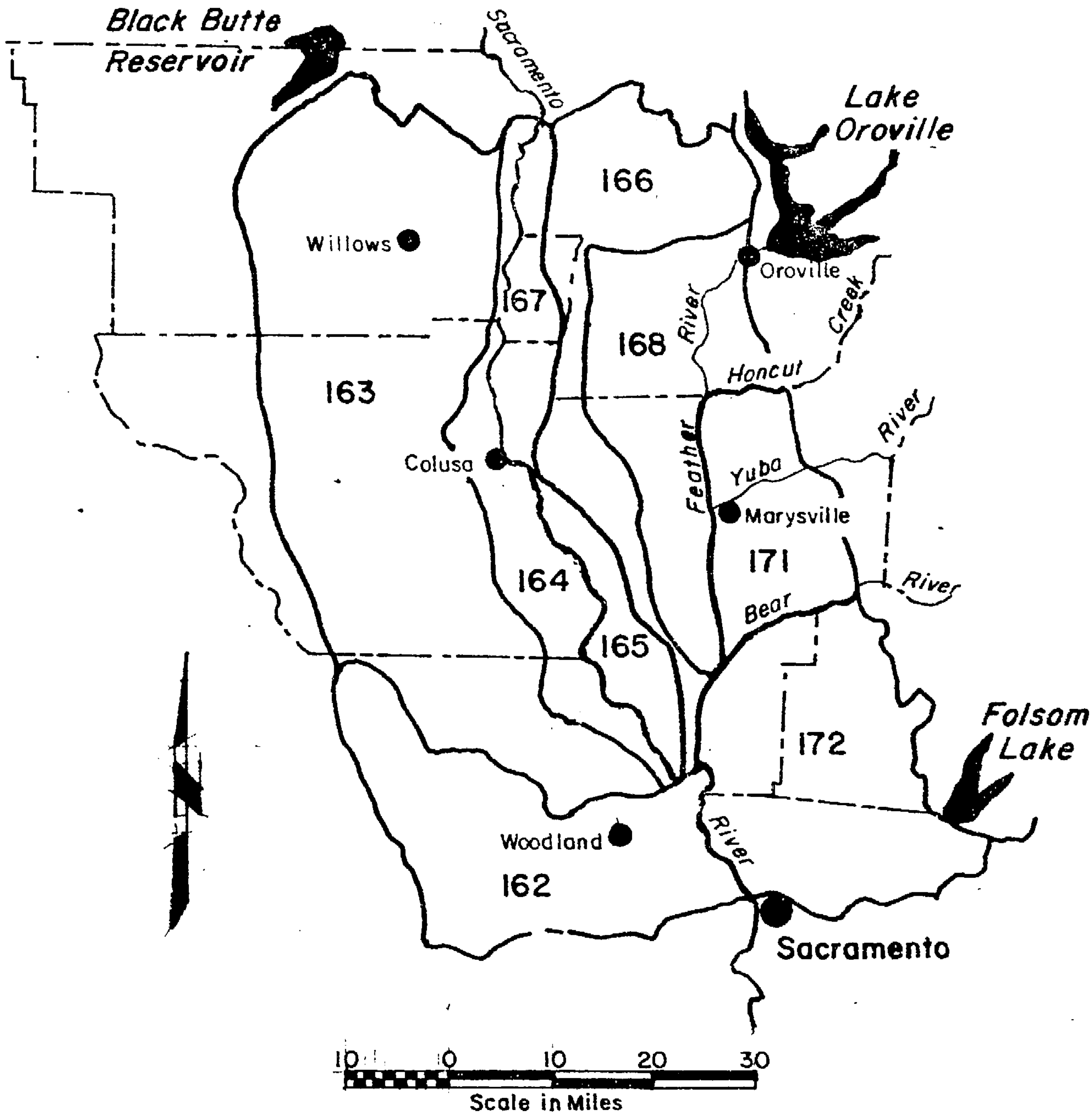
APPENDIX B

LAND AND WATER USE

Appendix B tabulates land use according to number of acres of each crop grown. Acreage is given for the crop, then the acre-feet of water used through evapotranspiration of applied water (ETAW), then the amount of applied water (AW). These calculations are made for irrigation from surface water supplies, from ground water, and from mixed sources. The sums of these are then tabulated. Ground water pumpage was calculated by the land-use method, that is, by using the known average irrigation figures for each given crop. Applied ground water was assumed to be equal to gross pumpage.

ETAW and AW figures from Bulletin 113-3, "Vegetative Water Use in California, 1974", are shown on page 93.

The index map overleaf shows the location of the Department's Detailed Analysis Units (DAU's) that compose the Sacramento Valley floor.



Detailed Analysis Units
Sacramento Valley
Rice Irrigation Hydrology Study

Study Area 1

DAU's 163 and 164

Summary of DAU 163 County Glenn County

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	11,800	7,080	10,620	14,600	8,760	11,680	6,600	3,960	3,170	33,000	19,800	25,470
Rice	67,560	229,700	574,260	1,840	6,260	11,040	1,400	4,760	10,080	70,800	240,720	595,680
Sugar Beets	1,590	3,500	6,360	1,620	3,560	4,700	290	640	1,000	3,500	7,700	12,060
Corn	6,750	11,480	20,930	4,600	7,820	10,580	1,950	3,320	5,270	13,300	22,620	36,780
Other Field	7,060	12,000	21,890	3,940	6,700	9,060	2,300	3,910	6,210	13,300	22,610	37,160
Alfalfa	4,260	12,350	24,710	6,300	18,270	25.830	2,440	7,080	12,200	13,000	37,700	62,740
Pasture	7,380	24,350	48,710	1,950	6,440	9,170	2,570	8,480	14,650	11,900	39,270	72,530
Tomatoes	90	180	240	10	20	30	0	-	-	100	200	270
Other Truck	70	90	150	0	-	-	30	40	60	100	130	210
Almonds	1,840	3,310	4,780	940	1,700	2,260	1,720	3,100	4,300	4,500	8,110	11,340
Other Deciduous	1,740	4,520	6,440	260	680	880	800	2,080	2,800	2,800	7,280	10,120
Subtropical	390	660	1,090	40	70	90	570	970	1,430	1,000	1,700	2,610
Grapes	0	-	-	640	1,280	1,730	760	1,520	2,200	1,400	2,800	3,930
Double Crop Grain	(3,610)	-	-	(2,350)	-	-	(1,840)	-	-	(7,800)	-	-
Total	110,230	309,220	721,180	36,740	61,560	87,050	21,430	39,860	63,370	168,900	410,640	870,900

Ground Water = 87.050 + 40% of 63,370 = 112,400

Summary of Colusa County DAU 163

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	15,600	9,360	14,040	4,040	2,430	3,240	-	-	-	19,640	11,790	17,280
Rice	94,630	321,740	643,470	-	-	-	-	-	-	94,630	321,740	643,470
Sugar Beets	-	-	-	-	-	-	-	-	-	-	-	-
Corn	-	-	-	-	-	-	-	-	-	-	-	-
Other Field	14,670	26,400	41,070	2,380	4,280	5,470	-	-	-	17,050	30,680	46,540
Alfalfa	3,100	9,310	16,450	710	2,140	2,930	-	-	-	3,810	11,450	19,380
Pasture	2,760	9,120	16,580	170	540	780	-	-	-	2,930	9,660	17,360
Tomatoes	-	-	-	-	-	-	-	-	-			
Other Truck	13,600	21,770	36,730	1,870	3,000	4,300	-	-	-	15,470	24,770	41,030
Almonds												
Other Deciduous	3,250	7,460	11,030	14,810	34,050	38,490	-	-	-	18,060	41,510	49,520
Subtropical	-	-	-	-	-	-	-	-	-	-	-	-
Grapes	-	-	-	-	-	-	-	-	-	-	-	-
Total	147,610	405,160	779,370	23,980	46,440	55,210				171,590	451,600	834,580

Summary of Yolo County DAU 163

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	6,970	4,180	6,270	10,690	6,410	8,550	-	-	-	17,660	10,590	14,820
Rice	5.590	19,000	38,000	-	-	-	-	-	-	5,590	19,000	38,000
Sugar Beets												
Corn												
Other Field	4,190	7,540	11,740	3,120	5,610	7,170	-	-	-	7,310	13,150	18,910
Alfalfa	4,940	14,830	26,190	1,930	5,780	7,900	-	-	-	6,870	20,610	34,090
Pasture	490	1,610	2,920	1,560	5,140	7,320	-	-	-	2,050	6,750	10,240
Tomatoes												
Other Truck	3,630	5,810	9,800	9,690	15,510	22,300	-	-	-	13,320	21,320	32,100
Almonds												
Other Deciduous	1,510	3,460	5,120	2,100	4,820	5,450	-	-	-	3,610	8,280	10,570
Subtropical	-	-	-	10	20	20	-	-	-	10	20	20
Grapes	180	360	550	10	20	20	-	-	-	190	380	570
Total	27,500	56,790	100,590	29,110	43,310	58,730				56,610	100,100	159,320

Summary of DAU 164 County Glenn County

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	360	220	320	840	500	670	0	-	-	1,200	720	990
Rice	200	680	1,700	0	-	-	0	-	-	200	680	1,700
Sugar Beets	0	-	-	300	660	870	0	-	-	300	660	870
Corn	0	-	-	200	340	460	0	-	-	200	340	460
Other Field	0	-	-	900	1,530	2,070	1,000	1,700	2,700	1,900	3,230	4,770
Alfalfa	0	-	-	100	290	410	0	-	-	100	290	410
Pasture	100	330	660	0	-	-	0	-	-	100	330	660
Tomatoes	0	-	-	0	-	-	0	-	-	0	-	-
Other Truck	0	-	-	200	260	360	0	-	-	200	260	360
Almonds	780	1,400	2,030	1,120	2,020	2,690	0	-	-	1,900	3,420	4,720
Other Deciduous	730	1,900	2,700	2,790	7,250	9,490	280	730	980	3,800	9,880	13,170
Subtropical	0	-	-	0	-	-	0	-	-	0	-	-
Grapes	100	200	330	0	-	-	0	-	-	100	200	330
Double Crop Grain	(80)			(280)						(360)	-	-
Total	2,270	4,730	7,740	6,450	12,850	17,020	1,280	2,430	3,680	10,000	20,010	28,440

Ground Water = 17,020 + 40% of 3,680 = 18,500

Summary of Colusa County DAU 164

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	24,660	14,800	22,190	520	310	420				25,180	15,110	22,610
Rice	33,960	115,470	230,940							33,960	115,470	230,940
Sugar Beets												
Corn												
Other Field	16,560	29,810	46,380							16,560	29,810	46,380
Alfalfa	2,370	7,110	12,560							2,370	7,110	12,560
Pasture	900	2,960	5,380							900	2,960	5,380
Tomatoes												
Other Truck	7,480	11,970	20,200	230	370	530				7,710	12,340	20,730
Almonds												
Other Deciduous	4,830	11,110	16,420	710	1,630	1,840				5,540	12,740	18,260
Subtropical												
Grapes												
Total	90,760	193,230	354,070	1,460	2,310	2,790				92,220	195,540	356,860

Summary of Yolo County DAU 164

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	6,460	3,870	5,810							6,460	3,870	5,810
Rice	13,330	45,330	90,660							13,330	45,330	90,660
Sugar Beets												
Corn												
Other Field	5,450	9,810	15,270	310	550	710				5,760	10,360	15,980
Alfalfa	1,060	3,180	5,610							1,060	3,180	5,610
Pasture				20	60	90				20	60	90
Tomatoes												
Other Truck	4,090	6,550	11,050	180	290	420				4,270	6,840	11,470
Almonds												
Other Deciduous	870	1,990	2,940							870	1,990	2,940
Subtropical												
Grapes												
Total	31,260	70,730	131,340	510	900	1,220				31,770	71,630	132,560

Study Area 2

DAU's 165, 166, 167 and 168

STUDY AREA 2 - SUMMARY
CROP ACRES AND WATER USE
(Acres and Acre-feet)

Crop	Surface Water			Ground Water			Total		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Rice	182,000	618,800	1,237,600	3,000	12,750	18,000	185,000	631,550	1,255,600
Other 1/	203,630	362,560	575,220	95,880	190,730	255,560	299,510	553,290	830,780
Total	385,630	981,360	1,812,820	98,880	203,480	273,560 2/	484,510	1,184,840	2,086,380

1/ Includes all irrigated crops other than rice. ETAW and AW unit values developed by weighting individual DAU data from each of the counties involved.

2/ On the basis of local information, ground water pumping in DAU 167, Colusa County was increased by approximately 3,000 acre-feet.

Study Area 3

DAU 168 East of Feather River

HONCUT VALLEY DAU 168
East of Feather

Summary of Butte County

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	70	40	60	300	180	270				370	220	330
Rice	700	2,380	4,200	3,000	10,200	15,600				3,700	12,580	19,800
Sugar Beets												
Corn												
Other Field	40	60	100	100	180	250				140	240	350
Alfalfa	150	450	700	160	470	740				310	920	1,440
Pasture	1,500	4,950	8,000	1,130	3,730	5,990				2,630	8,680	13,990
Tomatoes												
Other Truck	10	10	10	-	-	-				10	10	10
Almonds												
Other Deciduous	2,000	4,600	6,800	2,130	4,900	6,390				4,130	9,500	13,190
Subtropical	50	90	150	200	340	500				250	430	650
Grapes												
Total	4,520	12,580	20,020	7,020	20,000	29,740				11,540	32,580	49,760

Study Area 4

DAU 171 North of Yuba River

Summary of Yuba County DAU 171 - North

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	3,000	1,800	2,700	200	120	160				3,200	1,920	2,860
Rice	20,000	68,000	136,000	1,400	4,760	6,400				21,400	72,760	142,400
Sugar Beets				-								
Corn				-								
Other Field	750	1,350	2,100	750	1,350	1,730				1,500	2,700	3,830
Alfalfa	400	1,200	2,120	100	300	410				500	1,500	2,530
Pasture	3,000	9,900	15,840	800	2,640	3,760				3,800	12,540	19,600
Tomatoes				-								
Other Truck				280	450	650				280	450	650
Almonds												
Other Deciduous	10,000	23,000	34,000	2,700	6,210	7,020				12,700	29,210	41,020
Subtropical												
Grapes												
Total	37,150	105,250	192,760	6,230	15,830	20,130				43,380	121,080	212,890

Study Area 5

DAU 171 South of Yuba River

Summary of Yuba County DAU 171 - South

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	200	120	180	3,300	1,980	2,640				3,500	2,100	2,820
Rice	1,100	3,740	6,600	10,000	34,000	42,000				11,100	37,740	48,600
Sugar Beets												
Corn												
Other Field	1,200	2,160	3,360	5,000	9,000	11,500				6,200	11,160	14,860
Alfalfa	-			490	1,470	2,010				490	1,470	2,010
Pasture	490	1,620	2,940	13,000	42,900	52,000				13,490	44,520	54,940
Tomatoes												
Other Truck	170	270	460	1,700	2,720	3,910				1,870	2,990	4,370
Almonds												
Other Deciduous	3,910	4,390	6,490	10,000	27,600	31,200				13,910	31,990	37,690
Subtropical												
Grapes				710	1,420	1,700				710	1,420	1,700
Total	7,070	12,300	20,030	44,200	121,090	146,960				51,270	133,390	166,990

Study Area 6

DAU 172

Summary of Placer County DAU 172

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	4,030	2,420	3,630	900	540	720				4,930	2,960	4,350
Rice	9,400	31,960	63,920	600	2,040	3,600				10,000	34,000	67,520
Sugar Beets												
Corn												
Other Field	2,100	3,780	5,880	270	490	620				2,370	4,270	6,500
Alfalfa	870	2,610	4,610	-		-				870	2,610	4,610
Pasture	8,050	26,560	48,300	1,000	3,300	4,700				9,050	29,860	53,000
Tomatoes												
Other Truck	40	60	110	-	-	-				40	60	110
Almonds												
Other Deciduous	1,080	2,480	3,670	140	320	360				1,220	2,800	4,030
Subtropical	40	70	100	-	-	-				40	70	100
Grapes	150	300	450	-	-	-				150	300	450
Total	25,760	70,240	130,670	2,910	6,690	10,000				28,670	76,930	140,670

Summary of Sutter County DAU 172

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	3,060	1,840	2,750	4,500	2,700	3,600				7,560	4,540	6,350
Rice	24,500	83,300	166,600	7,800	26,520	46,800				32,300	109,820	213,400
Sugar Beets												
Corn												
Other Field	5,220	9,400	14,620	5,200	9,360	13,000				10,420	18,760	27,620
Alfalfa	--			2,000	6,000	9,400				2,000	6,000	9,400
Pasture	3,250	10,730	19,500	3,750	12,380	19,870				7,000	23,100	39,370
Tomatoes												
Other Truck	1,110	1,280	3,000	810	1,300	2,030				1,920	3,070	5,030
Almonds												
Other Deciduous	470	1,080	1,600	5,100	11,730	15,300				5,570	12,810	16,900
Subtropical												
Grapes												
Total	37,610	108,130	208,070	29,160	69,990	110,000				66,770	178,100	318,070

Summary of Sacramento County DAU 172

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	7,000	4,200	6,300	540	320	430				7,540	4,520	6,730
Rice	16,000	54,400	108,800	2,500	8,500	15,000				18,500	62,900	123,800
Sugar Beets												
Corn												
Other Field	12,000	21,600	33,600	90	160	210				12,090	21,760	33,810
Alfalfa	500	1,500	2,650	20	60	80				520	1,500	2,730
Pasture	8,000	26,400	48,000	900	2,970	4,230				8,900	29,370	52,230
Tomatoes												
Other Truck	3.000	4,800	8,100	10	20	20				3,010	4,820	8,120
Almonds												
Other Deciduous	1,230	2,830	4,180	-	-	-				1,230	2,830	4,180
Subtropical	30	50	70	-	-	-				30	50	70
Grapes	90	180	270	-	-	-				90	180	270
Total	47,850	115,960	211,970	4,060	12,030	19,970				51,900	127,990	231,940

Summary of Area 6 DAU 172

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	14,090	8,460	12,680	5,940	3,560	4,750				20,030	12,020	17,430
Rice	49,900	169,660	339,320	10,900	37,060	65,400				60,800	206,720	404,720
Sugar Beets												
Corn												
Other Field	19,320	34,780	54,100	5,560	10,010	13,830				24,880	44,790	67,930
Alfalfa	1,370	4,110	7,260	2,020	6,060	9,480				3,390	10,170	16,740
Pasture	19,300	63,690	115,800	5,650	18,650	28,800				24,950	82,330	144,600
Tomatoes												
Other Truck	4,150	6,640	11,210	820	1,320	2,050				4,970	7,950	13,260
Almonds												
Other Deciduous	2,780	6,390	9,450	5,240	12,050	15,660				8,020	18,440	25,110
Subtropical	70	120	170	-	-	-				70	120	170
Grapes	240	480	720	-	-	-				240	480	720
Total	110,220	294,330	550,710	36,130	88,710	139,970				147,340	383,020	690,680

Study Area 7

DAU 162

Summary of Yolo County DAU 162

Crop	Surface (1)			Ground(3)			Mixed (2)			Summary		
	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW	Acres	ETAW	AW
Grain	14.6	8.8	13.1	22.4	13.4	17.9	7.5	4.5	6.0	44.5	26.7	37.0
Rice	17.3	58.8	117.6	0.1	0.3	0.5	0.2	0.7	1.1	17.6	59.8	119.2
Sugar Beets												
Corn												
Other Field	24.8	44.6	69.4	18.0	32.4	41.4	6.0	10.8	15.0	48.8	87.8	125.8
Alfalfa												
Pasture	6.2	19.8	34.1	6.4	20.5	30.1	1.6	51.2	8.0	14.2	91.5	72.2
Tomatoes												
Other Truck	10.7	17.1	28.9	17.1	27.4	39.3	6.0	9.6	15.0	33.8	54.1	83.2
Almonds												
Other Deciduous	8.3	19.1	28.2	6.0	13.8	15.6	5.0	11.5	15.0	19.3	44.4	58.8
Subtropical												
Grapes	-	-	-	0.3	0.6	0.7	-	-	-	0.3	0.6	0.7
Total	81.9	168.2	291.3	70.3	108.4	145.5	26.3	88.3	60.1	178.5	364.9	496.9

RICE IRRIGATION RETURN FLOW STUDY
UNIT EVAPOTRANSPIRATION OF APPLIED WATER (ETAW)
AND
UNIT APPLIED WATER FOR STUDY AREAS 1-7
(Feet)

		Areas 1 and 2		Surface	Ground Water				Area 7	
Crop	ETAW	Surface	Ground	3-6	3	4	5	6	Surface	Ground
Grain	0.6	0.9	0.8	0.9	0.8	0.8	0.8	0.8	0.9	0.8
Rice	3.4	6.8	6.0	6.0 1/	5.2	6.0	4.2	6.0	6.8	5.0
Misc. Field	1.8	2.8	2.3	2.8	2.5	2.3	2.3	2.5	2.8	2.3
Alfalfa	3.0	5.3	4.1	4.7	4.7	4.1	4.1	4.7	5.3	4.1
Pasture	3.3	6.0	4.7	5.3	5.3	4.7	4.0	5.3	5.5	4.7
Truck	1.6	2.7	2.3	2.7	-	2.3	2.3	2.5	2.7	2.3
Deciduous Orchard	2.3	3.4	2.6	3.4	3.0	2.6	2.6	3.0	3.4	2.6
Subtropical Orchard	1.7	2.8	2.3	2.8	2.5	-	-	-	-	-
Vineyard	2.0	3.0	2.4	-	-	-	2.4	-	3.0	2.4

1/ Rice 6.8 ft in Area 4.

APPENDIX C

Appendix C summarizes crop acres, on-farm applied water (AW) and evapotranspiration of applied water (ETAW) by county within the major rice study areas. Ground water pumpage by county is also included.

STUDY AREA 1
CROP WATER USE, 1982
(Acres and Acre-feet)

	Glenn County 1/	Colusa County	Northern Yolo County	Total
Irrigated Land				
Rice	71,000	106,000	18,000	195,900
Other Crops	97,900	132,400	39,800	270,100
Total	168,900	238,400	58,700	466,000
Farm Applied Water				
Rice	597,380	720,800	128,500	1,446,680
Other Crops	301,960	370,600	162,900	835,460
Total	899,340	1,091,400	291,400	2,282,140
ETAW				
Rice	241,400	360,400	64,300	666,100
Other Crops	189,200	243,600	107,400	540,200
Total	430,600	604,000	171,700	1,206,300
Ground Water Pumpage	131,000	58,000	60,000	249,000

1/ That portion generally south of the Glenn-Colusa Irrigation District Service Area.

STUDY AREA 2
CROP WATER USE, 1982
(acres and acre-feet)

	Butte County	Colusa County	Glenn County	Sutter County	Total
Irrigated Land					
Rice	102,300	14,000	10,000	58,700	185,000
Other Crops	87,700	20,900	27,500	163,400	299,500
Total	190,000	34,900	37,500	222,100	484,500
Farm Applied Water					
Rice	695,600	95,200	66,800	398,000	1,255,600
Other Crops	269,900	56,200	57,400	443,000	826,500
Total	965,500	151,400	124,200	841,000	2,082,100
ETAW					
Rice	347,800	47,600	36,600	199,600	631,600
Other Crops	184,800	36,000	37,700	294,900	553,400
Wildlife - Riparian	35,000	12,000	5,000	8,000	60,000
Total	567,600	95,600	79,300	502,500	1,245,000
Ground Water Pumpage	69,000	3,000	58,000	146,400	276,400

STUDY AREA 3
CROP WATER USE, 1982
(Acres and Acre-feet)

Butte County

	Irrigated Land	Farm Applied Water	ETAW
Rice	3,700	19,800	12,600
Other Crops	7,830	30,000	21,000
Total	11,530	49,800	33,600

Ground Water Pumpage - 29,700

STUDY AREA 4
CROP WATER USE, 1982
(Acres and Acre-feet)

Yuba County

	Irrigated Land	Farm Applied Water	ETAW
Rice	21,400	142,400	72,700
Other Crops	22,000	70,500	48,300
Total	43,400	212,900	121,000

Ground Water Pumpage - 20,100

STUDY AREA 5
CROP WATER USE, 1982
(Acres and Acre-feet)

Yuba County

	Irrigated Land	Farm Applied Water	ETAW
Rice	11,100	48,600	37,800
Other Crops	40,200	118,400	95,600
Total	51,300	167,000	133,400

Ground Water Pumpage - 147,000

STUDY AREA 6
CROP WATER USE, 1982
(Acres and Acre-feet)

Irrigated Land	Sacramento	Placer	Sutter	Total
Rice	18,500	10,000	32,300	60,800
Other Crops	33,400	18,700	34,500	86,600
Total	51,900	28,700	66,800	147,400
Farm Applied Water (AW)				
Rice	123,800	67,500	213,400	404,700
Other Crops	108,100	73,100	104,600	295.800
Total	231,900	140,600	318,000	690,500
ETAW				
Rice	62,900	34,000	109,800	206,700
Other Crops	65,100	43,200	68,200	176,500
Total	128,000	77,200	178,000	383,200
Ground Water Pumpage	20,000	10,000	110,000	140,000

STUDY AREA 7
CROP WATER USE, 1982
(Acres and Acre-feet)

Yolo County

	Irrigated Land	Farm Applied Water	ETAW
Rice	17,600	119,200	59,800
Other Crops	160,900	377,700	305,200
Total	178,500	496,900	365,000

Ground Water Pumpage - 152,600