Lu Hintz:

Here is a copy of our memorandum report documenting the results of the Lower Colusa Basin Conjunctive Use pre-feasibility study. Please review the report and provide comments to me by August 25, 1997. After we have had the opportunity to consider needed revisions to the report, I expect that it will be published as a more formal "division report" by the Department. I suggest that we schedule a meeting with your board for sometime in September to brief them on the study and discuss their interest in continuing to cooperate in the project. In the mean time, please feel free to share the results of the study with them on an informal basis. If you have any questions or wish to discuss the study or the report please call me at 653-9495.

John Fielden

Received
7/30/97
L. Hintz

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Organization

STATE OF CALIFORNIA
Pete Wilson, Governor
THE RESOURCES AGENCY
Douglas P. Wheeler, Secretary for Resources

DEPARTMENT OF WATER RESOURCES
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GROUNDWATER SECTION

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This study was conducted as part of the Sacramento Valley Conjunctive Use Program, John Fielden Coordinator

Chapter 1

Introduction, Conclusions, and Recommendations

In an effort to identify and implement projects to augment water supplies for the State Water Project (SWP), the Department of Water Resources has undertaken a wide-ranging planning program. One aspect of this program evaluates the potential for developing conjunctive use projects within the Sacramento Valley groundwater basin.

Conjunctive use can be defined as the combined use of surface and groundwater systems and sources to optimize resource use and prevent or minimize adverse effects of relying on a single source. In effect, it makes the water supply system more efficient. To some extent this occurs without deliberate action, because surface and groundwater are hydraulically interconnected in the Sacramento Valley. However, carefully planned and operated projects are needed to further develop the conjunctive use potential while not interfering with existing water rights and uses.

The investigation of the conjunctive use potential of the Sacramento Valley has followed three parallel tracks. The first is identification and evaluation of the legal and institutional framework to partially define the types of and limitations on potential projects. The second track developed an inventory water supply infrastructure, water use, hydrogeologic properties and environmental resources of the valley to identify areas most suitable for conjunctive use projects. Although the inventory provides a general direction, information is usually insufficient to design specific projects or to quantify the potential in any given area. The final track is designed to circumvent this shortcoming through pre-feasibility investigations of specific potential projects. These studies recommend either more comprehensive feasibility investigation or development of small scale demonstration and testing projects. These investigations and demonstration programs are conducted in cooperation with local interests.

This report documents the results of a pre-feasibility investigation of the Lower Colusa Basin area of Yolo and Colusa Counties. The investigation was conducted in cooperation with Reclamation District No. 108 (RD-108), Colusa County Water District (CCWD) and Yolo-Zamora Water District (YZWD). The Dunnigan Water District (DWD), Reclamation District No. 787 (RD-787) and the Colusa Drain Mutual Water Company (CBMWC) also serve portions of the study area but did not participate in the study.

The study area is generally bounded on the north by an east-west line extending from Grimes to the Coast Range foothills. The eastern boundary is the Sacramento River. The southern boundary is a generally southeast trending line from the outlet of the Colusa

Basin Drain to the passage of Cache Creek though the Dunnigan Hills. The western boundary is formed by the Dunnigan Hills and the Coast Range foothills. With the exception of minor urban land use it is entirely developed to agriculture.

Conclusions

- The results of this study indicate that it is probable that a cost effective conjunctive use project could be developed and that study and testing at the feasibility level is merited.

- Data on aquifer properties for the area of a proposed well field within RD-108 is extremely limited and is insufficient for a determination of project feasibility without additional data collection.

- Conditions within the project area are not generally suitable for direct recharge to groundwater. Therefore, the project should be designed to accomplish recharge by inlieu means.

- Groundwater constitutes the sole source of supply within Yolo-Zamora Water District and a partial supply within the Dunnigan and Colusa County Water Districts. Sufficient groundwater demand exists within these agencies to meet the inlieu recharge requirements for the project being evaluated. Two alternatives, I and II would provide recharge to YZWD and to CCWD respectively.

- As much as 34,800 acre-feet of water can be supplied for inlieu recharge in wet and above normal years to accomplish recharge on lands partially or totally reliant on groundwater for irrigation within YZWD. Alternatively about 14,200 acre-feet per year could be supplied to CCWD. This will require a diversion of about 38,300 and 15,600 acre-feet respectively. New diversion, conveyance and distribution facilities will be required to accomplish inlieu recharge.

- Several potentially viable alternatives exist for supplying water to the local participants. These include use of the Tehama-Colusa Canal and alternate means to deliver water from the Sacramento River to the Colusa Basin Drain.

- Delivery of water for inlieu recharge will require an exchange between the State Water Project and the Central Valley Project (CVP).

- Over the 1922 through 1992 hydrologic sequence, about 1,300,000 or 530,000 acre-feet would be delivered for inlieu recharge and about 940,000 or 389,000 acre-feet would be returned to the State Water project by the local participants under alternatives I and II respectively. This can be accomplished without long-term depletion of the groundwater resources available in the study area.

- Reclamation Districts No. 108 and 787 rely on diversions from the Sacramento River and to a lesser extent the Colusa Basin Drain as their source of water.

- Groundwater substitution is a suitable means for transferring water to the State Water Project. Reclamation District No. 108 has sufficient contractual rights to divert water from the Sacramento River to accomplish the transfer. The potential exists for RD-787 to participate in a transfer. Such transfers may require approval by the U. S. Bureau of Reclamation (USBR).

- The alternatives evaluated could produce up to 34,800 or 14,200 acre-feet of water for use by the State Water Project in dry and critical years.

- Project operation can be accomplished without reducing deliveries to non-participating State Water Contractors that would occur in the absence of the project.

- Losses between the project site and Banks Pumping Plant are expected to be negligible. Further analysis of Delta salinity conditions are needed to verify this expectation. This conclusion assumes continuation of the existing regulatory scheme in the Delta and should be revisited as new requirements are adopted.

- Existing information is insufficient to quantify losses resulting from potential changes to surface-groundwater interaction due to project operation.

- Estimated capital cost for new facilities for alternative I and II are $17.99 million and $4.44 million respectively. Annual operation and maintenance costs will average $325,000 and $135,100 for each alternative.

- Equivalent unit cost of developing additional surface water in dry and critical years for alternative I and II is about $87 and $61 per acre-foot.

- Land subsidence has been documented in portions of the study area with as much as six feet having occurred between Zamora and Knights Landing.

- Inlieu recharge should help alleviate subsidence with Yolo-Zamora Water District. However, development and operation of a well field within Reclamation District No. 108 could result in land subsidence in this area. Insufficient information is available to evaluate the effects of project operation on land subsidence.

- Shallow groundwater levels exist in much of the study area. It may be necessary to initiate project operation with an extraction phase to assure adequate storage space is available to accommodate expected recharge. Project operations have the potential to increase the need to actively manage shallow groundwater conditions.

- Poor quality groundwater has been identified in portions of the study area. The primary constituents of concern are boron and total dissolved solids both of which could adversely affect crop production in some areas.

- Permits or other approval may be required under the State and Federal Endangered Species Acts, Section 404 (including water quality certification) of the Clean Water Act, the National Historic Preservation Act, the State Lands Commission, the Reclamation Board and the Department of Fish and Game for streambed alteration permits. Conditions associated with permits and approvals may affect project feasibility.

- The Department of Water Resources may need to apply to the State Water Resources Control Board (SWRCB) for expansion of the place of use of the State Water Project and for additional points of diversion to serve the project area. The Department and the U. S. Bureau of Reclamation will need to enter into an exchange agreement to supply water for inlieu recharge.

- Local participating districts may need to apply to the State Water Resources Control Board to transfer water to the State Water Project.

- Groundwater management and regulation is in a continuing state of flux with significant uncertainty relating to the roles of different governmental entities. Future groundwater management activities, including adoption of AB-3030 management plans and county ordinances, may affect project operation. These uncertainties are unlikely to be resolved soon.

- The pending renewal of water supply contracts between the local participants and the U. S. Bureau of Reclamation lend a degree of uncertainty to long-term project viability.

- Plans and activities of CALFED, CUWA-Ag and others constitute a complex web of competing or conflicting project and management proposals. Project implementation will be affected by the outcome of these activities and close coordination will be required to assure project success.

- The project is expected to be relatively environmentally benign. Primary species of concern include Sacramento splittail, winter run chinook salmon, giant garter snake, tricolored blackbird and Swainson's hawk. A detailed environmental assessment has not been completed, nor have the degree of impact and possible mitigation requirements been resolved. The cost of mitigation and monitoring, if any, will increase the unit cost of water developed by the project.

Recommendations

- The Department should develop a proposed work plan for the conduct of a feasibility investigation of the proposed project. The water transfer guidelines adopted by Yolo County should be consulted when formulating this study and associated environmental assessments. Feasibility investigations should evaluate additional options for delivering water to the inlieu recharge areas. These include use of the Tehama-Colusa Canal and alternative diversion locations on the Sacramento River.

- The State Water Contractors should be given the opportunity to opt-out of participation in the proposed feasibility study.

- The Department should negotiate a cooperative agreement with local participants for completion of the proposed feasibility study to address outstanding technical and institutional issues.

- The Department should consult with Colusa and Yolo Counties and with other local agencies and interests that may be affected by the conjunctive use project.

- The Department should initiate consultation with the U. S. Bureau of Reclamation and other regulatory agencies to obtain guidelines for obtaining necessary agreements or approvals.

- The Department should endeavor to participate in CALFED. CUWA-Ag and other planning processes that could affect continuing project viability.

- The Department should continue installation of a dedicated monitoring well network and related technical studies to improve understanding of the hydrogeologic properties of the basin, the potential for additional land subsidence and the degree of surface and groundwater interaction. The need for numerical modeling of the groundwater system should be evaluated.

- The Department in cooperation with the local participants should develop a groundwater quality monitoring program and identify options for managing water of less than desirable quality.

- The Department should encourage and cooperate with local agencies in the project area to develop an integrated water management plan.

Chapter 2

Background and Local Institutional Framework

The Lower Colusa Basin conjunctive use study area encompasses an area of approximately 300 square miles in southern Colusa and northern Yolo Counties (Figure 1). It is generally coextensive with the service areas of Reclamation Districts No. 108 and 787, Colusa County Water District, Dunnigan Water District, Yolo-Zamora Water District and the Colusa Drain Mutual Water Company. Small areas of unorganized land are also included. The eastern boundary is the Sacramento River and the western boundary is generally along the Dunnigan Hills and the eastern foothills of the Coast Range and effectively marks the western edge of the groundwater basin. The northern and southern boundaries generally follow the boundaries of districts in the project area.

The western portion of the study area is characterized by low rolling dissected uplands and alluvial fans associated with the ephemeral streams draining the area. These merge with flood basin lands to the east with the lowest elevations generally occurring along the Colusa Basin Drain. The topography then rises gently as the natural levees of the Sacramento River are approached.

The area has a mediterranean type climate with cool, relatively wet winters and hot summers with little precipitation. Partial rainfall records are available for Williams, Colusa, Knights Landing and Dunnigan. These records were extended to estimate rainfall during the study period. Long-term average annual precipitation at these stations is 16.47, 15.76, 16.47 and 18.04 inches respectively. The average monthly distribution of precipitation at these stations is shown in figure 2.

The predominant land use in the study area is food and forage production. Figure 3 is a generalized agricultural land-use map of the study area. The predominant crops grown in the study area are shown in tables 1 and 2 for years when DWR land use surveys were conducted. Statistics reported in County Agricultural Commissioner reports were used to estimate crop acreage during the remaining years of the 1976-94 study period.

Total crop acreage has been relatively stable during the study period, averaging about 148,000 acres including some double cropping. It ranged from a low of about 122,000 acres in 1983 to a high of about 164,000 acres in 1989. Greater year-to-year variation has occurred in the Colusa County portion of the study area than in Yolo County.

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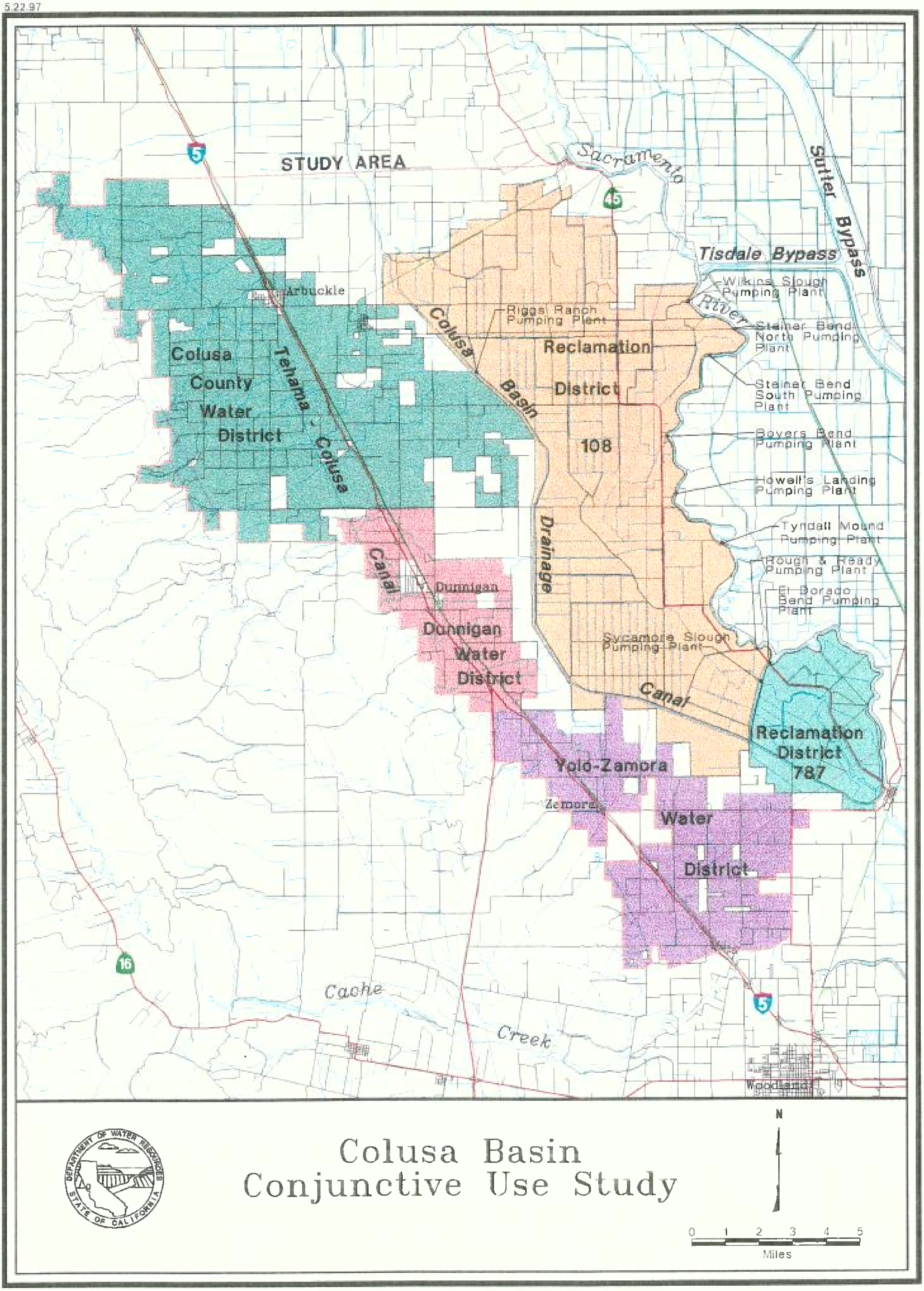
STUDY AREA
Sacramento
River
Sutter Bypass
Tisdale Bypass
Wilkins Slough Pumping Plant
Arbuckle
Riggs Ranch Pumping Plant
Steiner Bend North Pumping Plant
Steiner Bend South Pumping Plant
Boyers Bend Pumping Plant
Howell's Landing Pumping Plant
Tyndall Mound Pumping Plant
Rough & Ready Pumping Plant
El Dorado Bend Pumping Plant
Sycamore Slough Pumping Plant
Colusa County Water District
Tehama - Colusa Canal
Colusa Basin Drainage Canal
Reclamation District 108
Dunnigan
Dunnigan Water District
Reclamation District 787
Yolo-Zamora Water District
Zamora
Cache Creek
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Colusa Basin
Conjunctive Use Study
DEPARTMENT OF WATER RESOURCES
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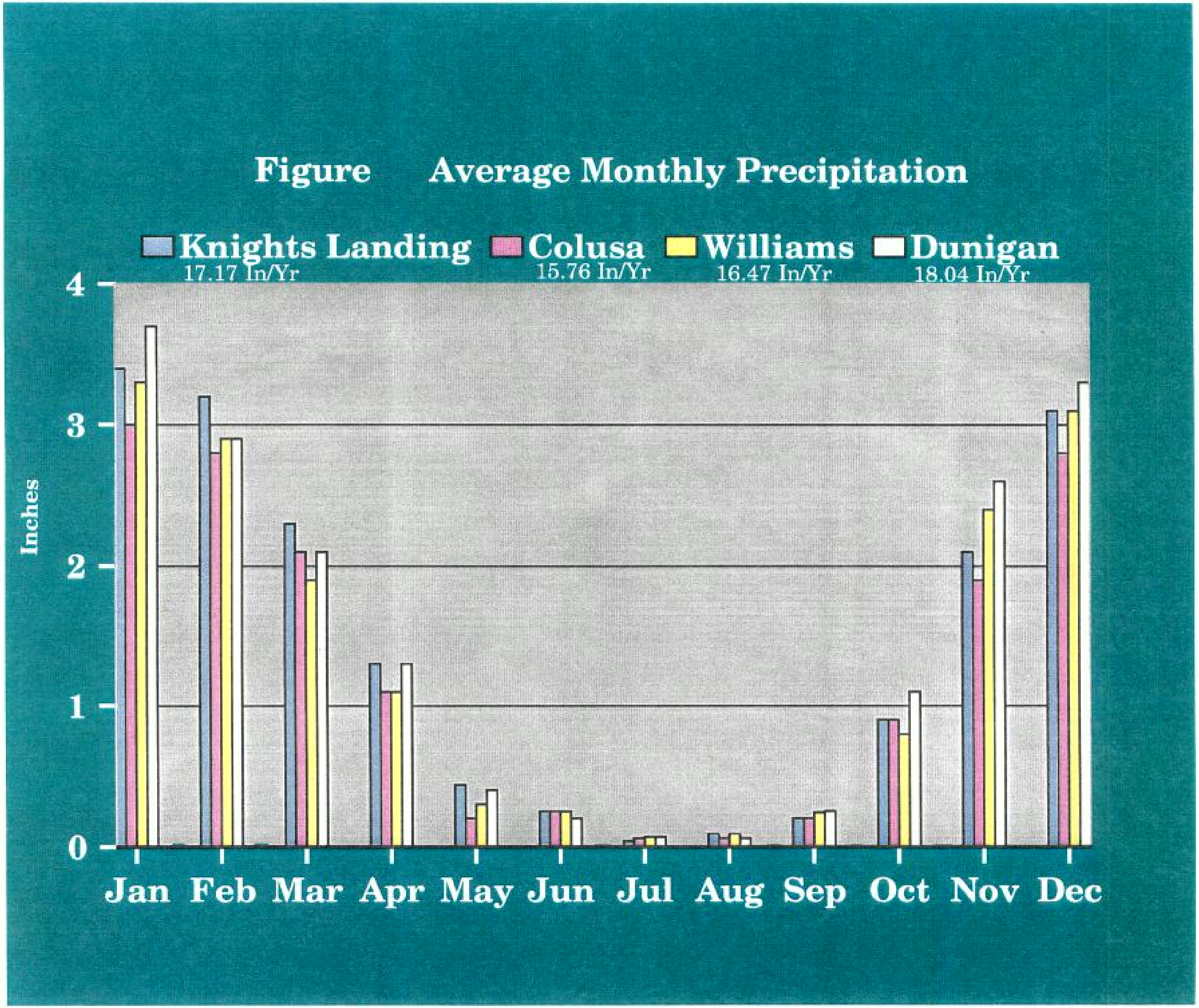


Figure Average Monthly Precipitation
Knights Landing 17.17 In/Yr
Colusa 15.76 In/Yr
Williams 16.47 In/Yr
Dunigan 18.04 In/Yr
Inches
0
1
2
3
4
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

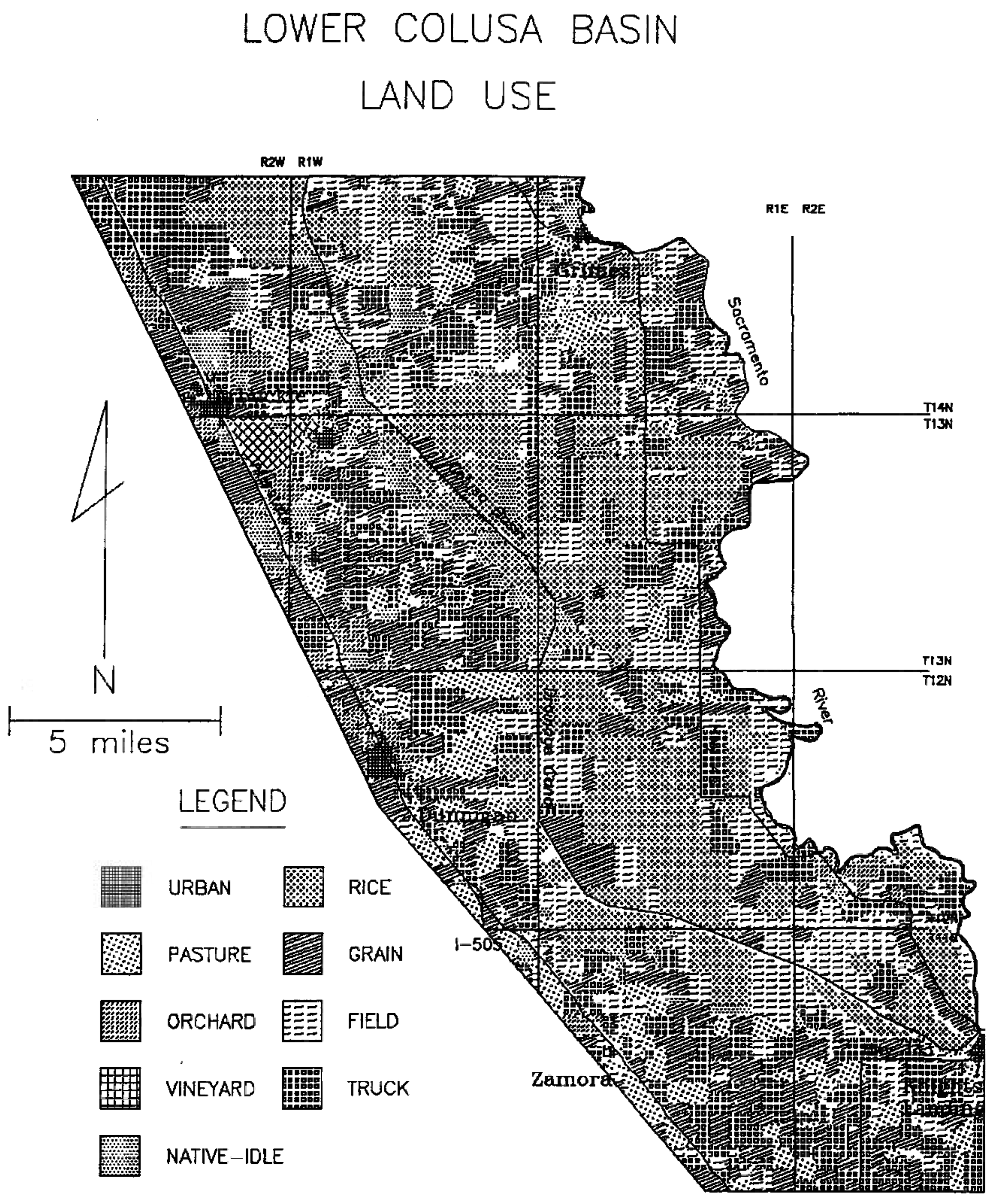


Figure 3. Lower Colusa Basin Land Use

The small population in the area, about 4,500 in 1990, is concentrated in the small communities of Arbuckle, College City, Dunnigan, Zamora and Yolo.

Table 1. Crop Acreage in Colusa County Portion of Study Area

Crop	1976 Acres	1980 Acres	1985 Acres	1988 Acres
Grain	23,443	18,001	23,341	15,505
Rice	15,877	20,742	21,099	21,175
Almonds	14,520	14,587	17,355	14,112
Sugar Beets	7,024	4,303	4,867	5,536
Misc. Field	3,532	3,257	3,617	7,111
Corn	3,327	2,118	3,292	1,921
Safflower	2,983	4,145	6,120	6,280
Tomatoes	2,889	3,234	4,206	4,245
Misc. Truck	2,641	4,492	8,091	3,963
Alfalfa	2,441	2,680	3,894	5,188
Deciduous	1,160	1,273	2,405	2,150
Pasture	765	581	858	1,126
Vineyard	N/R	N/R	17	511
Idle	N/R	851	1,014	2,058

Table 2. Crop Acreage in Yolo County Portion of Study Area

Crop	1976 Acres	1981 Acres	1989 Acres
Grain	17,233	22,945	17,046
Rice	14,453	18,432	16,306
Tomatoes	12,825	13,211	14,832
Alfalfa	6,536	7,161	9,158
Misc. Field	5,436	1,987	5,613
Safflower	5,239	2,486	6,689
Corn	4,743	4,781	2,795
Deciduous	3,924	1,634	1,658
Sugar Beets	2,326	2,341	1,993
Misc. Truck	1,835	2,916	4,395
Pasture	569	388	841
Almond	0	2,479	2,998

Agricultural Water Demand

Applied irrigation water demand was estimated from DWR land use surveys when available and from County Agricultural Commissioners' Annual Reports for years between surveys. In the Colusa County portion of the study area the average applied water factors for the period 1988-93 were used to develop demand estimates. In the Yolo County area factors for 1985 were applied to the 1976 and 1981 land use surveys and the 1990 factors to the 1989 survey. The ratios of total county crop acreage to study area acreage for survey years was used to adjust county wide crop acreage from the Agricultural Commissioners' reports and estimate study area crop acreage in other years. Estimated applied demand for irrigation water in the study area is shown in Table 3.

Table 3. Applied Water Demand (acre-feet)

Year	Demand	Year	Demand
1976	484,000	1986	434,000
1977	459,000	1987	452,000
1978	434,000	1988	556,000
1979	409,000	1989	533,000
1980	478,000	1990	525,000
1981	511,000	1991	470,000
1982	513,000	1992	487,000
1983	394,000	1993	505,000
1984	488,000	1994	540,000
1985	538,000		

Conveyance system losses were estimated to be three percent of deliveries made from the Sacramento River and Tehama-Colusa Canals and three percent of the applied water demand for unorganized areas that land use surveys indicate are irrigated with surface water. These losses are not included in Table 3. Municipal, industrial and domestic water supply needs are a small fraction of agricultural demand and were not estimated. It should be noted that in very wet years such as 1983 water demand decreases significantly. This reflects the extensive and prolonged flooding that occurs along the Colusa Basin trough. Future water demands for the study area are not expected to change significantly.

Water Supply

The U. S. Bureau of Reclamation is the principal supplier of surface water in the Study Area. USBR has entered into water right settlement agreements with Reclamation Districts No. 108 and 787 to supply up to 232,000 acre-feet and 29,800 acre-feet respectively from the Sacramento River. The contract amounts are subject to a twenty five percent reduction in dry years. This constitutes essentially the entire supply for these districts. The schedule of monthly diversions for RD-108 is shown in table 4.

Table 4. **Schedule of Monthly Diversions for RD-108 (acre-feet)**

	Base Supply	CVP Supply	Total
April	34,000	0	34,000
May	50,500	0	50,500
June	49,000	0	49,000
July	31,500	16,000	47,500
August	16,500	15,000	31,500
September	16,000	2,000	18,000
October	1,500	0	1,500

During the study period diversions from the Sacramento River ranged from about 100,000 acre-feet is 1983 to 222,000 acre-feet in 1981 with an average diversion of about 171,000 acre-feet per year.

Within the study area, the Colusa County Water District and the Dunnigan Water District have contracts with USBR to receive water from the Tehama-Colusa Canal. Colusa County Water District has contracted for a supply of 62,200 acre-feet per year. It also receives up to 5,965 acre-feet per year by assignment from the Colusa County contract with USBR. In addition, Colusa County Water District has requested that USBR increase its contract amount by an additional 55,000 acre-feet per year. The USBR has made a preliminary determination that this water is needed by the district, assuming a groundwater safe yield of 11,000 acre-feet per year. Initial deliveries from the Tehama-Colusa canal began in 1980. Deliveries have only approached the contractual amounts in 1987 and 1988. In the early years, in district conveyance facilities were limited and in subsequent years water availability was limited by drought conditions and restrictions on diversion into the Tehama-Colusa Canal. Prior to initial deliveries from the canal, the district received Central Valley Project water from a temporary diversion from the Colusa Basin Drain. Central Valley Project water provides a supplemental supply to the district with the remainder of its demand being met with groundwater. Deliveries to Colusa County Water District are shown in Table 5.

Table 5. **Tehama-Colusa Canal Deliveries to Colusa County Water District (acre-feet per year)**

Year	Delivery
1980	19,729
1981	24,796
1982	19,827
1983	17,367

1984	31,904
1985	37,945
1986	43,816
1987	63,073
1988	62,767
1989	60,631
1990	41,332
1991	33,460
1992	28,084
1993	48,241
1994	38,928

Dunnigan Water District has contracted with the USBR for up to 19,000 acre-feet per year but has not received that amount to date because of limitations on water availability from the Tehama-Colusa Canal. Dunnigan has requested that the USBR increase its contract for CVP water by 10,000 acre-feet per year. However, the USBR has made a preliminary determination that the district's need for additional water is only 5,600 acre-feet per year. The USBR has also estimated the groundwater safe yield of the district to be 5,300 acre-feet per year. The Central Valley Project supply is for supplemental water with the remainder of district demand being met with groundwater. Deliveries to Dunnigan Water District are shown it Table 6.

Members of the Colusa Drain Mutual Water Company, a portion of which is in the study area, divert water from the Colusa Basin Drain. The USBR considers a portion of the water being diverted to be drainage return flows and that its use depletes flows available to the USBR on the Sacramento River. The USBR has entered into a contract with the Colusa Drain MWC to receive payment for the water diverted. Under the contract with Colusa Basin Drain MWC the Bureau does not release or make water available to the Company from Central Valley Project facilities. The diversions are self reported, based on irrigated acreage, by the Colusa Drain MWC with records available beginning in 1988. Table 7 shows estimated diversions by the Company from the Colusa Basin Drain for this period.

Diversions by the Colusa Drain MWC, to a considerable extent, depend on the continuing availability of drainage water from districts discharging to the drain. The future availability of this water is unknown as these districts generally claim a right to recapture this drainage water for their own use. It is expected that recapture and increased water use efficiency by upstream districts will reduce the amount of water available to the Company in the study area.

Table 6. Tehama-Colusa Canal Deliveries to Dunnigan Water District (acre-feet per year)

Year	Delivery
1981	565
1982	296
1983	6,156
1984	14,887
1985	13,058
1986	11,261
1987	14,913
1988	15,530
1989	13,813
1990	8,930
1991	5,217
1992	4,125
1993	8,806
1994	7,900

Table 7. Diversions from the Colusa Basin Drain by Colusa Drain MWC (acre-feet per year)

Year	Diversion
1988	39,789
1989	50,210
1990	80,325
1991	87,742
1992	20,389
1993	47,458
1994	25,882
1995	44,666

Numerous water rights exist for diversion from the Colusa Basin Drain in the study area. The aggregate allowable diversion rate under these rights is approximately 600 cfs. During the study period inflow is approximated by the gage at Highway 20 and has varied from a high of about 1,142,000 acre-feet in 1983 to a low of about 249,000 acre-feet in 1992 and 1994. The average inflow was approximately 581,045 af/yr. Outflow from the study area is approximated by the record at the Knights Landing outfall gates. This record represents minimum outflow as it does not include the unrecorded outflow to the Yolo Bypass through the Knights Landing Ridge Cut. Outflow at the outfall gates has ranged between about

97,000 af and 559,000 af and averaged about 309,000 af/yr. The amount of drainage to the Colusa Basin Drain between the measured inflow and outflow points is unknown. Both inflow and outflow from the study area are heavily influenced by winter flooding and by the fall release of water from the extensive rice cultivation occurring in the drainage area.

Groundwater pumpage in the study area is not measured. However, it was estimated as the difference between the applied water demand, including estimated conveyance losses, and the reported deliveries of surface water. This approach over estimates the amount of groundwater extraction that occurs in the study area. It does not account for effective precipitation, incomplete diversion data for the Colusa Basin Drain, possible greater irrigation efficiency when groundwater is used, or undetected land fallowing that may occur in years when land use surveys are unavailable. With these caveats, the estimated groundwater pumpage in the study area is shown in Table 8.

Table 8. Estimated Groundwater Pumpage (acre-feet per year)

Year	Pumpage	Year	Pumpage
1976	239,000	1986	194,000
1977	254,000	1987	175,000
1978	214,000	1988	305,000
1979	166,000	1989	287,000
1980	218,000	1990	252,000
1981	222,000	1991	201,000
1982	257,000	1992	278,000
1983	226,000	1993	262,000
1984	237,000	1994	320,000
1985	282,000		

Figures 4 through 23 show spring groundwater levels for each year of the 1976 through 1995 study period. These groundwater level maps are generally reflective of the reliance on groundwater in the study area. Reclamation Districts 108 and 787 have essentially no groundwater use and have had relatively shallow and stable groundwater levels throughout the study period. Groundwater elevations are generally within the 10 to 20 foot range in these districts. At the opposite extreme is Yolo-Zamora Water District and most of the non-district lands in the study area that are totally reliant on groundwater. Lands within the Dunnigan and Colusa County Water Districts and the Colusa Drain MWC are irrigated with a mix of surface and groundwater. During the study period the former two districts relied heavily on groundwater prior

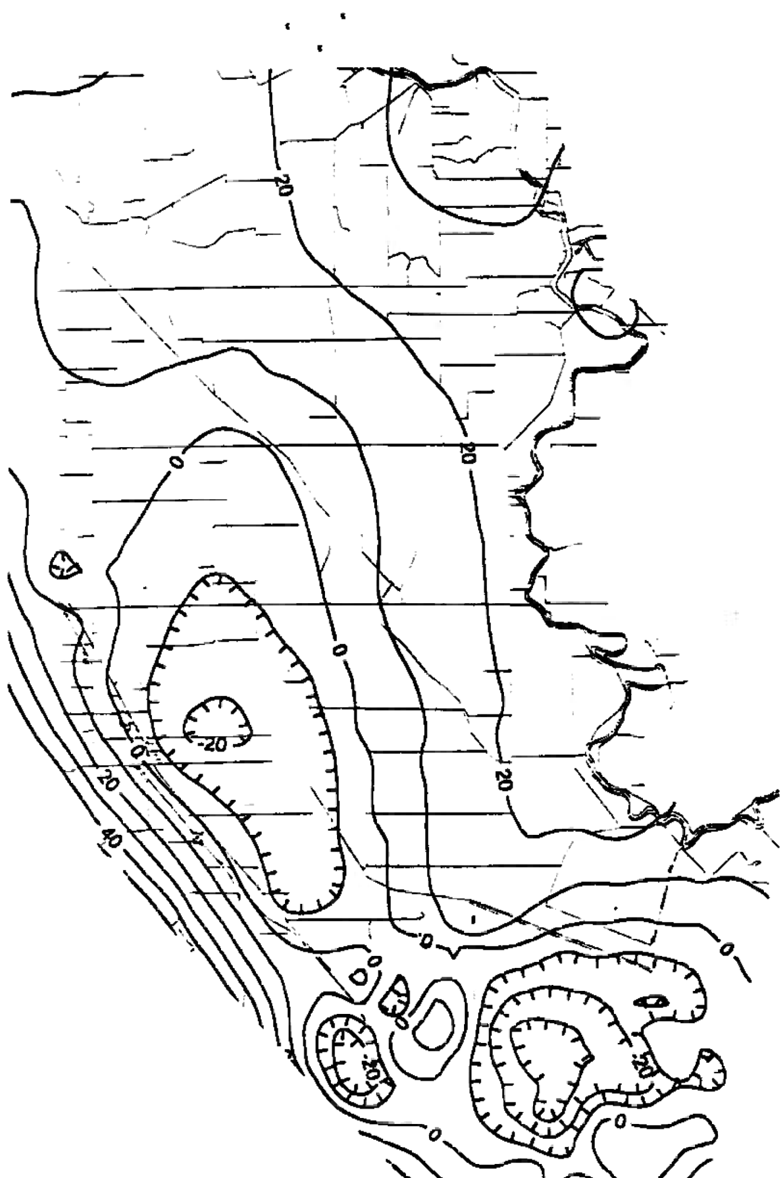


Figure 4. 1976 Groundwater Elevation - Lower Colusa Basin

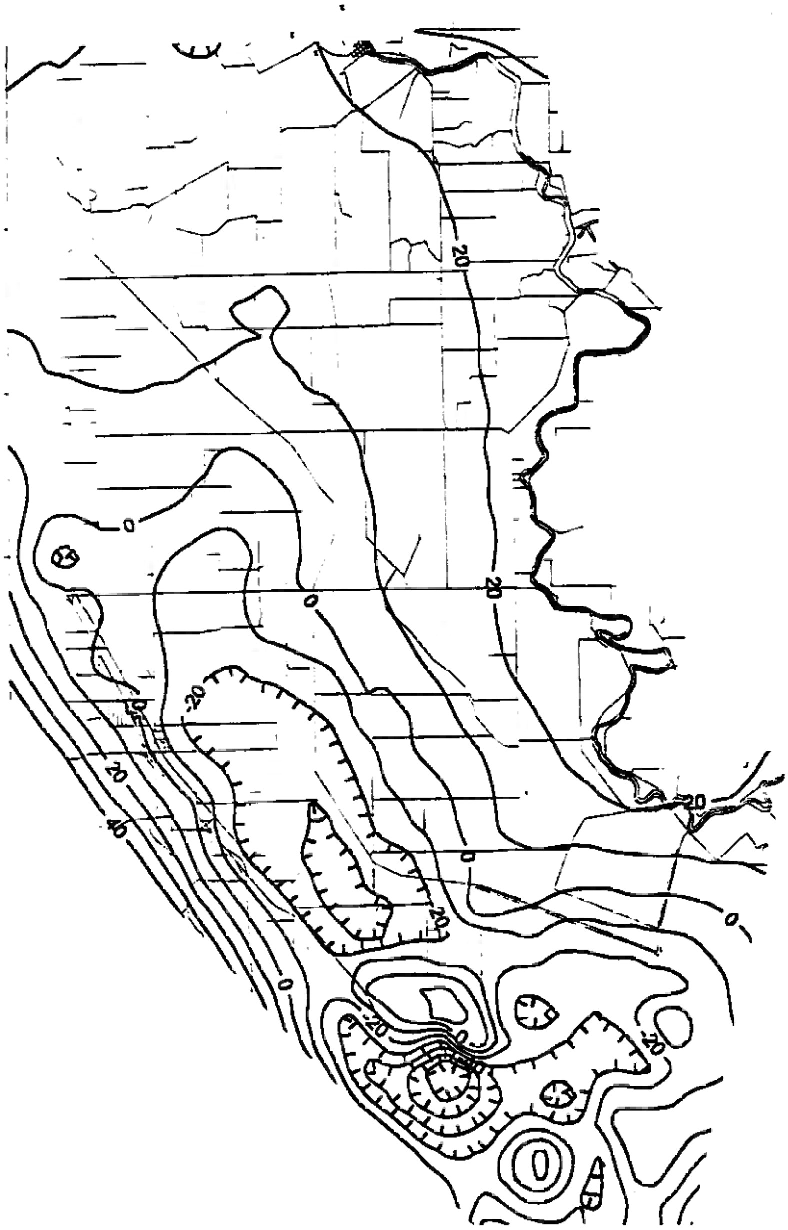


Figure 5. 1977 Groundwater Elevation - Lower Colusa Basin

Figure 6. 1978 Groundwater Elevation - Lower Colusa Basin

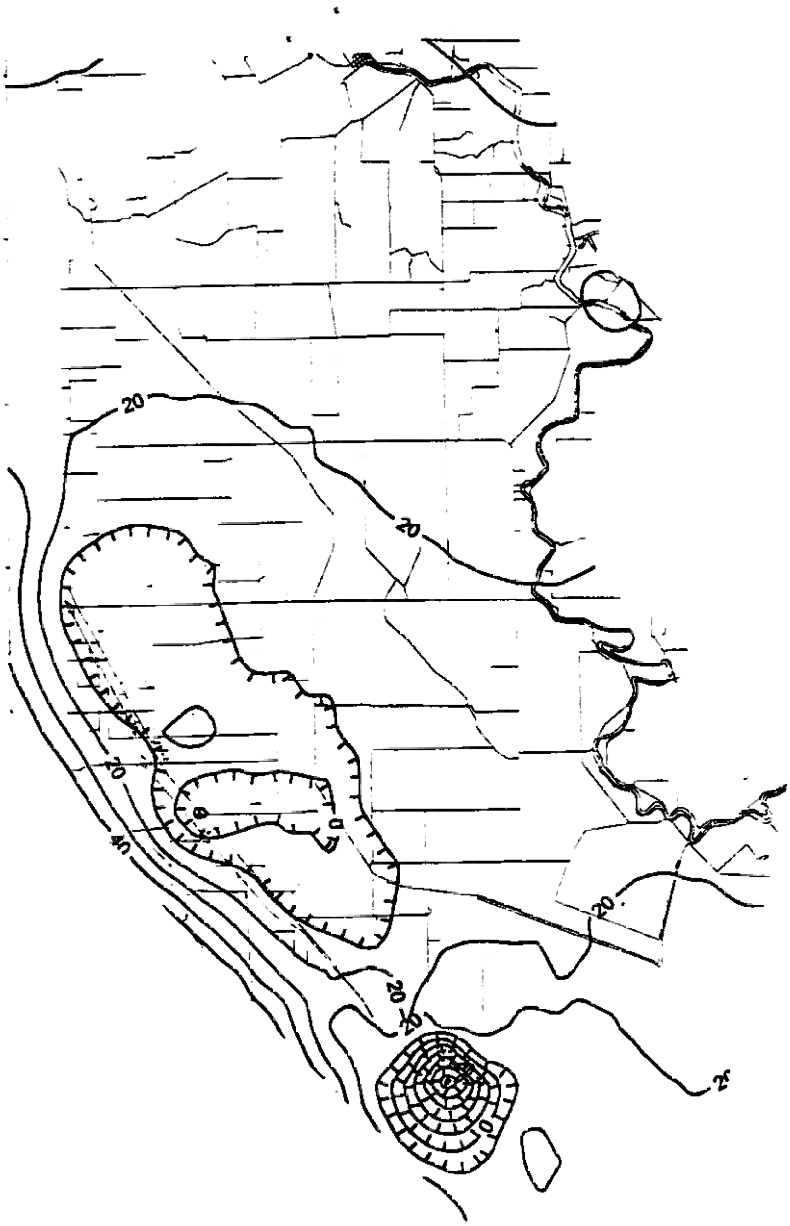


Figure 7. 1979 Groundwater Elevation - Lower Colusa Basin

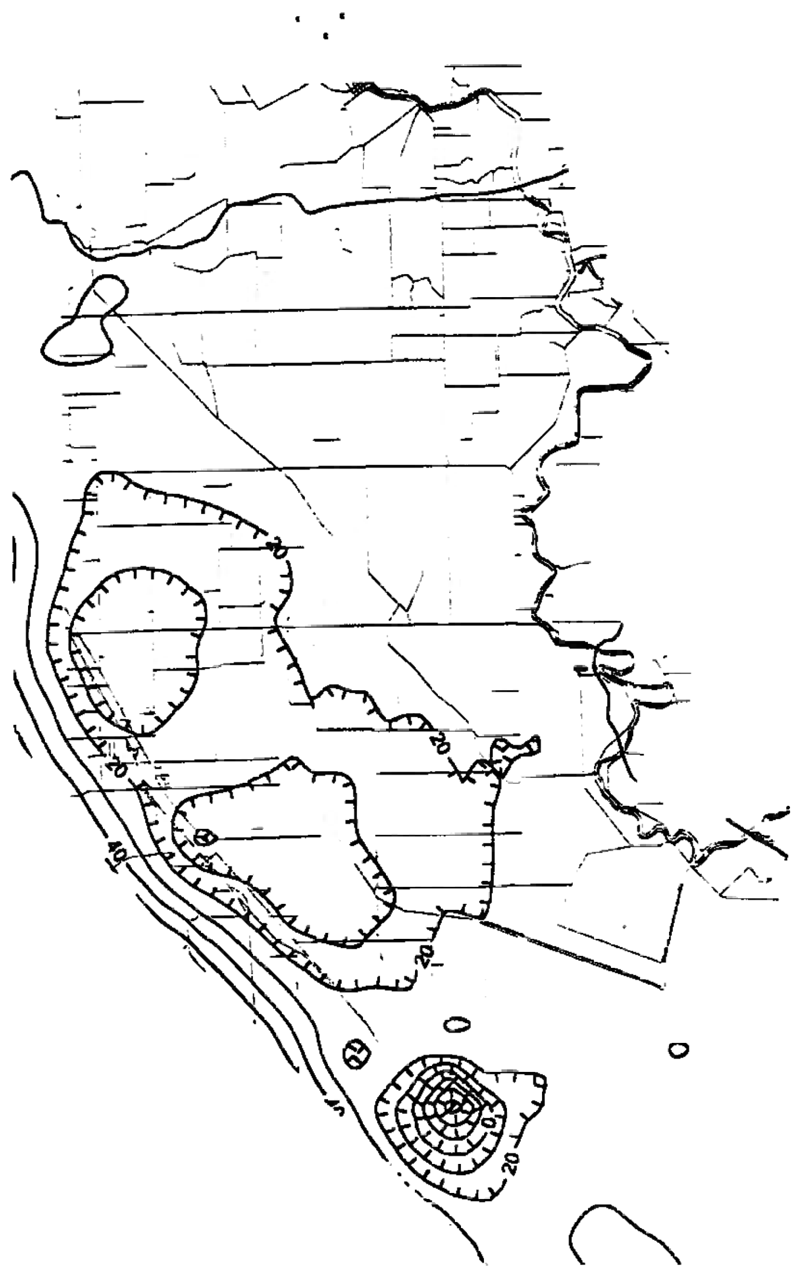


Figure 8. 1980 Groundwater Elevation - Lower Colusa Basin

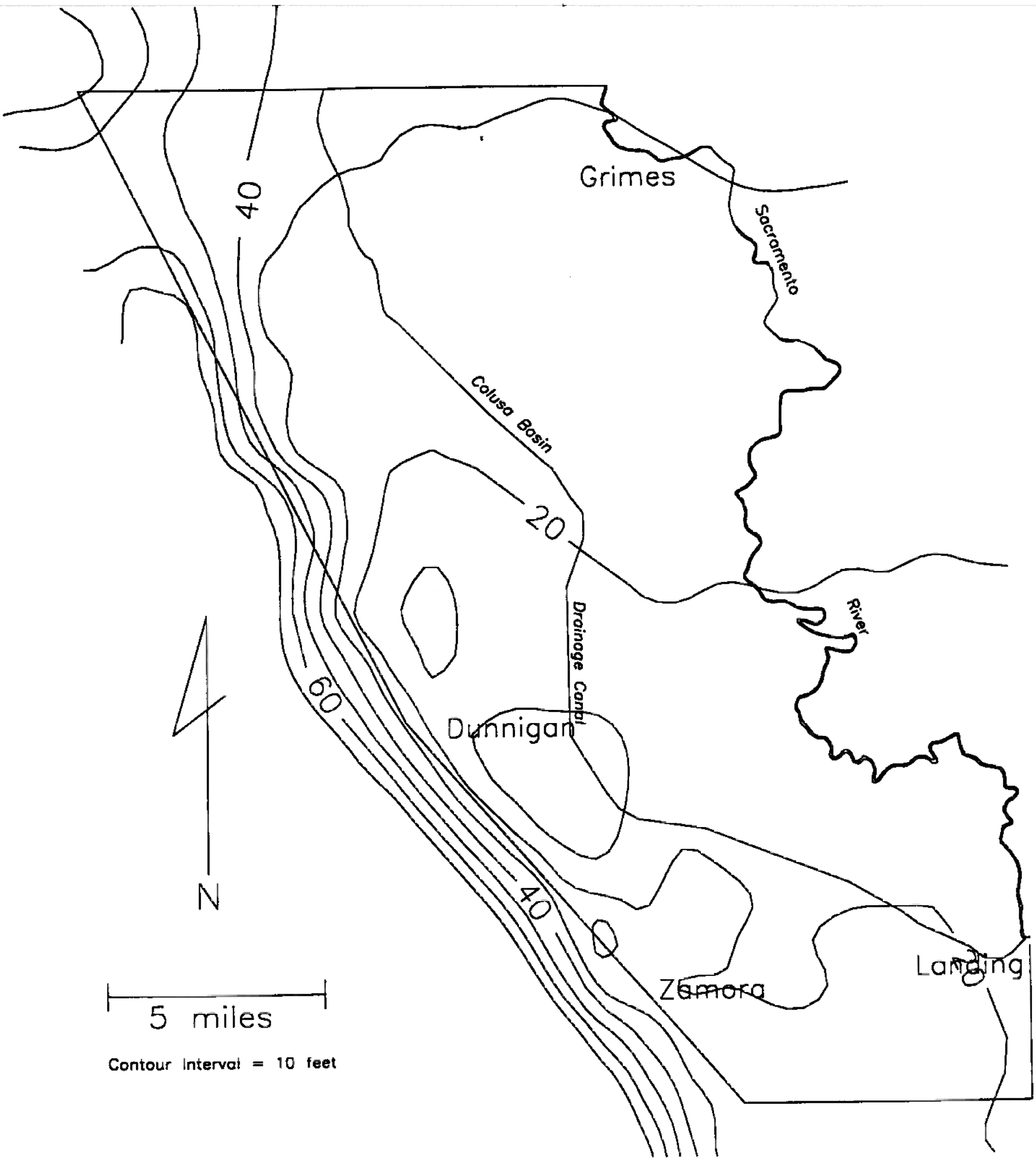


Figure 9. 1981 Groundwater Elevation - Lower Colusa Basin

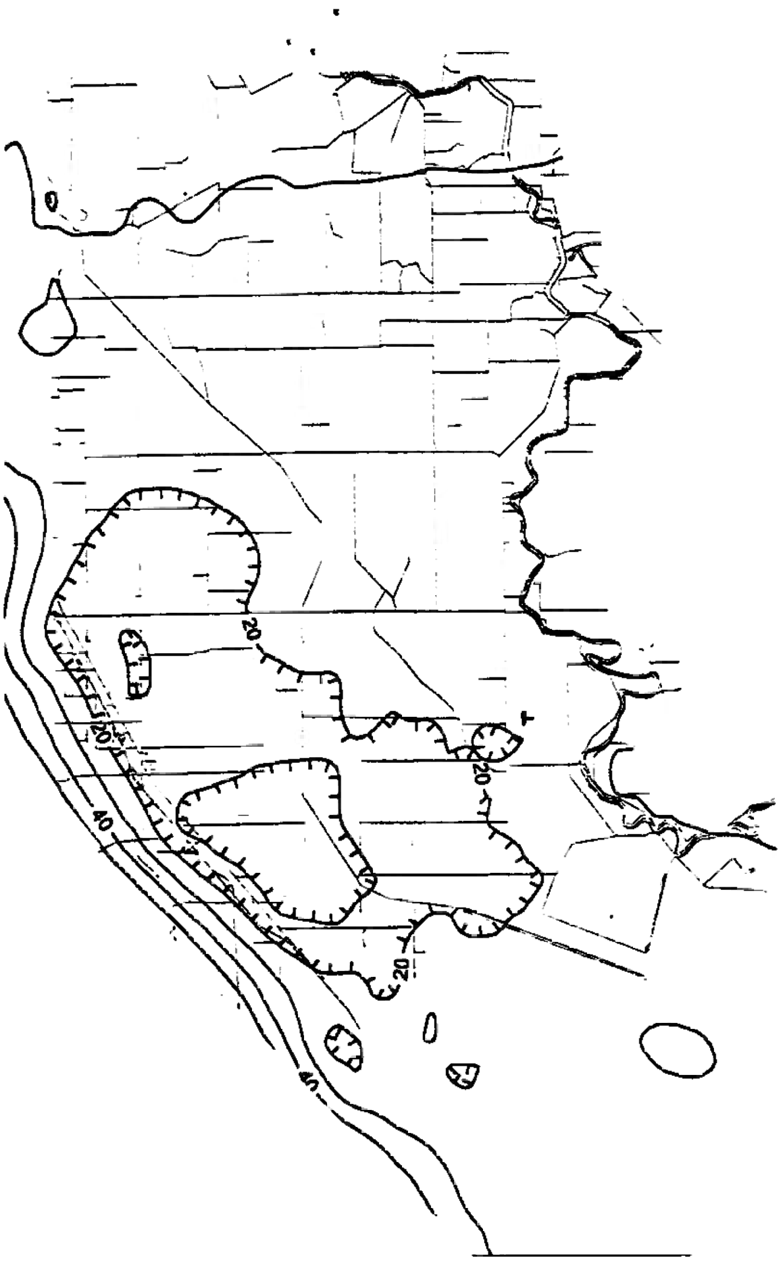


Figure 10. 1982 Groundwater Elevation - Lower Colusa Basin

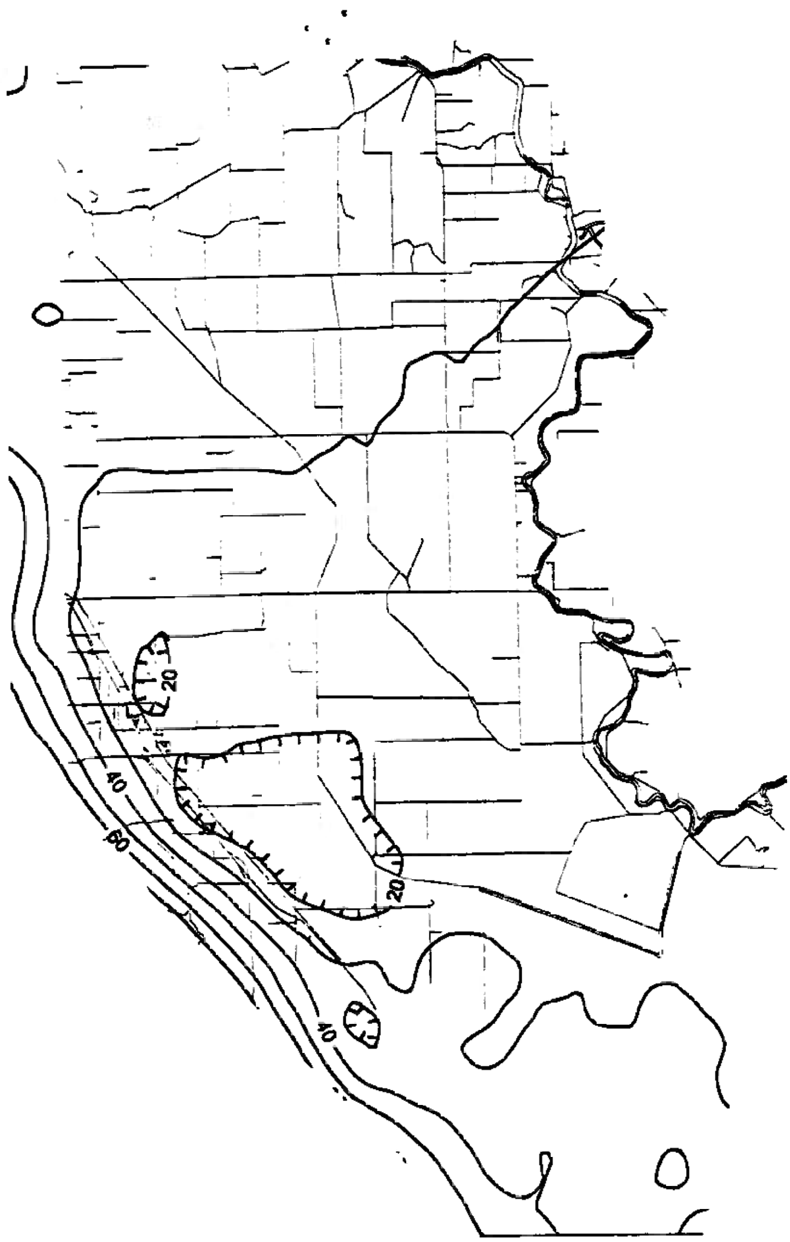


Figure 11. 1983 Groundwater Elevation - Lower Colusa Basin

Figure 12. 1984 Groundwater Elevation - Lower Colusa Basin

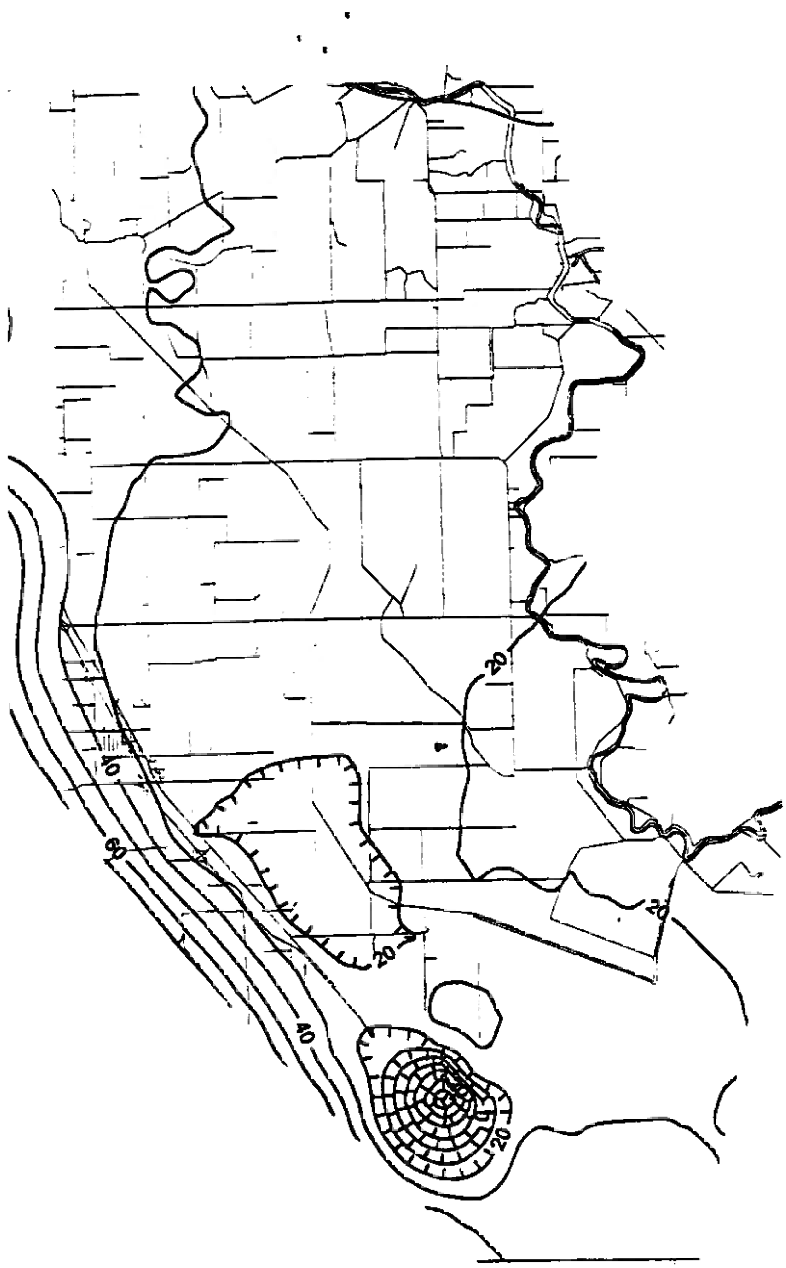


Figure 13. 1985 Groundwater Elevation - Lower Colusa Basin

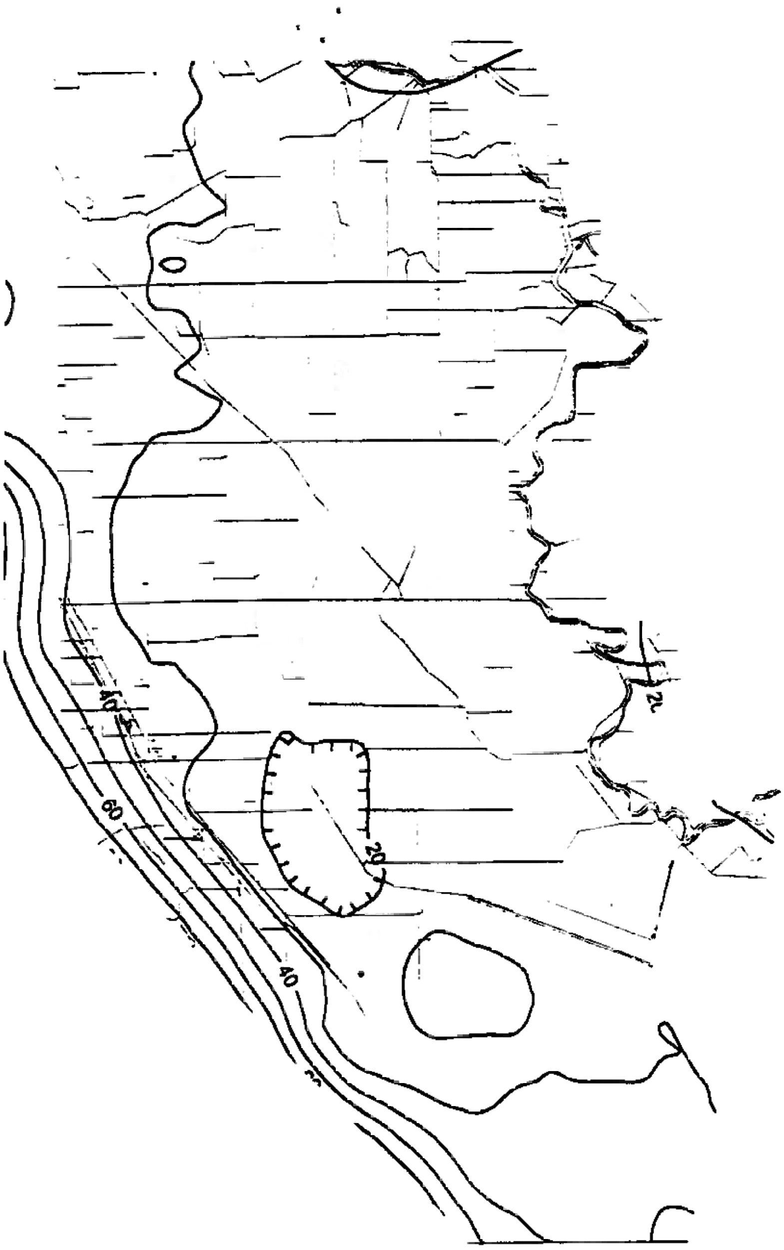


Figure 14. 1986 Groundwater Elevation - Lower Colusa Basin

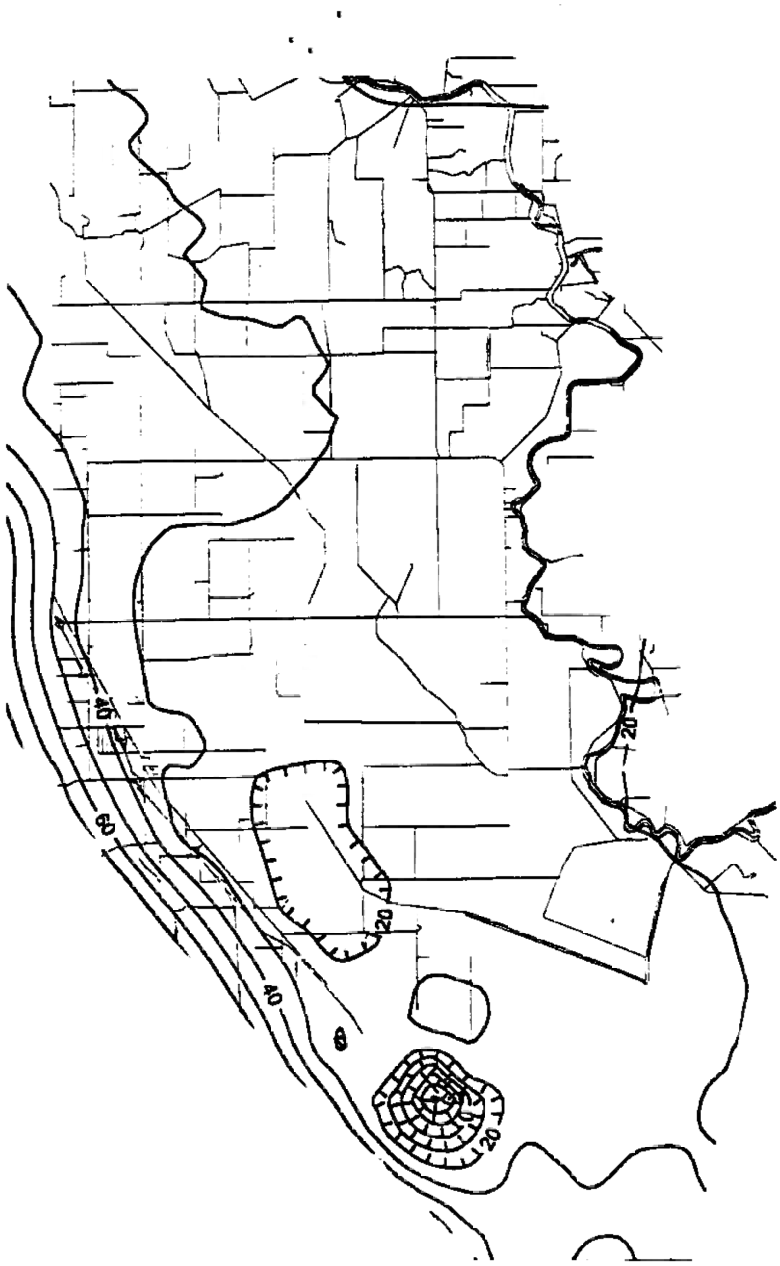


Figure 15. 1987 Groundwater Elevation - Lower Colusa Basin

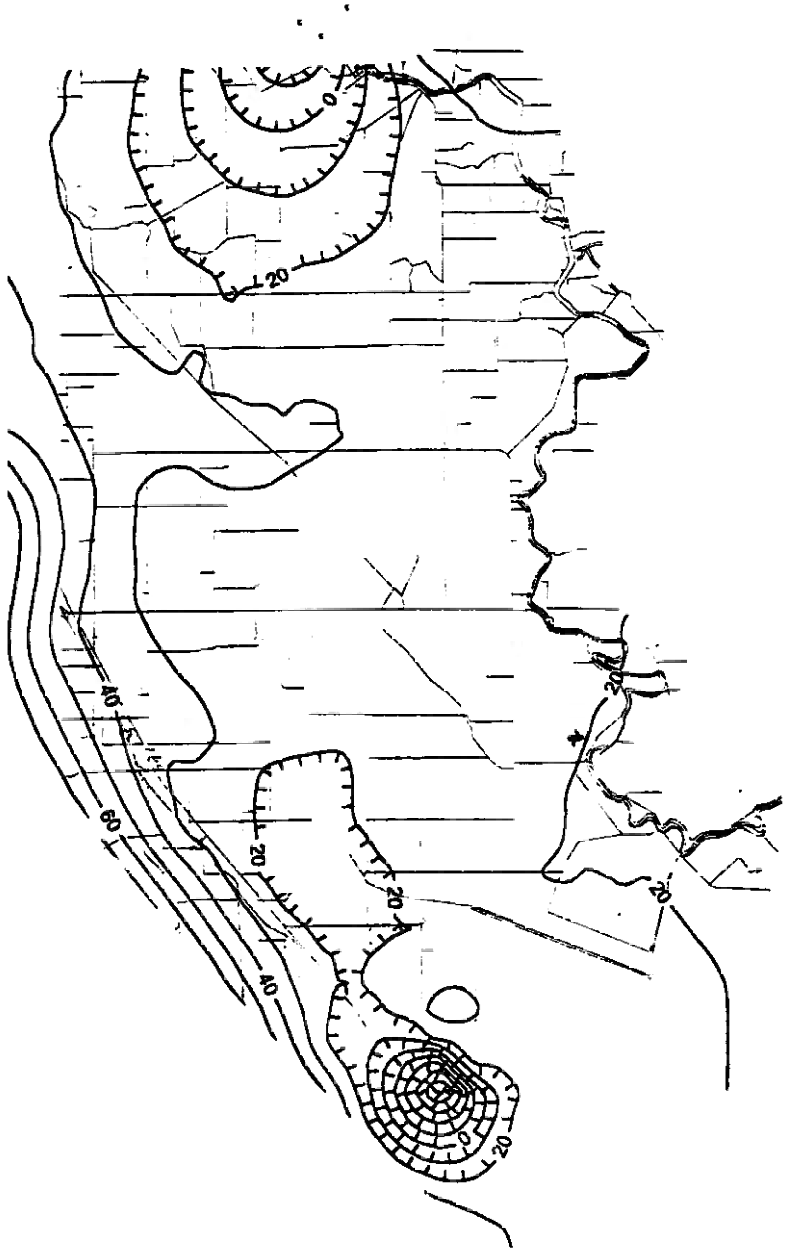


Figure 16. 1988 Groundwater Elevation - Lower Colusa Basin

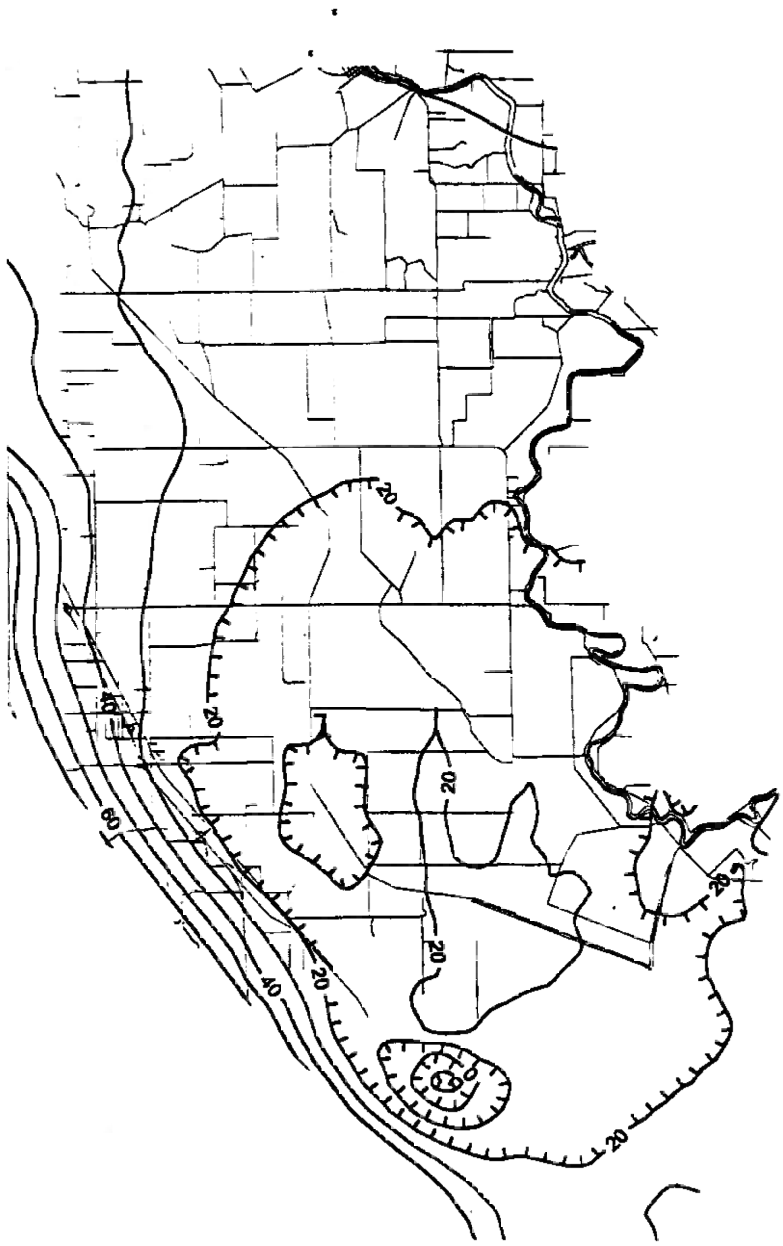


Figure 17. 1989 Groundwater Elevation - Lower Colusa Basin

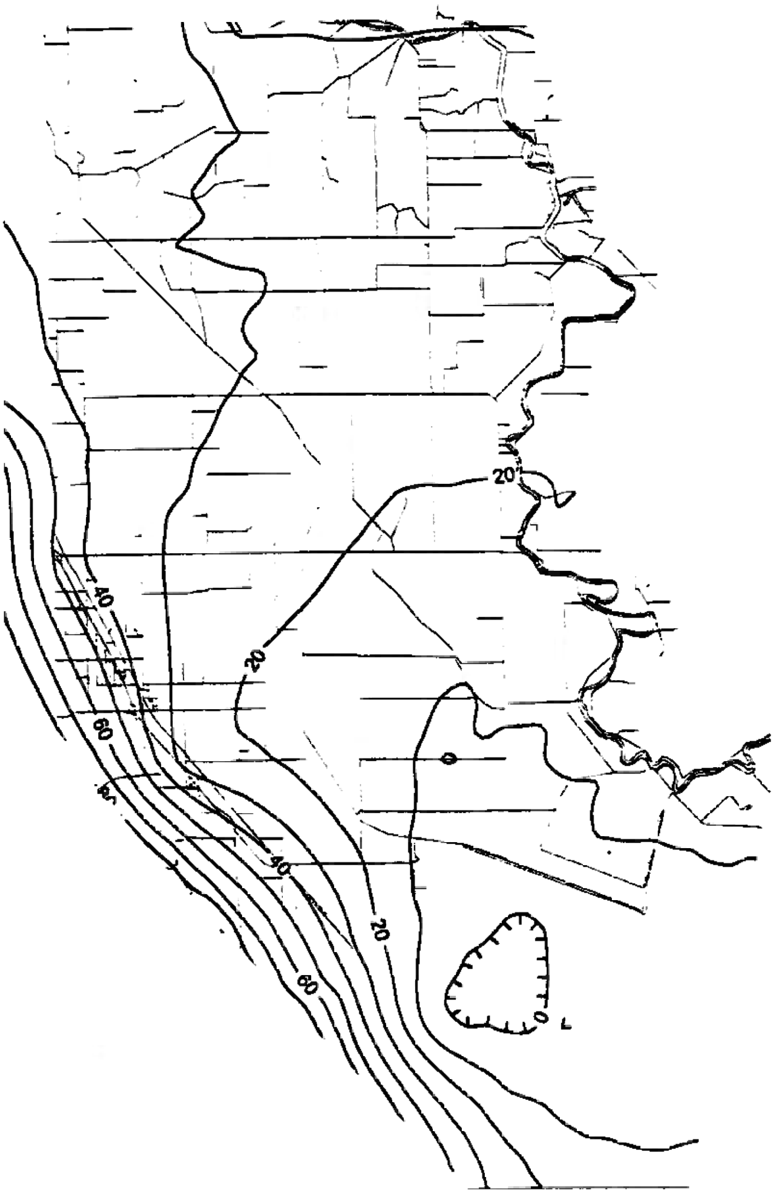


Figure 18. 1990 Groundwater Elevation - Lower Colusa Basin

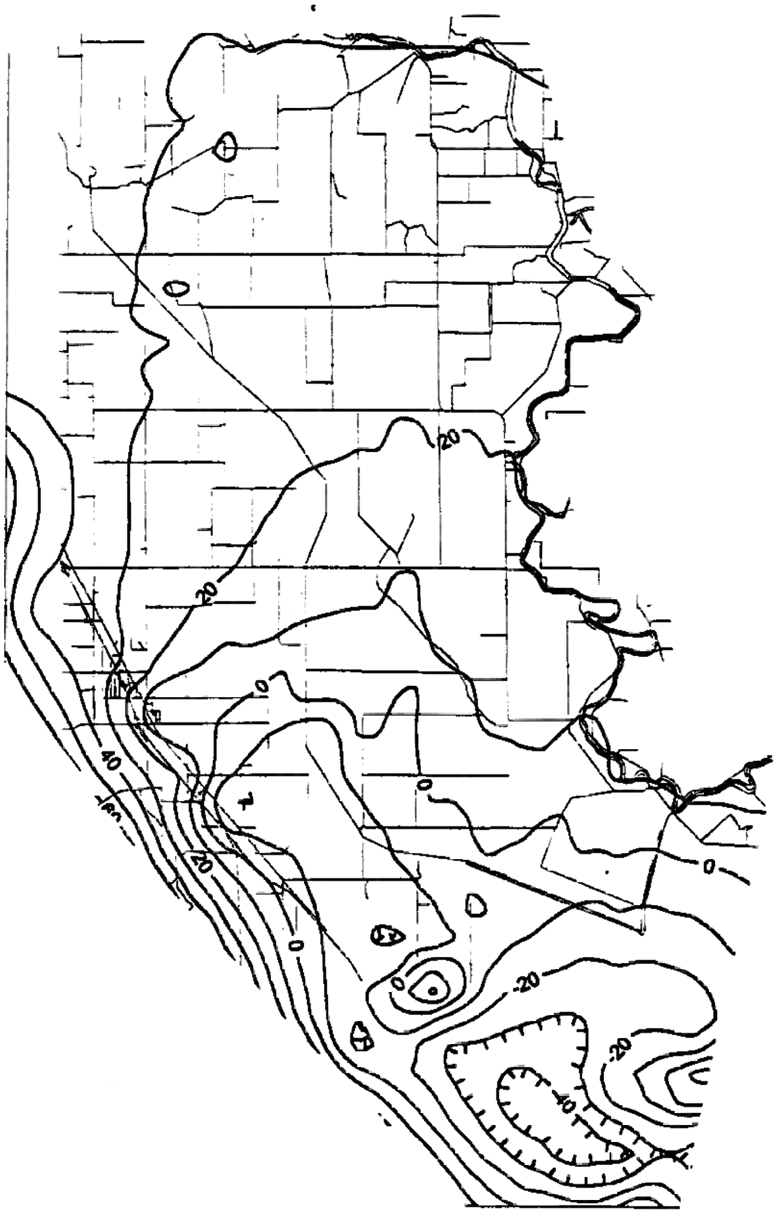


Figure 19. 1991 Groundwater Elevation - Lower Colusa Basin

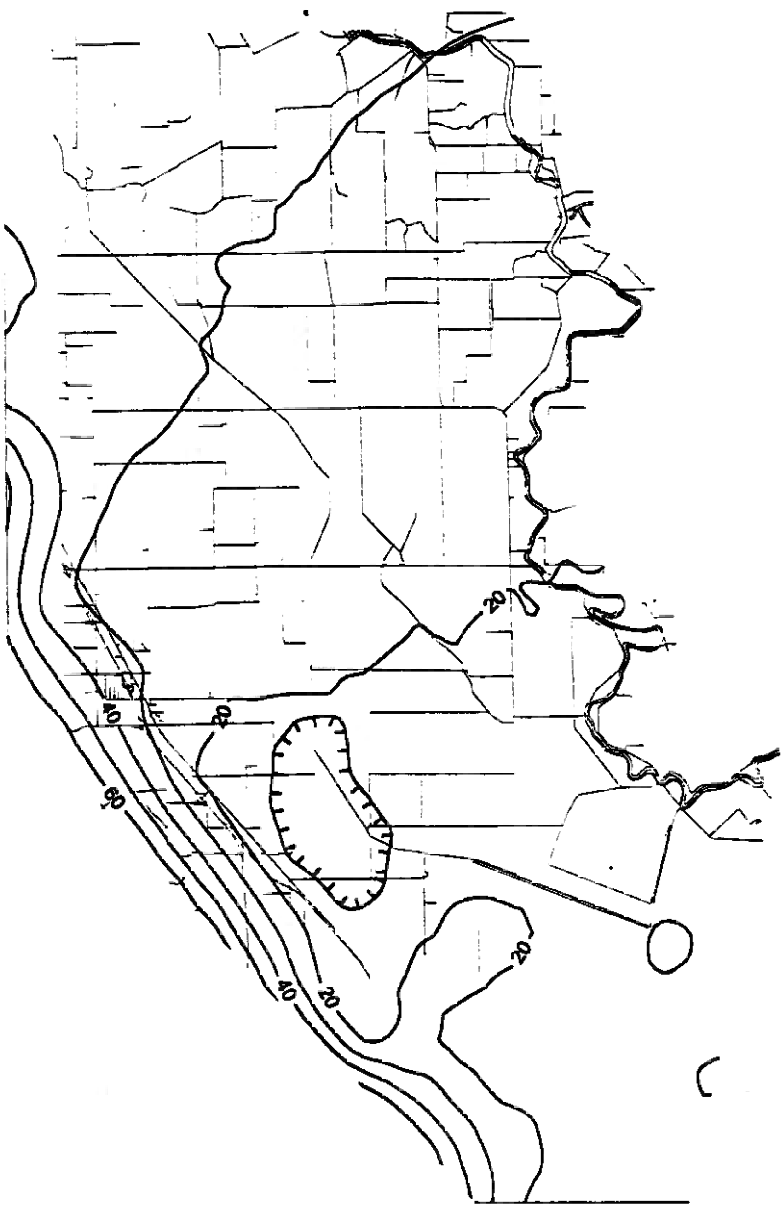


Figure 20. 1992 Groundwater Elevation - Lower Colusa Basin

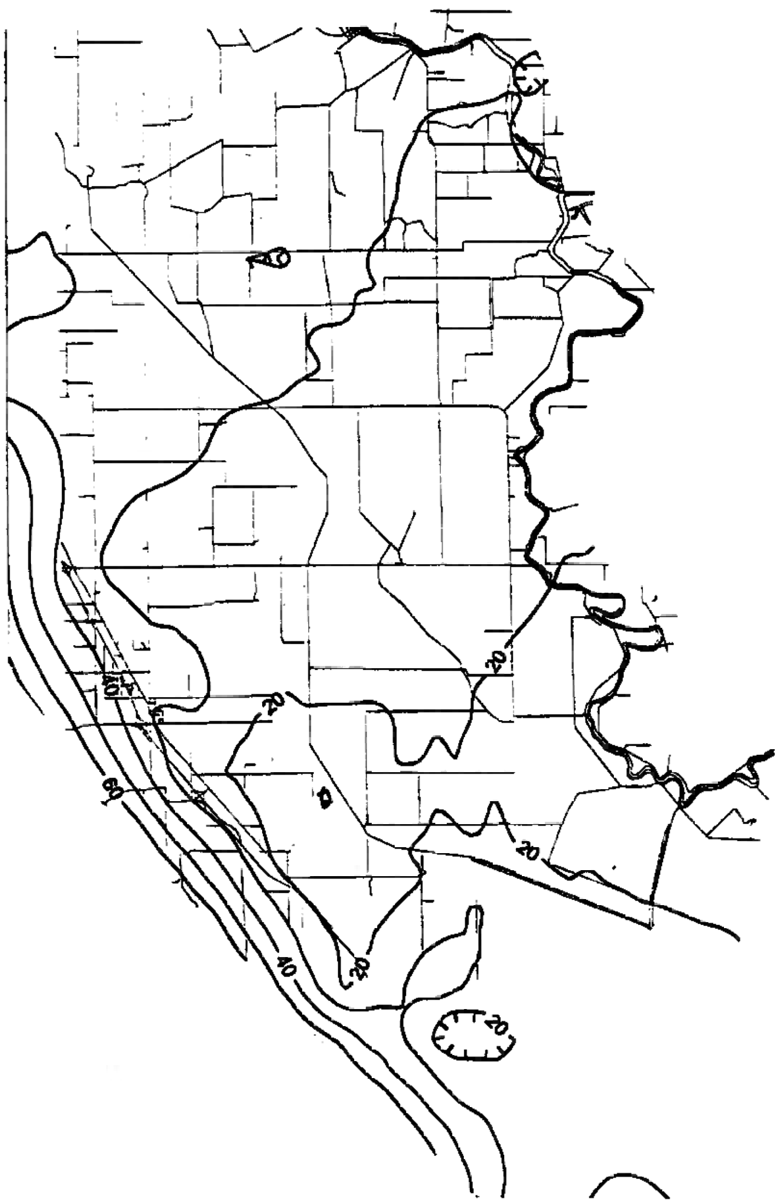


Figure 21. 1993 Groundwater Elevation - Lower Colusa Basin

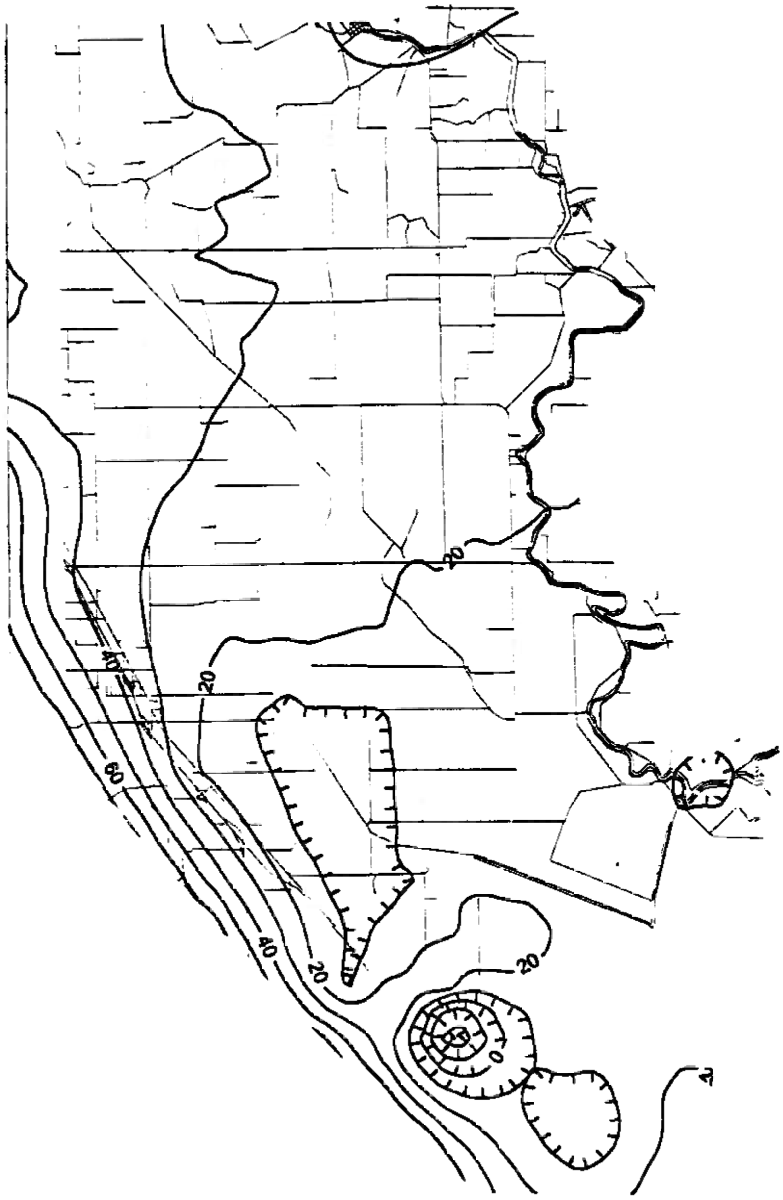


Figure 22. 1994 Groundwater Elevation - Lower Colusa Basin

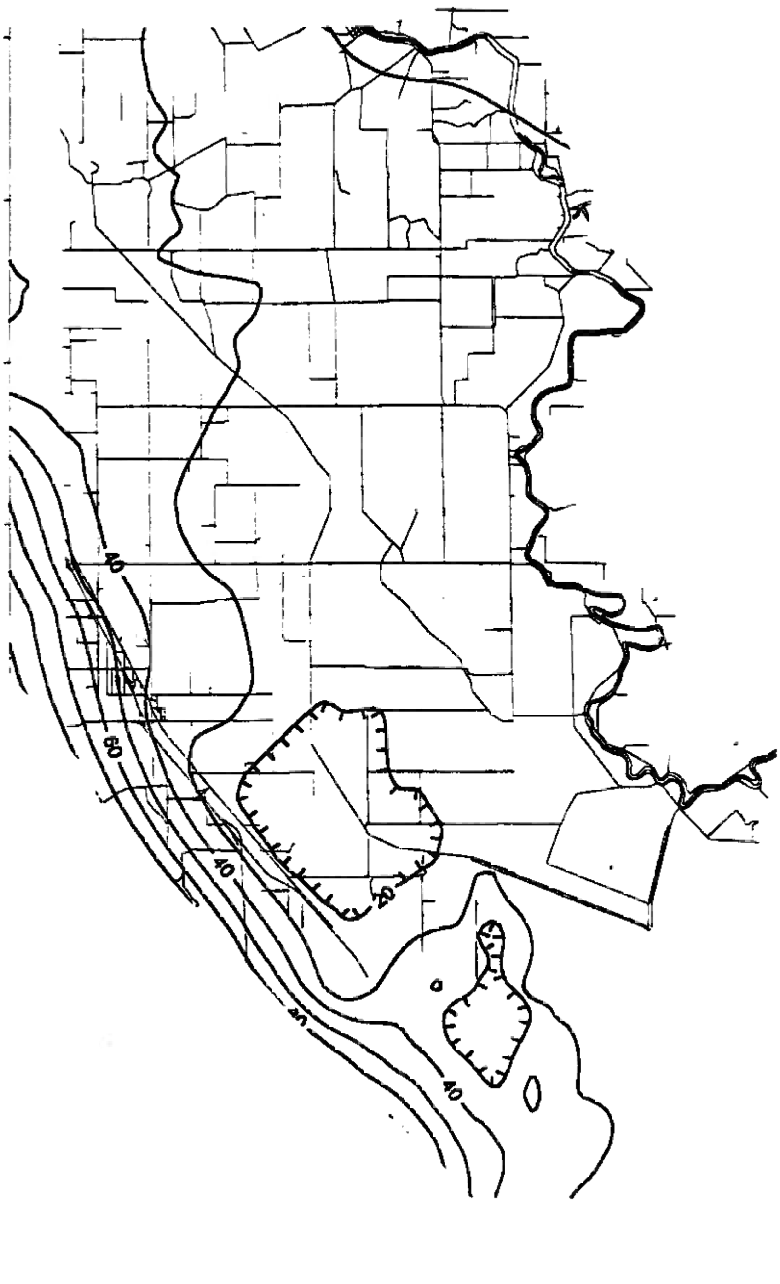


Figure 23. 1995 Groundwater Elevation - Lower Colusa Basin

to completion of the Tehama-Colusa Canal and during the recent drought. This reliance on groundwater is reflected in the groundwater depressions that persist in the western part of the study area underlying Dunnigan and Yolo-Zamora. During the intense 1976-77 drought much of the area within these districts had groundwater elevations below sea level. Between this period and the 1987-92 drought water levels generally recovered in the area with only limited areas, primarily within Yolo-Zamora in the drier years, having groundwater elevations below sea level. This condition continued into the recent drought. However, extensive areas with sub-sea level groundwater elevations did not develop until 1991 and was followed by recovery during the latter part of the study period.

Local Water Purveyors

Reclamation District No. 108, Colusa County Water District and Yolo-Zamora Water District are participating in this investigation. The proposed project would deliver water to Yolo-Zamora and Colusa County Water District in wet and above normal years for inlieu recharge. For Colusa County Water District, existing facilities would be modified as necessary and used to convey water to the recharge areas. No conveyance facilities exist within Yolo-Zamora and the new required facilities are discussed in Chapter 6. Facilities within RD-108 may be used to convey water from the Sacramento River to the Colusa Basin Drain for subsequent deliveries to the other districts. In dry years these districts would revert to their normal operations. Moreover, in these years, RD-108 would pump groundwater to substitute for a portion of the diversions it would otherwise make from the Sacramento River. The existing facilities within these districts is briefly described in the following sections.

Reclamation District No. 108

Reclamation District No. 108 provides drainage, water supply and flood protection within its service area. The major facilities of the district are shown in figure 24.

Reclamation District No. 108 provides drainage service to approximately 58,000 acres between the Sacramento River and the Colusa Basin Drain. The district operates and maintains about 301 miles of drainage ditches and two pumping plants that return drainage to the Sacramento River. Six units at the Rough and Ready plant have a capacity of 800 cfs and one unit at the El Dorado Bend plant has a capacity of 150 cfs. In addition, pumping plants at Sycamore Slough, Riggs Ranch, and on lateral 8 recirculate a portion of the district's drain water back into the irrigation delivery system. Annual drainage discharges from the Rough and Ready plant for the period 1980-95 are listed in table 9. The

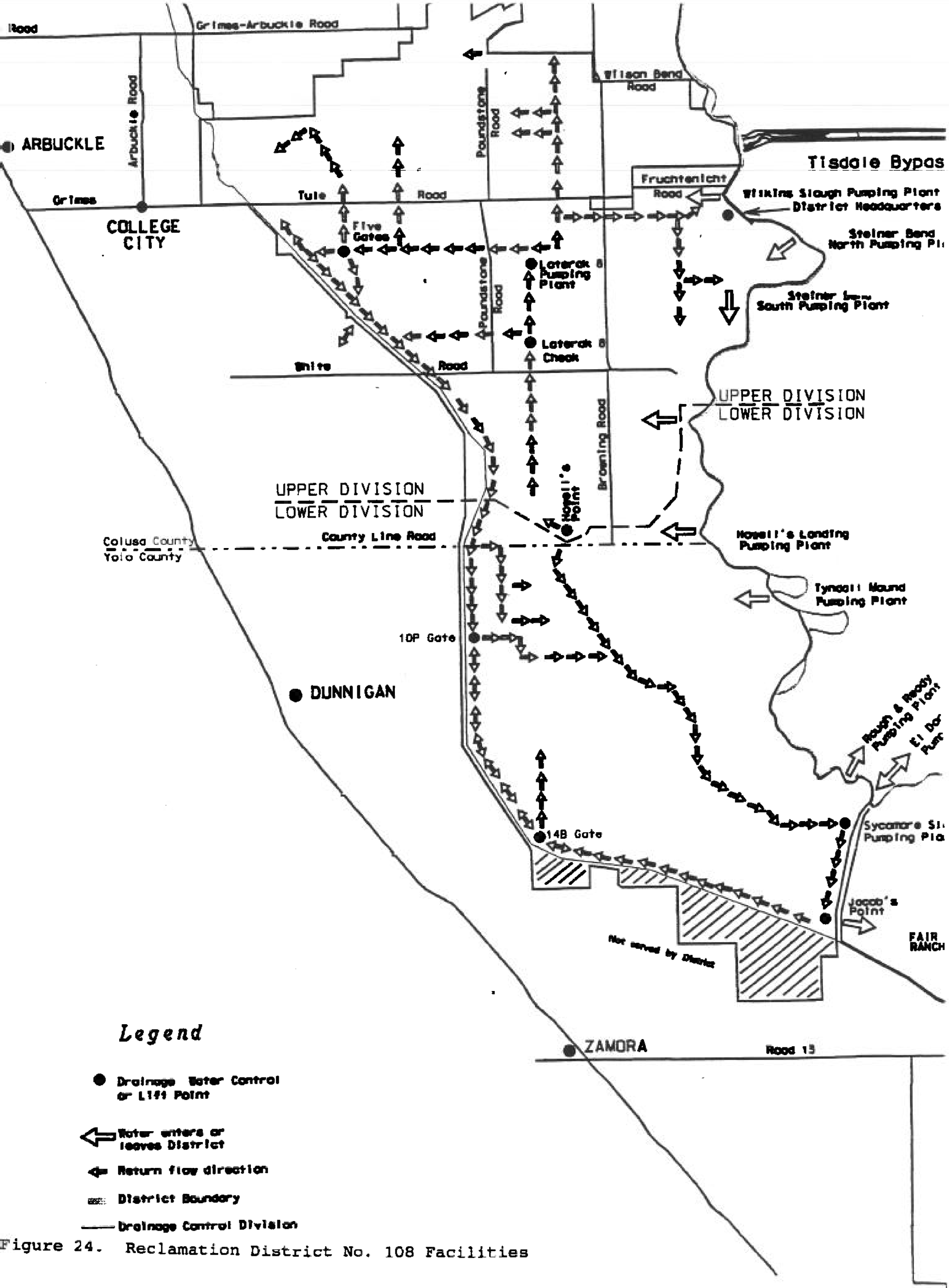


Figure 24. Reclamation District No. 108 Facilities

average discharge to the Sacramento River during this period was approximately 49,700 af/yr. At present, the district operates the drainage system to retain all drainage in the district during the period when rice herbicides are present.

Table 9. Annual Drainage Discharge at the Rough and Ready Plant (acre-feet)

Year	Discharge	Year	Discharge
1980	79,307	1988	33,976
1981	80,396	1989	22,946
1982	100,711	1990	23,183
1983	25,547	1991	16,800
1984	46,510	1992	12,243
1985	43,740	1993	67,108
1986	37,184	1994	23,528
1987	39,989	1995	132,355

RD-108 operates seven pumping plants to divert water from the Sacramento River for irrigation purposes. The capacities of these plants is shown in table 10. In addition, the Riggs Ranch Pumping Plant has the capability of diverting water from the Colusa Basin Drain. Irrigation service is provided to approximately 47,000 acres within the district.

The district is constructing fish screens for the Wilkins Slough plant that are expected to reduce useable capacity at the plant to 700 cfs. An additional pumping unit is installed at El Dorado Bend but is not operational.

The district delivers water through a system of 35 miles of concrete-lined canals and 84 miles of unlined canals that serve all lands within the district with the exception of a small area southwest of the Colusa Basin Drain that is not presently served.

The district owns three wells that can be used to supplement surface water deliveries.

Colusa County Water District

Colusa County Water District contracts with the U. S. Bureau of Reclamation for a supplemental surface water supply for lands within the district. The sole source of supply is deliveries from the Tehama-Colusa Canal. The district delivers water to an irrigated area of approximately 40,300 acres through a 105-mile system of pipelines. All deliveries are metered. Prior to completion of the Tehama-Colusa Canal the district received water

Table 10. RD-108 Pumping Plant Capacity (cfs)

Plant	Capacity
Wilkins Slough	910
North Steiner	6
South Steiner	12
Boyer Bend	130
Howell's Landing	70
Tyndall Mound	200
El Dorado Bend	160

through a temporary diversion from the Colusa Basin Drain. The pumping plant from the drain has been abandoned and removed. However, the pipeline that delivered water to the Tehama-Colusa Canal remains in place and is currently used for gravity delivery of water from the canal. The major facilities of the district are shown in figure 25.

Yolo-Zamora Water District

Lands within the Yolo-Zamora Water District are reliant on groundwater. The district does not own or control either wells or surface conveyance facilities. The Yolo County Flood Control and Water Conservation District occasionally provides limited amounts of surface water to lands along China Slough.

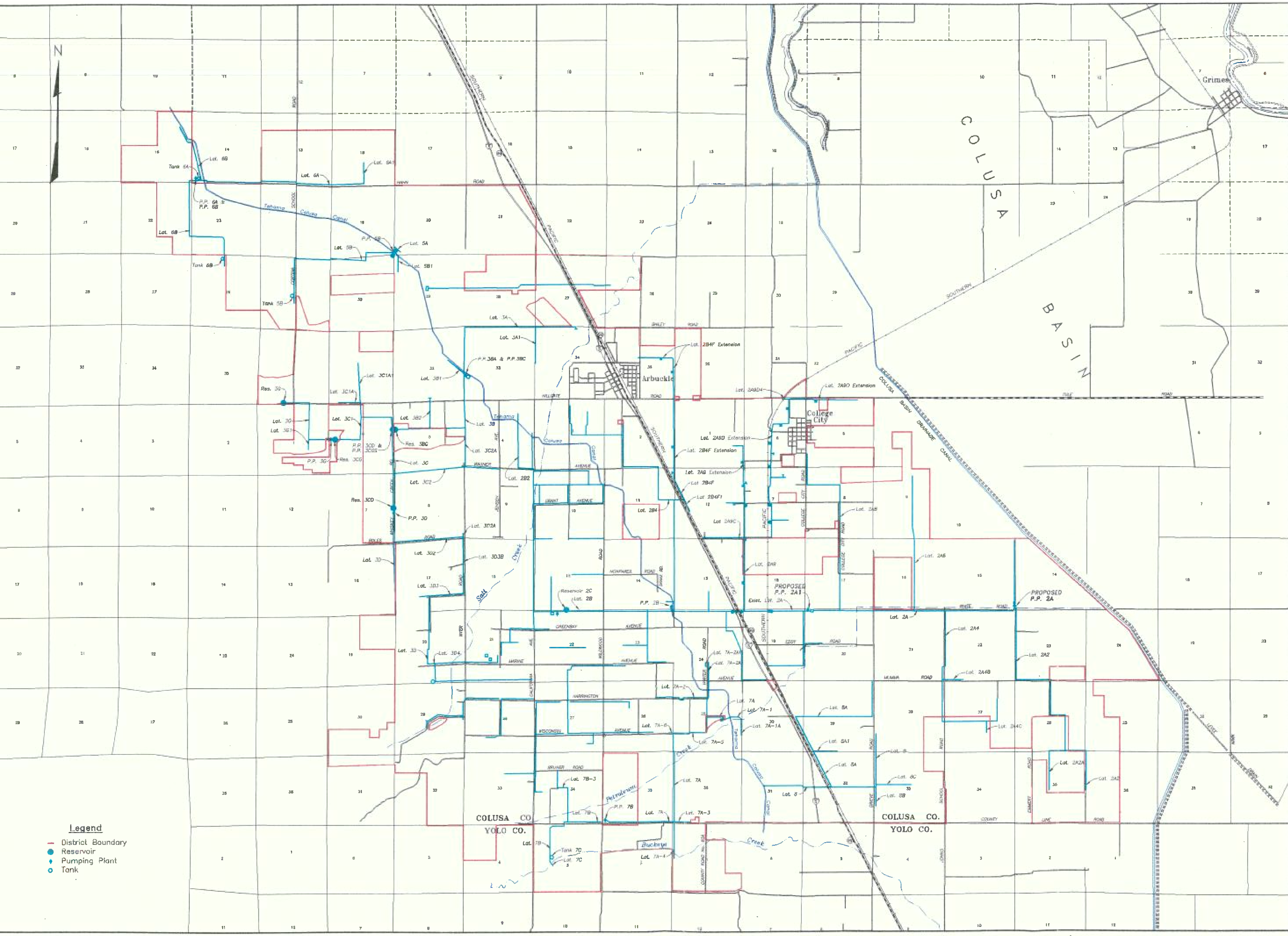


Figure 25
COLUSA COUNTY WATER DISTRICT
IRRIGATION SYSTEM WITH PROPOSED FACILITIES

Chapter 3

GEOLOGY AND HYDROGEOLOGY

Available data indicate that the Lower Colusa Basin is suitable for conjunctive operation. There are more than 1,000 feet of fresh water-bearing deposits throughout most of the study area. Wells 300-600 feet deep typically produce 2,500 to 3,000 gallons per minute. Area aquifers typically exhibit increasing confinement with depth, suggesting several potential production zones exist. A large area in the central part of the study area, with limited groundwater development, exists which could be used for project extraction with limited impact to other users. Finally, increased groundwater levels resulting from increased surface water via the Tehama Colusa Canal indicate that in lieu recharge is viable in the study area.

The Sacramento Valley (Valley) comprises the northern one-third of the Central Valley, a large, northwest-trending structural trough. The Valley is bounded on the east by the Sierra Nevada Range and on the west by the Coast Range.

The Valley is filled with up to 50,000 feet of sediment (Page 1986). This sediment was deposited mainly in marine environments from the early Cretaceous to the Eocene epoch (Table 11), and in nonmarine settings from the post-Eocene to Holocene (Olmstead and Davis 1961). Nonmarine sediments generally constitute the upper 1,500 to 3,000 feet of fill and contain the fresh groundwater resources of the Valley.

Table 11. Geologic Time Scale

Era	Period/ Epoch	Beginning of Period/Epoch (million years before present)
Cenozoic	Quaternary	
	Holocene	0.01
	Pleistocene	2
	Tertiary	
	Pliocene	5
	Miocene	24
	Oligocene	39
	Eocene	54
	Paleocene	65
Mesozoic	Cretaceous	144
	Jurassic	208
	Triassic	245
Paleozoic	Permian	286
	Pennsylvanian	320
	Mississippian	360
	Devonian	408
	Silurian	438
	Ordovician	505
	Cambrian	570

Local Structure and Features

The Zamora syncline trends from southeast to northwest through the study area (Figure 26). South and southwest of the study area are the Dunnigan Hills anticline and the Zamora fault. These structures are believed to have formed during the last 1.0 m.y. and were active to the present. They are observed in the post-Eocene sediments (Harwood and Helley 1987). The presence of these structures is an indicator that undetected structures may exist in the subsurface within the study area.

Several gas fields are present within the study area (Figure 27). The fields are associated with structures in the marine formations from the Eocene epoch and earlier. These structures do not significantly impact the later nonmarine deposits.

The land surface of the study area is gently sloping with local relief provided by manmade levees and the natural levees of the Sacramento River. Near surface sediments are primarily finer-grained flood basin deposits from the Sacramento River (Figure 26). Recent alluvium of the Sacramento River channel borders the study area to the east while alluvial fan deposits from the Coast Range are present in the west.

Water Bearing Units

In general, fresh groundwater in the study area is found in the Tehama Formation and more recent deposits. These units are briefly described in the following sections.

Tehama Formation

The Tehama Formation represents the primary source of groundwater on the west side of the Sacramento Valley. In general, the formation consists of thick-bedded sandy silt and clays with thin, discontinuous gravel and sand lenses deposited in a floodplain environment. These sediments were derived from the Coast Ranges to the west and the Klamath Mountains to the northwest. The Tehama Formation is estimated to be approximately 1,500 to 2,000 feet thick near the study area with the lower 1,000 feet below the base of fresh water (~2,000 mg/l).

Red Bluff Formation

The Red Bluff Formation is not considered to be an important source of groundwater in the Valley. The Red Bluff Formation consists of poorly sorted gravel in a silty/sandy matrix with a typical thickness of less than 50 feet. The Red Bluff Formation was reported as overlying the Tehama Formation in the Dunnigan Hills (Olmstead and Davis 1961), but according to Hollinger

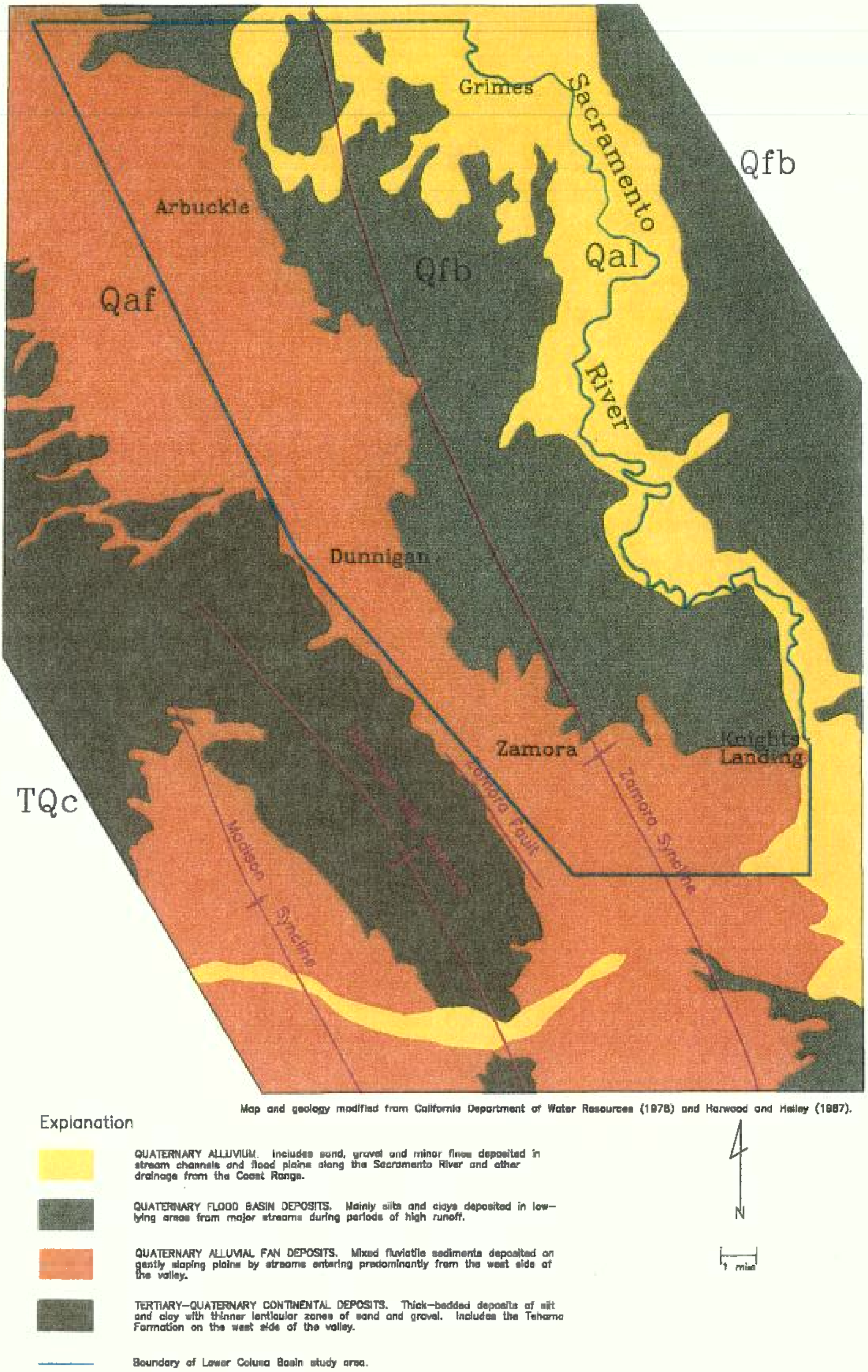


Figure . Geologic formations and structures in the Lower Colusa Basin study area.

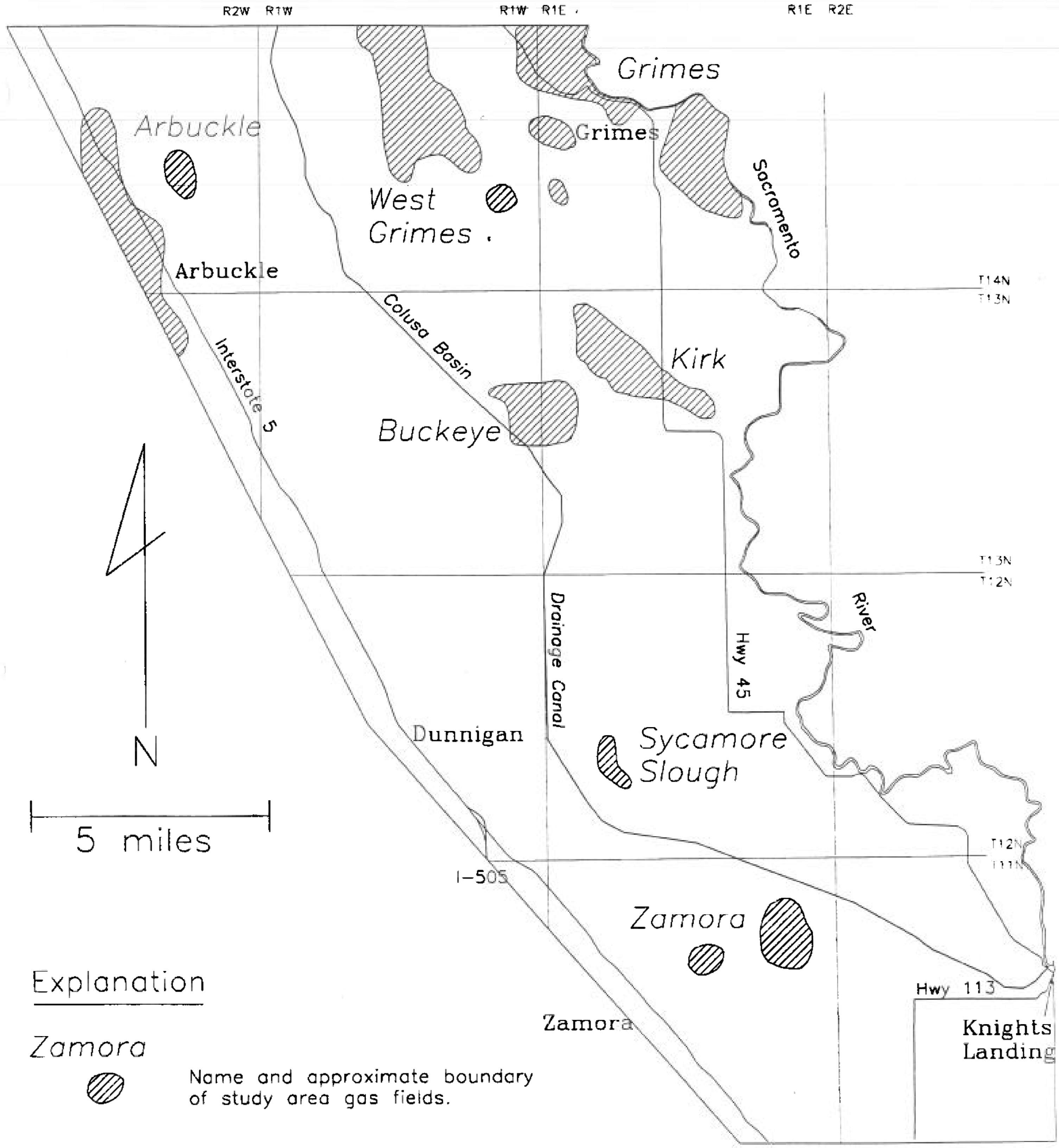


Figure 27. Locations of Natural Gas Fields in the Lower Colusa Basin Study Area

(1980), recent data indicate the Red Bluff Formation exists only in the northern Sacramento Valley.

Alluvium

Alluvium constitutes a significant source of groundwater locally. Sediments range from silts and clays of the flood basin to silts, sands and gravel in the Sacramento River channel. Recent alluvium generally occupies the upper 100 feet of sediments in the study area and together with older alluvium may comprise the upper few hundred feet of the aquifer system. The thickness of this unit is difficult to determine because the boundary with the underlying Tehama Formation is not distinct.

Alluvial Fan Deposits

Alluvial fan deposits are a source of groundwater to smaller domestic wells. Sediments are typically inter-fingered silts and clays with sand and gravel deposited by runoff from the Coast Ranges. Alluvial fan deposits occupy less than the upper 100 feet of sediments along the west side of the study area.

Soil Properties

Bertoldi (1974) provided general estimates of the permeability of soils in the Sacramento Valley. Figure 28 is modified from Bertoldi to show the relative ability of soils to impede the vertical flow of water in the surface area. These soils are potentially suitable for direct recharge.

Soils along the outer boundaries of the study area generally have few barriers to the vertical flow of water. On the east, these soils are associated with the Sacramento River levees. This area is undesirable for direct recharge because significant amounts of groundwater could be lost to the river. Along the western and southern boundary, soils with few barriers to vertical flow are associated with ephemeral streams draining the Coast Range. Groundwater recharged from these streams is thought to be generally poor quality making these areas undesirable for direct recharge.

Throughout most of the rest of the study area, soils are associated with flood basin deposits containing enough clay to effectively limit the vertical flow of water. These soils are generally unsuitable for direct recharge.

Hydrogeologic Cross-Sections

Electric logs from water and oil/gas wells were selected to represent the subsurface geology. A geologic map, and contour maps of the base of fresh water and continental deposits were

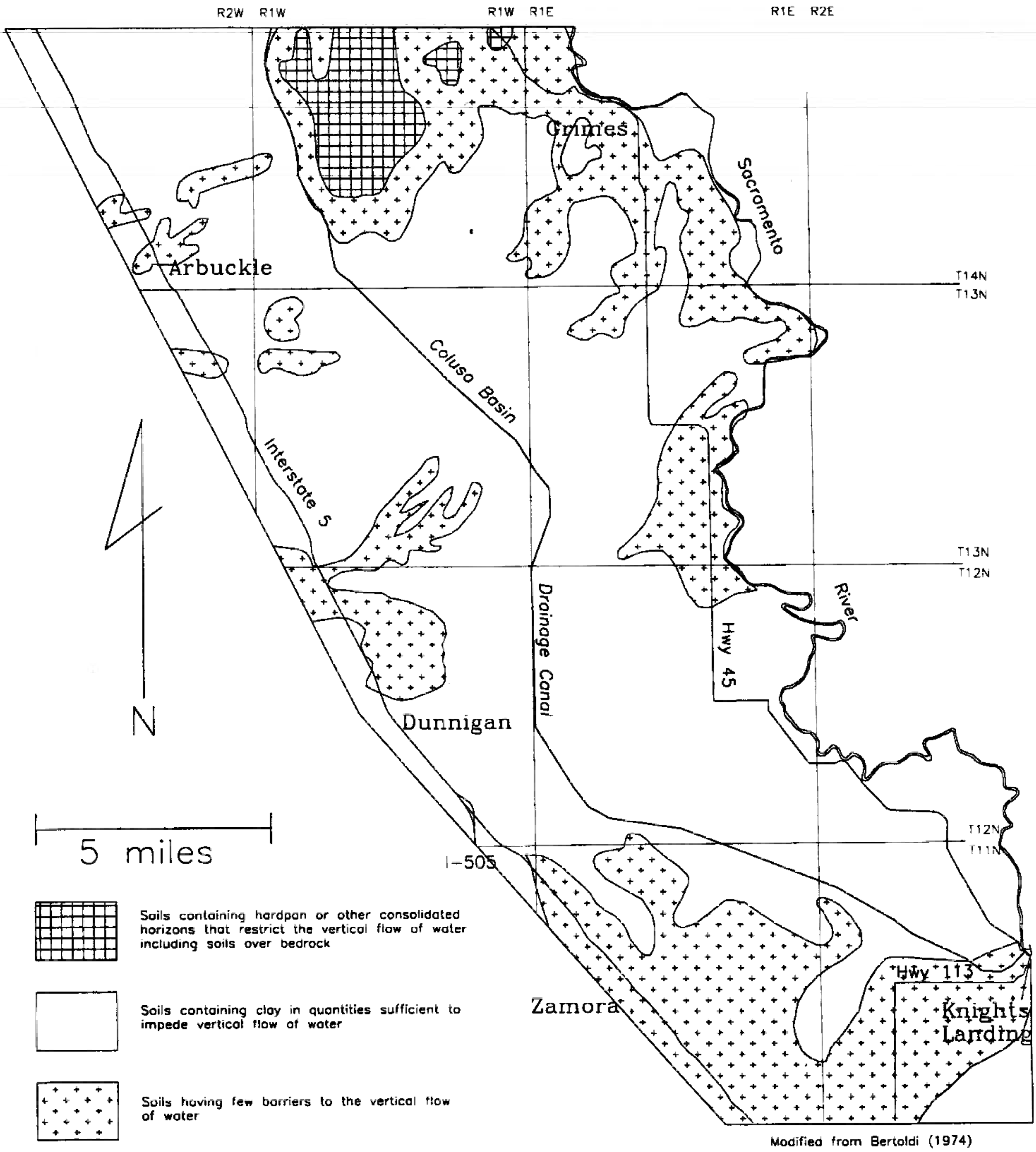


Figure 28. Barriers to Vertical Flow in Soils in the Lower Colusa Basin Study Area

used to construct a fence diagram of the upper 2,500 to 3,000 feet of sediments near the study area. The diagram shows the thickness of continental deposits, the base of fresh water, distribution of some potentially significant aquifer zones, and shallow alluvial and flood basin deposits.

The thickness of post-Eocene non-marine sediments was estimated based on work by Page (1974). Non-marine sediments in the study area range from approximately 2,250 feet to 3,000 feet thick. The base of fresh water (2,000 mg/l) was estimated from available electric logs and from previous work by Berkstresser (1973). The base of fresh water in the study area ranges from approximately -800 feet to -2,800 feet as shown in figure 29. East of the study area, the base of fresh water shallow is as shallow as 400 feet below sea level.

Electric logs from water and oil/gas wells were selected along transects to characterize the upper 1,000 feet of sediments in the study area (Figure 30). Spontaneous potential curves were not used in correlations because of the limited response in the fresh water portion of the basin. Instead, the resistivity curve and available lithology logs were used.

Cross sections A-A' through E-E' (Figures 31-35) were constructed with existing data. Additional sections in the southern portion of the study area may be completed as future exploration is completed. Three depth zones were selected for discussion: the shallow zone extends from approximately 0-300 feet; the intermediate zone is from 300-600 feet; and the deep zone is from 600-1,000 feet deep. These depth zones correspond to groundwater development in the study area. Small domestic wells are usually completed in the shallow zone. Large irrigation wells are primarily completed in the intermediate zone with a few completed in the deep zone.

Shallow Zone

The shallow zone encompasses a variety of depositional environments. It includes alluvial fans from the west, alluvium from the Sacramento River channel and flood basin deposits from the Sacramento River. While gravel/sand zones of significant thickness exist in this depth interval, they are generally not correlatable over long distances and do not appear to be deposited by sources from the west (sections C-C' and E-E').

Intermediate Zone

The intermediate zone likely consists of the upper Tehama Formation. This zone contains prominent units, that can exceed 100 feet thickness, described as a loose gravel or rough loose gravel on drillers logs. These gravel are easily observed on sections A-A', B-B', and C-C'. The cross-sections suggest that

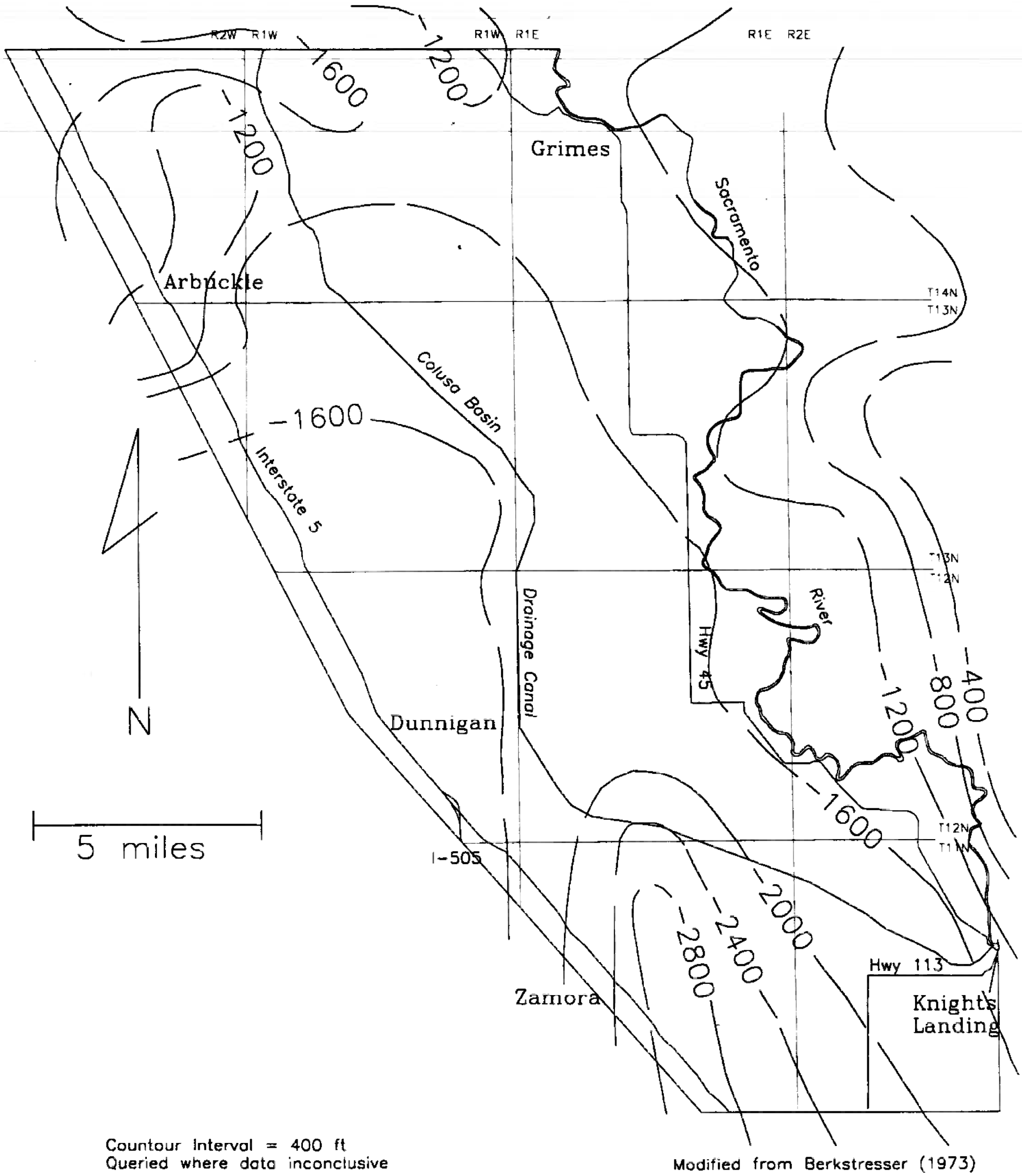


Figure 29. Contours of Elevation of Base of Fresh Water in the Lower Colusa Basin Study Area

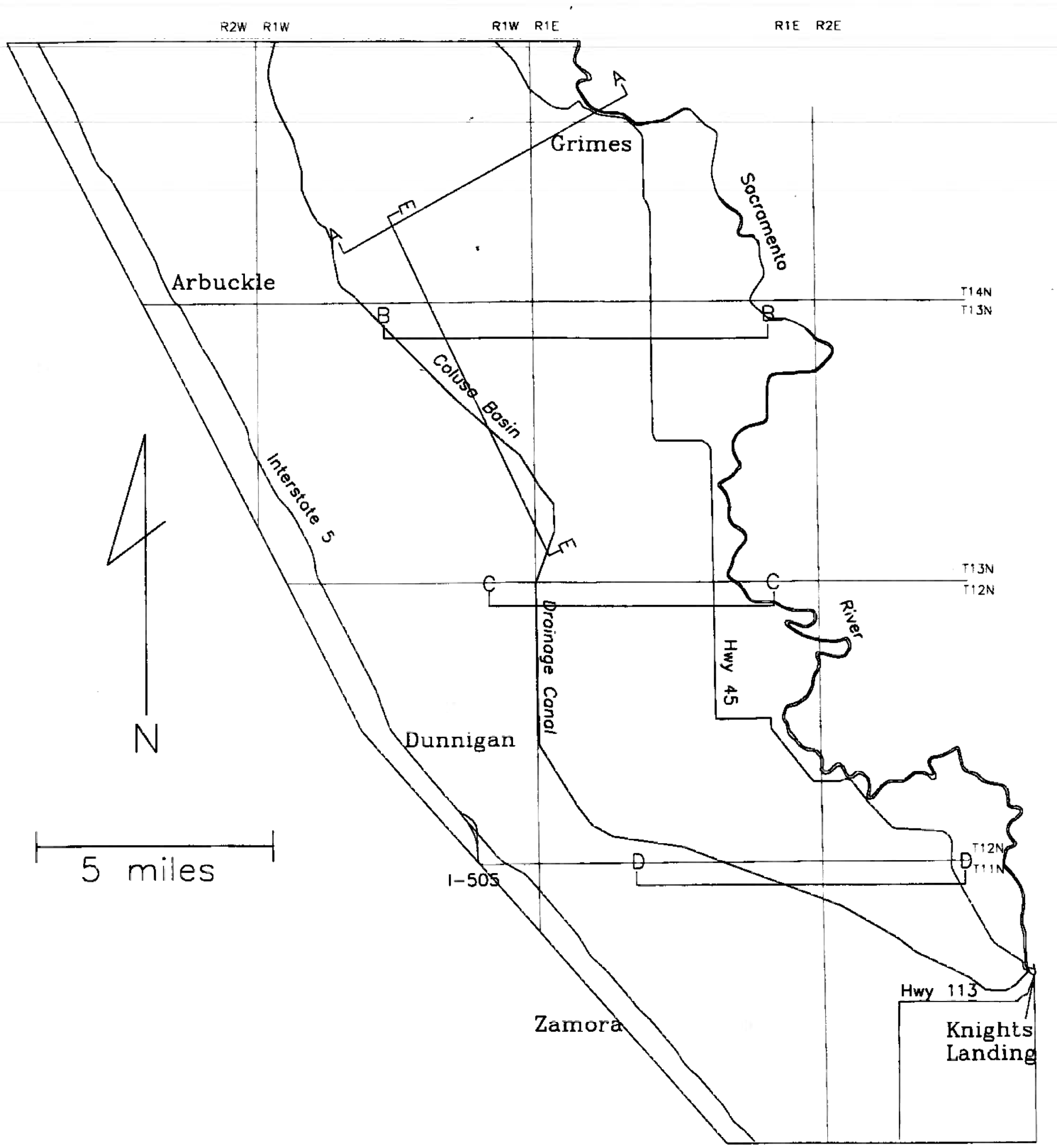
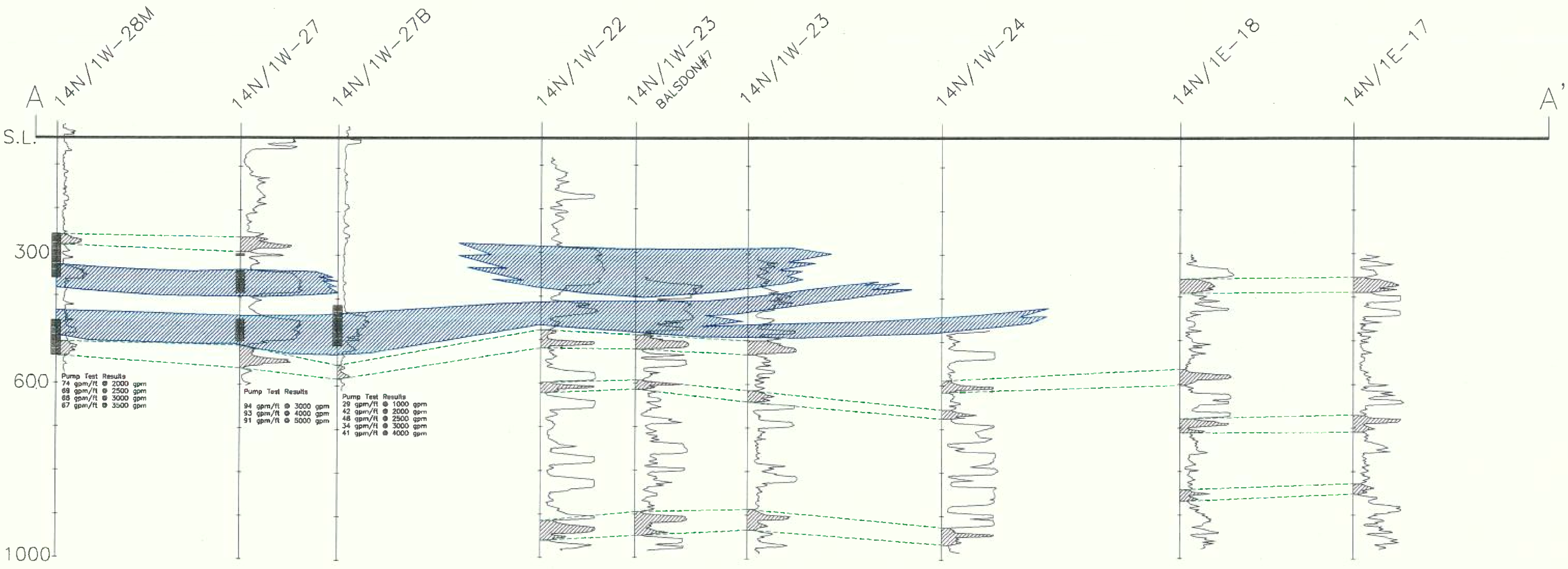


Figure 30. Alignment of Cross-Sections in Lower Colusa Basin Study Area



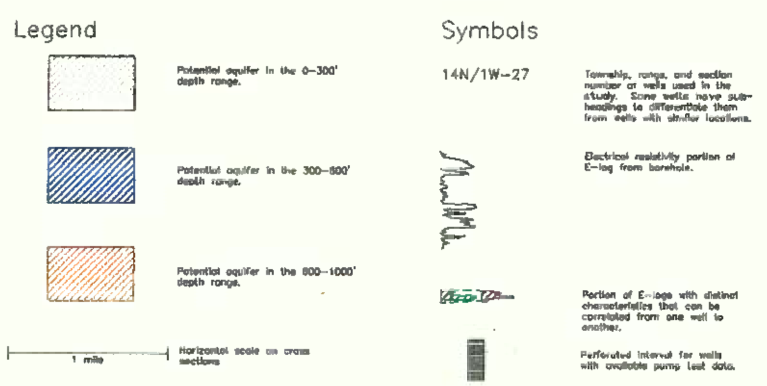
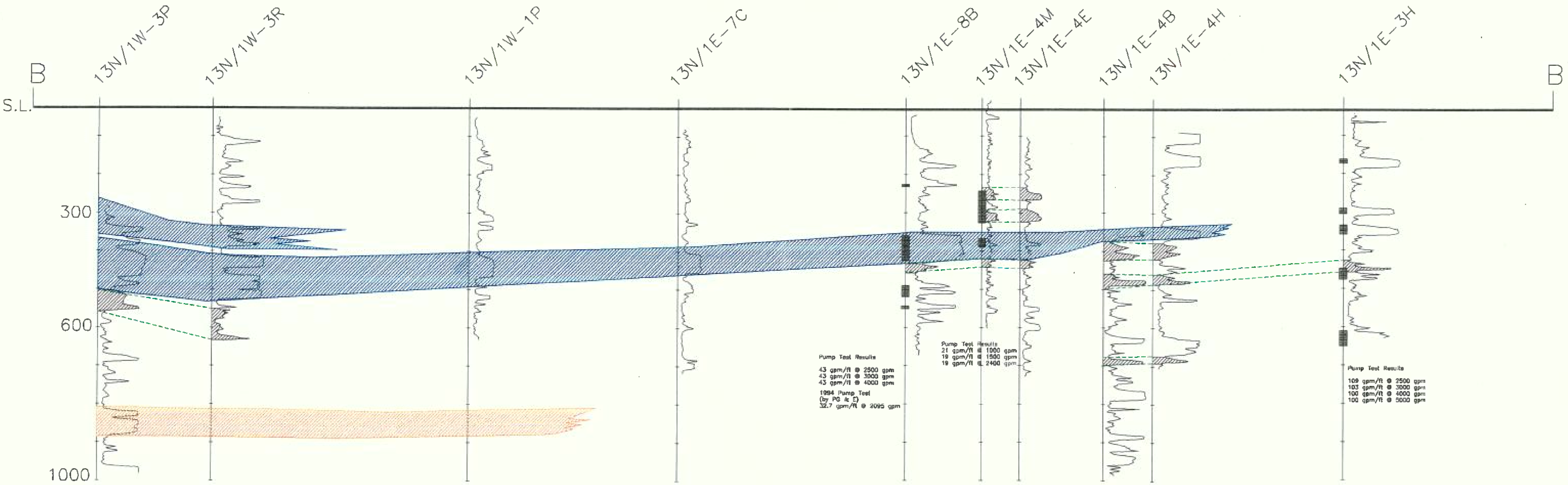


Figure 31. Geologic Section A-A'.



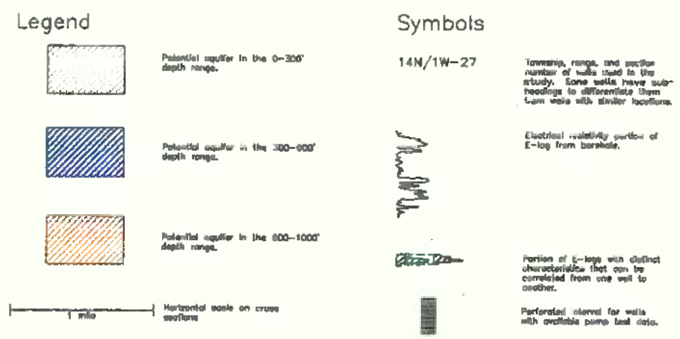


Figure32 . Geologic Section B-B'.

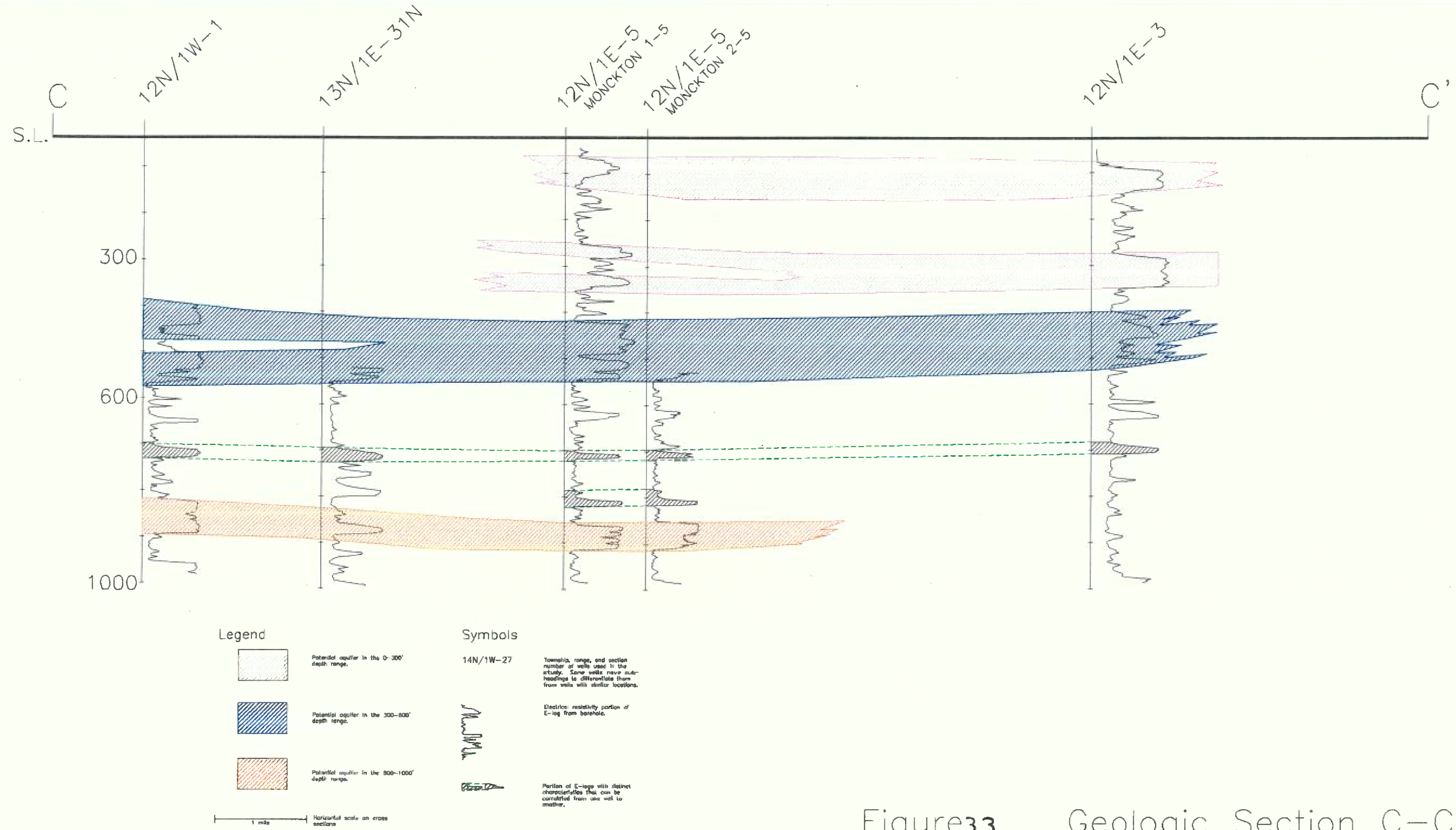


Figure 33. Geologic Section C–C'.

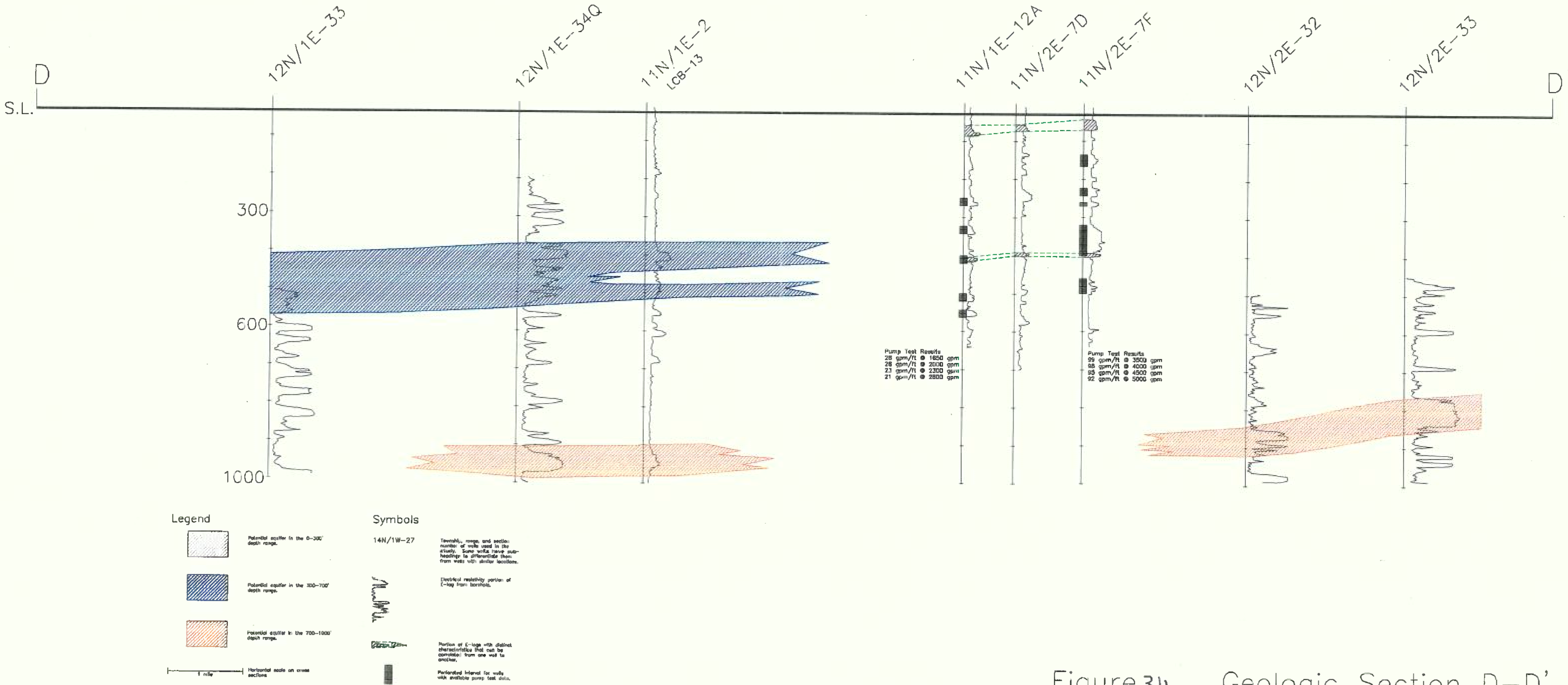


Figure 34. Geologic Section D-D'.

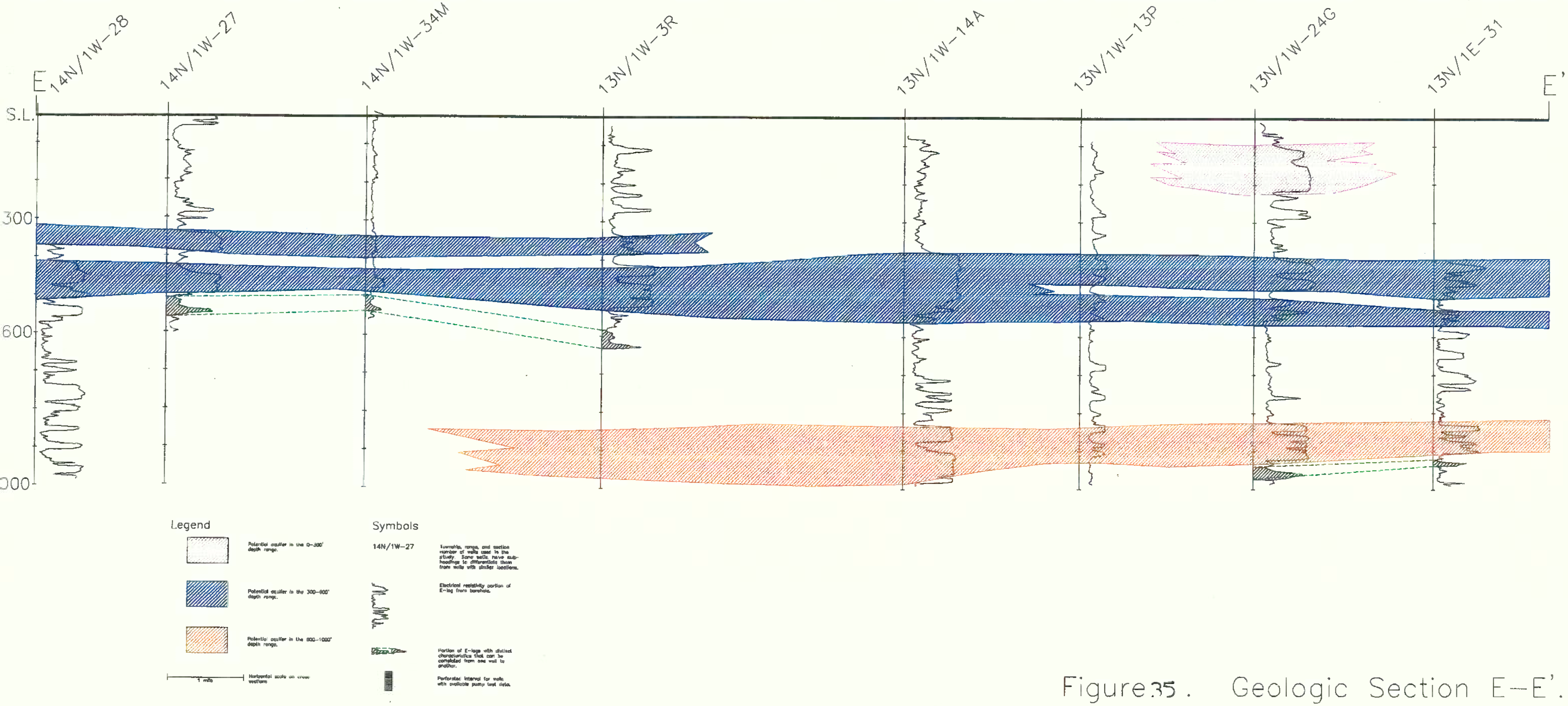


Figure 35. Geologic Section E–E'.

the gravel zones have a maximum thickness somewhere between section B-B′ and C-C′. Section D-D′ also contains a gravel unit within the same depth interval as the other sections but it is less continuous and less pronounced. The extent of the gravel unit to the south of section C-C′ and whether it is related to the gravel on section D-D′ will be investigated as data from continued exploratory drilling becomes available.

Deep Zone

The deep zone is likely exclusively within the Tehama Formation. This zone contains a prominent gravel/sand unit that can be correlated over several miles. This unit may extend north to section A-A′, but it does not appear to extend as far east as the intermediate zone gravel. The extent of this unit to the south is unknown, but it does not appear to be related to the deep gravel zone on section D-D′.

Existing Groundwater Development

This report does not attempt to identify all groundwater wells in the study area. A limited review of logs for wells constructed mainly in the southern half of the study area indicates that nearly half of the irrigation wells were constructed from 1960 to 1980. Since 1980, the number of new wells has been low and stable, possibly due to increased surface water supplies. There was an increase in well construction in the early 1990′s, probably due to drought conditions, but the increase in construction was not nearly as dramatic as new construction associated with the 1976-1977 drought.

In general, wells used for irrigation are concentrated in the northern, southern and western portions of the study area. The central and eastern areas have low irrigation well concentrations. Most of the wells can also be grouped as being completed in the shallow, intermediate or deep intervals of the aquifer system. Domestic wells are concentrated predominantly around towns near Interstate 5.

Wells completed primarily in the upper 300 feet of the aquifer system for irrigation purposes are concentrated along the eastern side of the study area and are completed in recent and older channel deposits of the Sacramento River. There are also shallow wells completed in the northern and southern parts of the study area, but these are typically smaller domestic wells.

Most of the large irrigation wells are completed to a depth of between 300 and 600 feet. This depth interval would likely correspond to the Tehama Formation.

In general, wells in the study area have not been completed deeper than 600 feet. Recent Water Well Completion Reports submitted to DWR indicate that there have been several wells drilled to near 1,000 feet over the last several years in the northern part of the study area. These wells also into the Tehama Formation.

Aquifer Properties and Well Discharge Characteristics

Discharge rates, where available, for the wells are presented in Figure 36. Specific capacity was calculated by dividing the well discharge by the drawdown. In many cases, several tests were conducted on a single well at varying discharge rates. Only data for the maximum discharge rate are presented here.

It is important to note that most of these tests were conducted over short time intervals (< ~2 hours) and the tests were after initial construction of the wells. Long-term well discharge data for study area irrigation wells is very limited. However, the available data should provide a reasonable estimate of expected well discharge in the basin.

A total of 28 irrigation wells with discharge data were utilized. The average total depth of the wells is 439 feet with the average top of perforated casing at about 212 feet. The average discharge for the irrigation wells is 3,197 gpm with a specific capacity of 54 gpm/ft. Eight wells are completed predominantly in the shallow zone, 17 wells in the intermediate zone, and three are in multiple zones.

The shallow zone wells have an average discharge of near 2,700 gpm with a range from 800 to 3,630 gpm. The average specific capacity is about 62 gpm/ft with a range from 13 to 92 gpm/ft.

The intermediate zone wells have an average discharge of approximately 3,370 gpm and range from 1,650 to 5,000 gpm. The average specific capacity is about 50 gpm/ft with a range from 19 to 93 gpm/ft.

No pump tests are available for wells completed exclusively in the deep zone. One well in the northern part of the study area is completed through the intermediate and deep zone. This well discharged 4,000 gpm with a specific capacity of about 87 gpm/ft when constructed.

Information on aquifer properties in the study area is limited. Bloyd (1978) estimated the storage coefficient in the unconfined portion of the aquifer ranging from 0.06 to 0.09, and transmissivities ranging from about 8,700 to 64,800 feet squared per day. Williamson and others, 1989, estimated transmissivities in the vicinity of the proposed well field to be approximately 9,300 feet squared per day to 12,700 feet squared per day based on the calibration of a simulation model of the Central Valley.

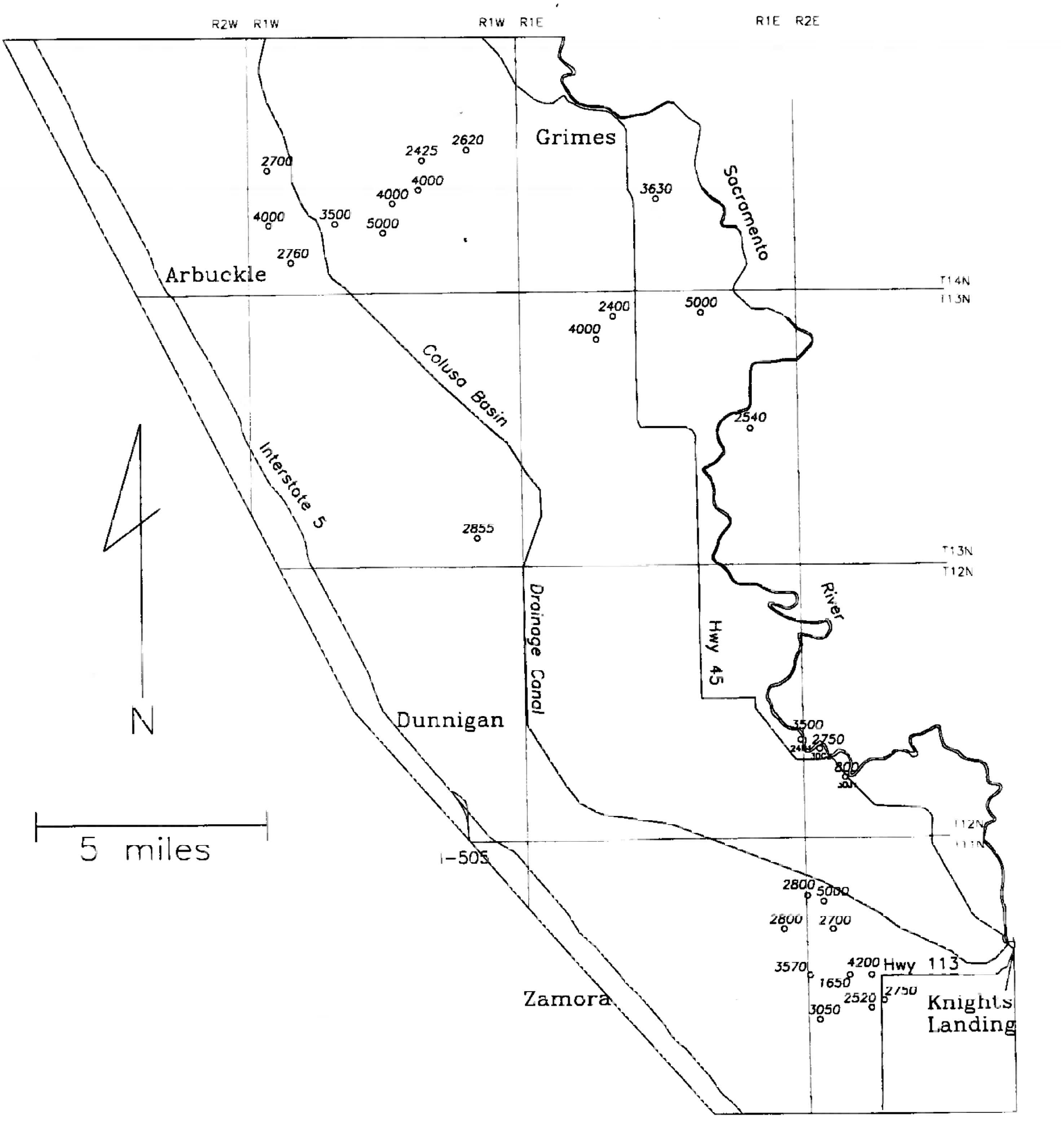


Figure 36. Discharge Rates (in gpm) for Irrigation Wells in Lower Colusa Basin Study Area

For the purpose of estimating seasonal drawdown associated with project pumping a field of twenty nine wells on a one mile spacing was assumed within RD-108. The transmissivity of the well field area was estimated to be about 13,300 feet squared per day based on the average specific capacity of wells completed in the middle aquifer zone. A storage coefficient of 0.003 was selected to represent semi-confined conditions. With the assumption of a 150 day pumping period the seasonal drawdown of the piezometric surface in the center of the well field could be as much as 150 feet. This decline is largely the result of interference effects within the well field. The expected decline would diminish rapidly with distance outside the well field. The estimated decline appears excessive given the lesser response seen with YZWD to normal pumping in that district. This could result from either an underestimate of the transmissivity in the project area or there being a lesser degree of confinement than assumed. It is likely that the transmissivity is under estimated since it was not increased to account for the shallow zone. Given the near complete lack of information on aquifer properties within RD-108, these estimates should be considered rather speculative and high priority should be given to obtaining improved estimates.

By making several assumptions, an estimate of the range of expected water table declines as a result of the proposed project extraction can be derived. These assumptions are listed below:

- The aquifer is homogeneous and isotropic
- Groundwater extraction is evenly distributed over the well field and no other extraction is occurring within the area.
- The pumping zone is recharged through leakage from the shallow unconfined aquifer

The drawdown is calculated by the following formula:

$$\Delta h = \frac{V}{SA}$$

where:

Δh	=	the change in groundwater head in feet
V	=	the volume of groundwater extracted from the aquifer in acre-feet
S	=	the storage coefficient of the aquifer (unitless)
A	=	the area from which groundwater is extracted in acres

Using a groundwater extraction volume of 34,000 acre-feet, a storage coefficient ranging from 0.06 to 0.09, and an area of about 20,480 acres, the calculated decline in the water table would range from about 18 feet to 27 feet. This estimate represents the average incremental decline of the water table resulting from imposing project extraction. It does not represent the total drawdown that would result from all pumping in the area.

Groundwater Levels

The Department of Water Resources, with other agencies, collects and maintains water level records for hundreds of wells in northern Yolo County and southern Colusa County. Some records date back to the 1920's. Representative years were selected to create groundwater elevation contour maps from available data. From this data set, several wells were selected for representative hydrographs in the study area. Additionally, hydrographs have been created for two monitoring wells constructed specifically for the proposed project.

Groundwater Elevation Contour Maps

Groundwater elevation maps were created showing Spring 1960, 1977, 1983, and 1996. Spring water levels generally represent the highest groundwater conditions during the year. No anomalies were observed on the contour maps within the study area. This indicates that if subsurface faulting does exist, it does not significantly impact the flow of groundwater in the study area.

The year 1960 was selected to represent somewhat natural conditions in the aquifer because it precedes much of the major groundwater development in the study area. Groundwater elevations for 1960 indicate that groundwater flow into the study area is primarily from the west and north (Figure 37). This flow pattern is consistent in subsequent years. The lowest groundwater elevation is about 20 feet in the central part of the study area and the 30 foot elevation is at the northern boundary of the study area.

In the drought year of 1977, decreased surface water supplies caused an increase in the amount of groundwater pumped and expected lowering of the water table (Figure 38). The 0 and 10 foot contours are in the central part of the study area and the 20 foot elevation is at the northern study area boundary. Additionally, pumping depressions have developed near Zamora and Dunnigan.

In a very wet 1983, groundwater levels appear to have completely recovered from the late 1970's drought (Figure 39). There are no pumping depressions near Zamora and Dunnigan and the 20 foot contour returned to the central portion of the study area. Note that the 40 foot contour is near the northern study area boundary. Water levels appear to exceed 1960 levels overall.

Finally, 1996 was selected to represent current groundwater elevations in the study area. Recent groundwater elevations

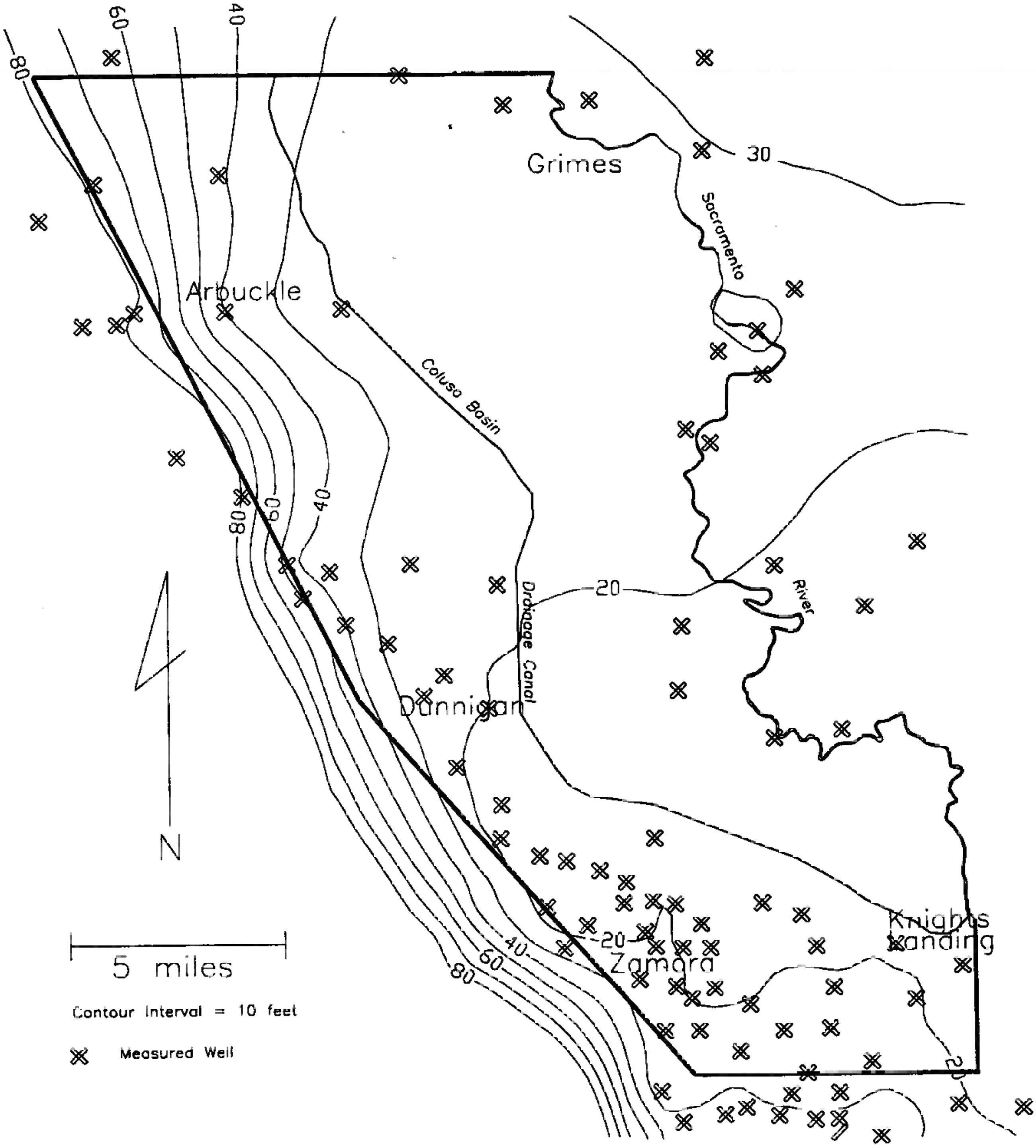


Figure 37. Spring 1960 Groundwater Elevations

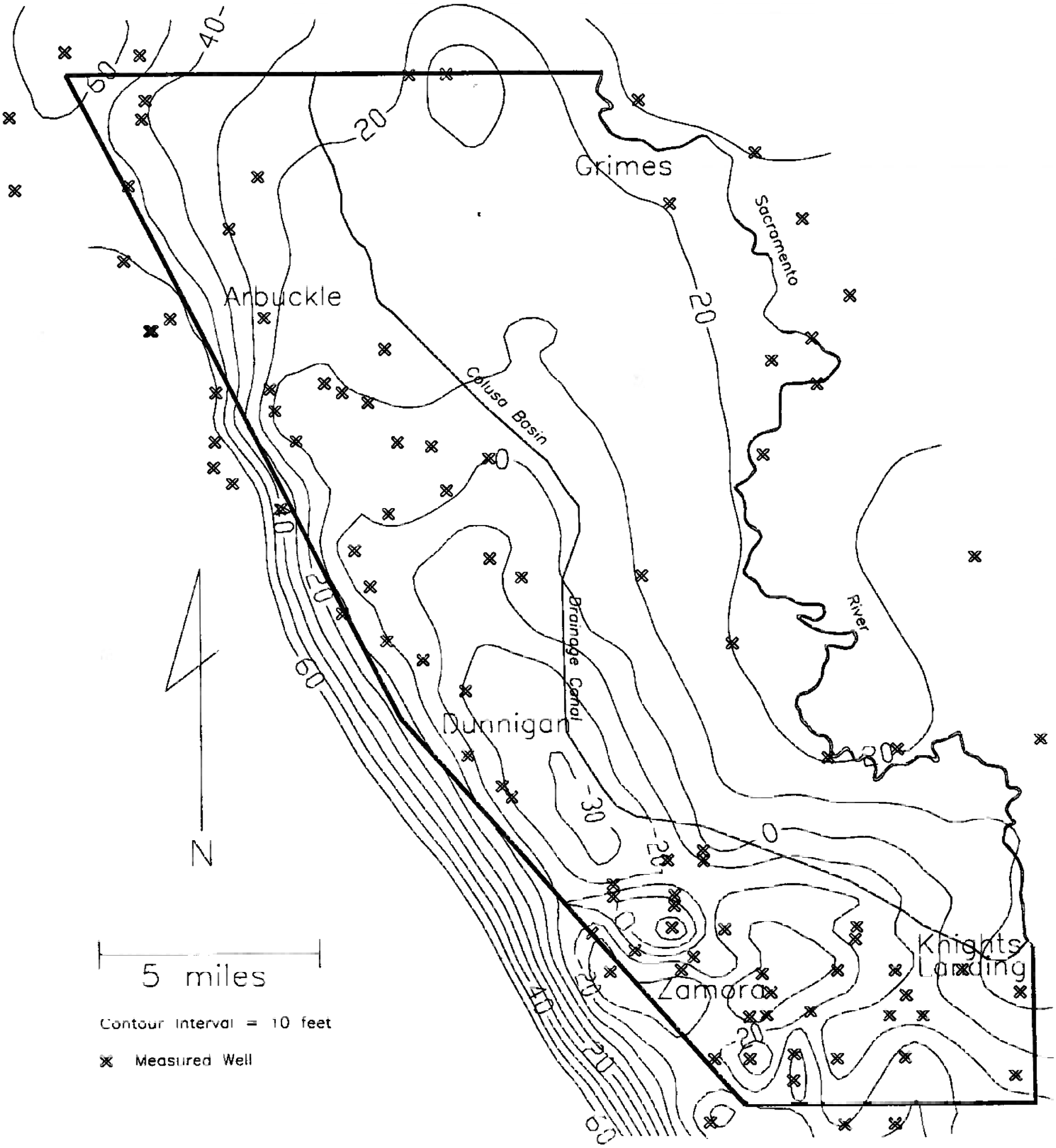


Figure 38. Spring 1977 Groundwater Elevations

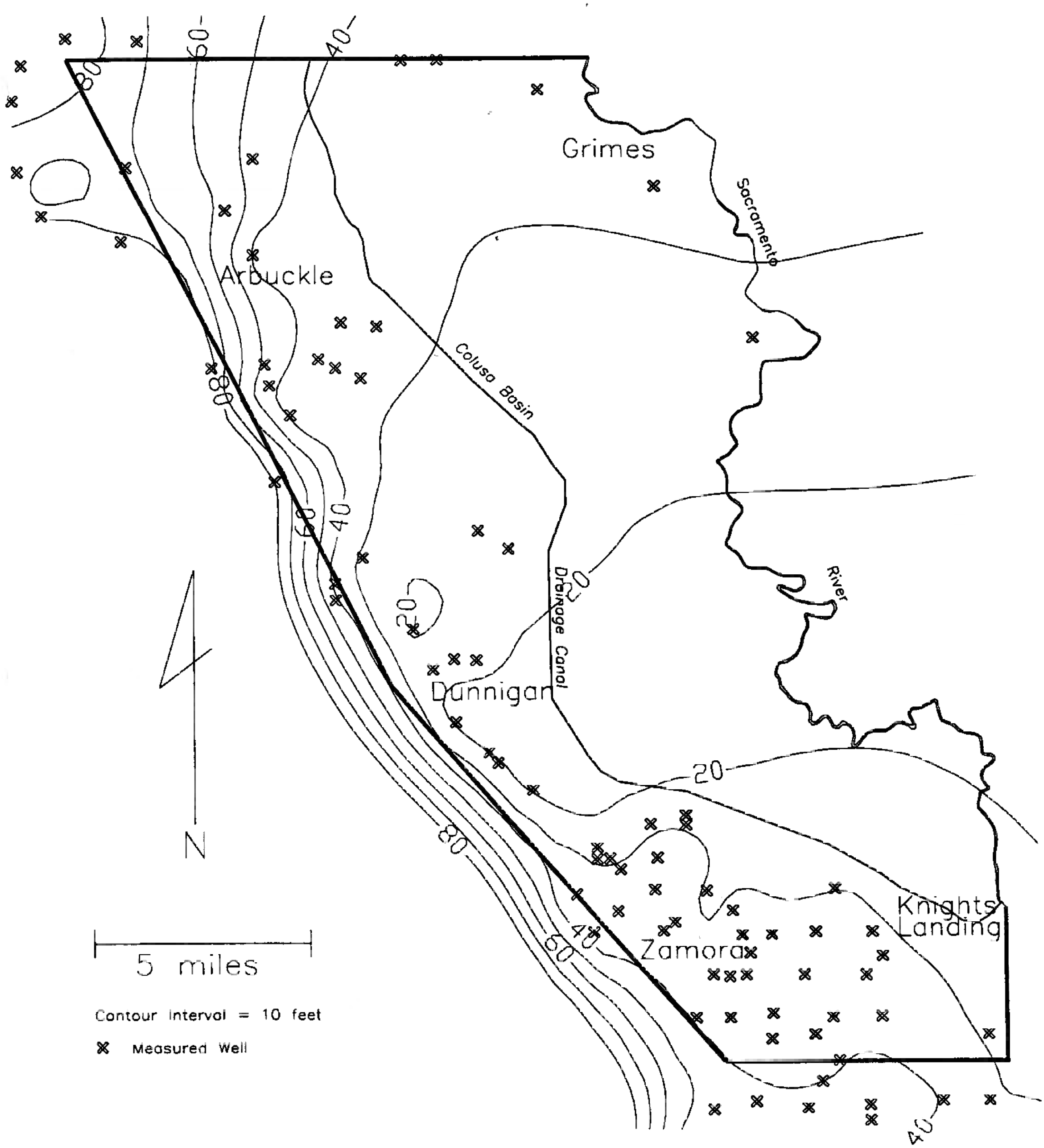


Figure 39. Spring 1983 Groundwater Elevations

indicate similar conditions to those observed in 1983 (Figure 40).

Hydrographs

Eight wells were selected to serve as representative hydrographs in the study area. These wells were selected to obtain coverage of the study area with respect to surface location as well as depth. The wells were also selected because they are all currently monitored for water levels by the Department of Water Resources.

Locations of wells used for hydrographs are shown in figure 41. In general, water levels in most of the wells had a downward trend prior to the late 1970's when surface water supplies became available along the west side of the study area via the Tehama Colusa Canal. Water levels typically fluctuate by 20 feet or more annually indicating semi-confined to confined conditions throughout the study area.

Well 11N/01E-16P01M (Figure 42) near Zamora is a shallow domestic well (<200 ft deep). This well shows annual water level fluctuations of near 100 feet suggesting significant confinement at shallow depths around Zamora. This area has documented subsidence related to groundwater pumping.

Well 11N/02E-20K04M (Figure 42) is also a shallow domestic well (~225 ft deep). This well shows less confinement at shallow depths to the east. Water levels show an upward trend in the early 1980's. The cause of this recovery is unknown. The well appears to be too far away to be affected the Tehama Colusa Canal imports.

Wells 12N/01W-05B01M (Figure 43) and 12N/01W-22R01M (Figure 43) are shallow domestic wells (<200 ft deep) along Interstate 5. The downward trend prior to the Tehama Colusa Canal is particularly evident well 12N/01W-05B01M. Water levels indicate some confinement in the shallow aquifer in this area.

Wells 13N/01W-22P02M (Figure 44), 13N/01W-23F02M (Figure 44) and 14N/02W-13N01M (Figure 45) are irrigation wells along the west side of the study area. These wells all show an upward groundwater level trend starting in the 1980's and an annual fluctuation of about 20 feet indicating some confinement in the aquifer in this area. Note the pronounced downward water level trend prior to the late 1970's in well 14N/02W-13N01M.

Well 13N/01E-11A01M (Figure 45) near the Sacramento River is an exception to the previously noted trends. This well appears to be semi-confined to unconfined. The more consistent water levels are typical of wells located along the river and may reflect limited pumping and hydraulic connection between the aquifer and

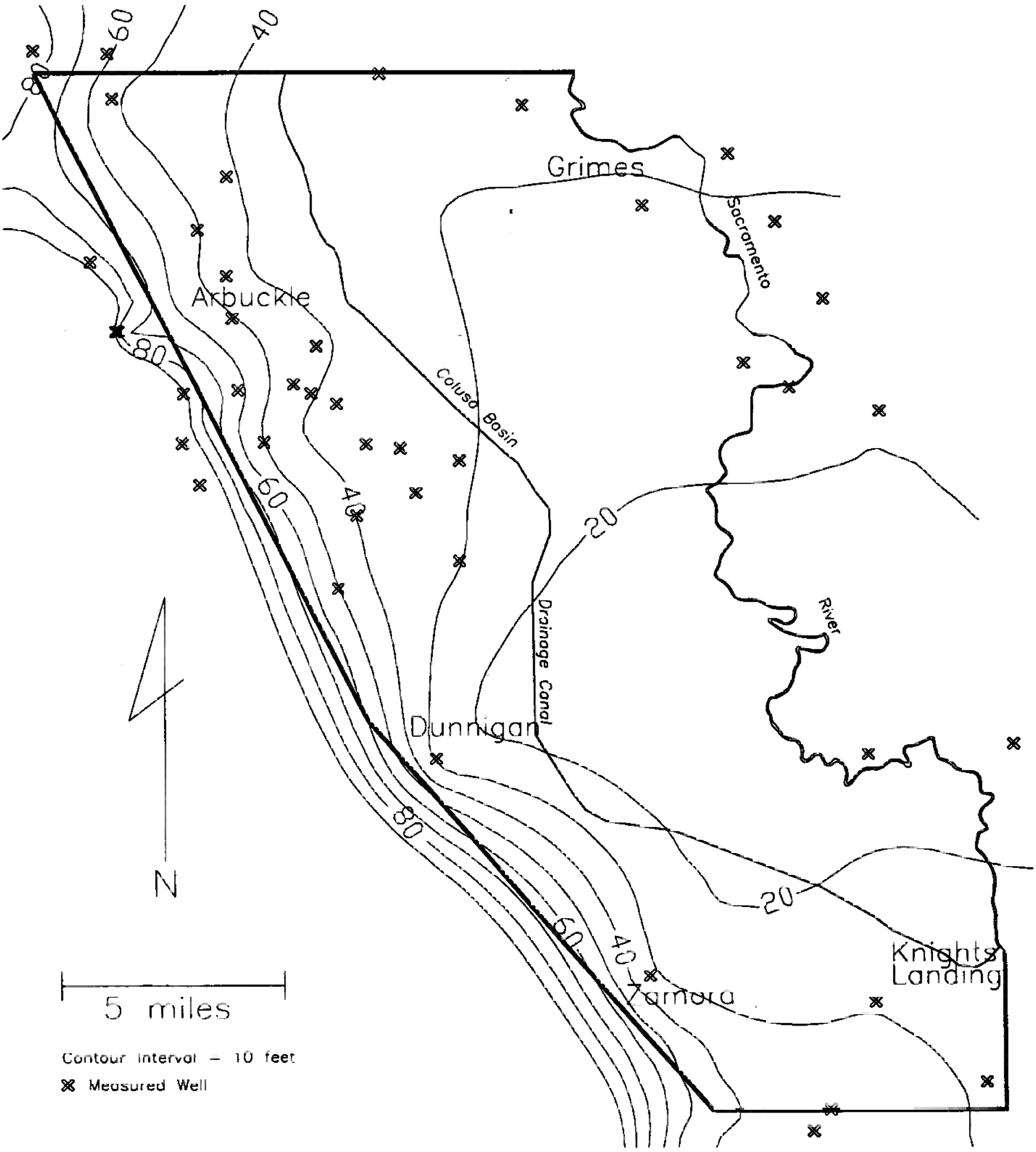


Figure 40. Spring 1996 Groundwater Elevations

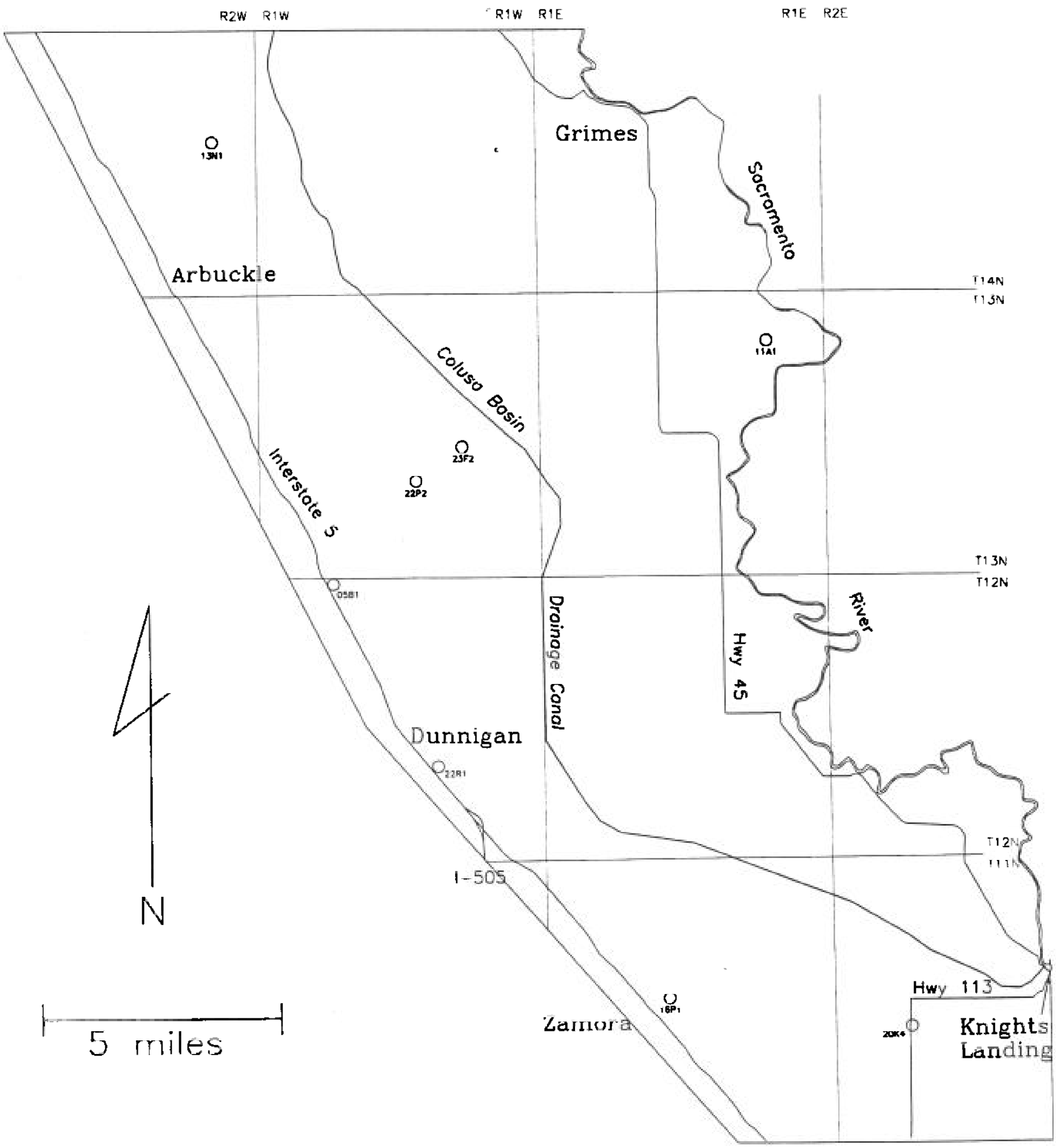


Figure 41. Locations of Active Wells Selected for Representative Hydrographs in the Lower Colusa Basin Study Area

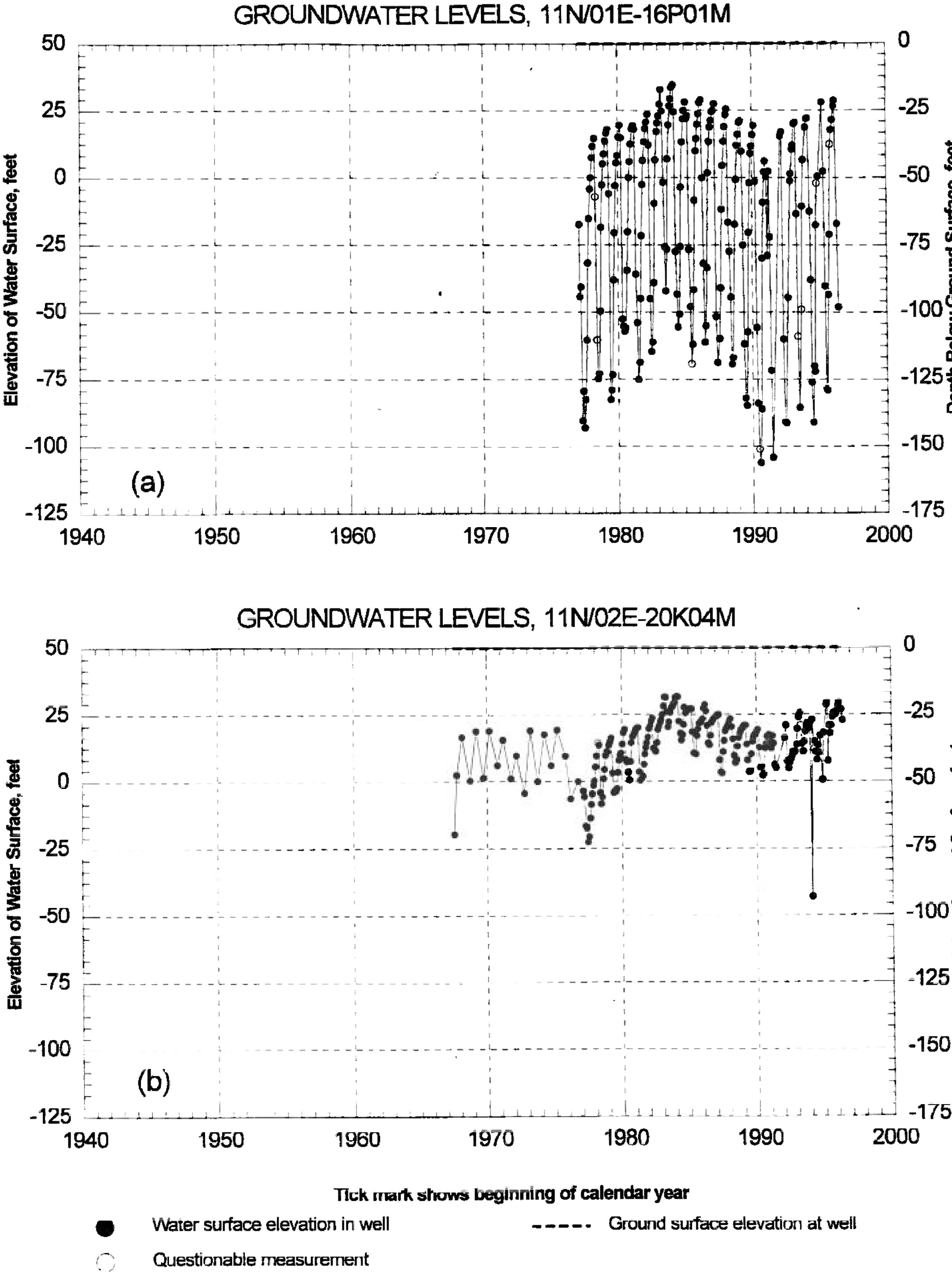
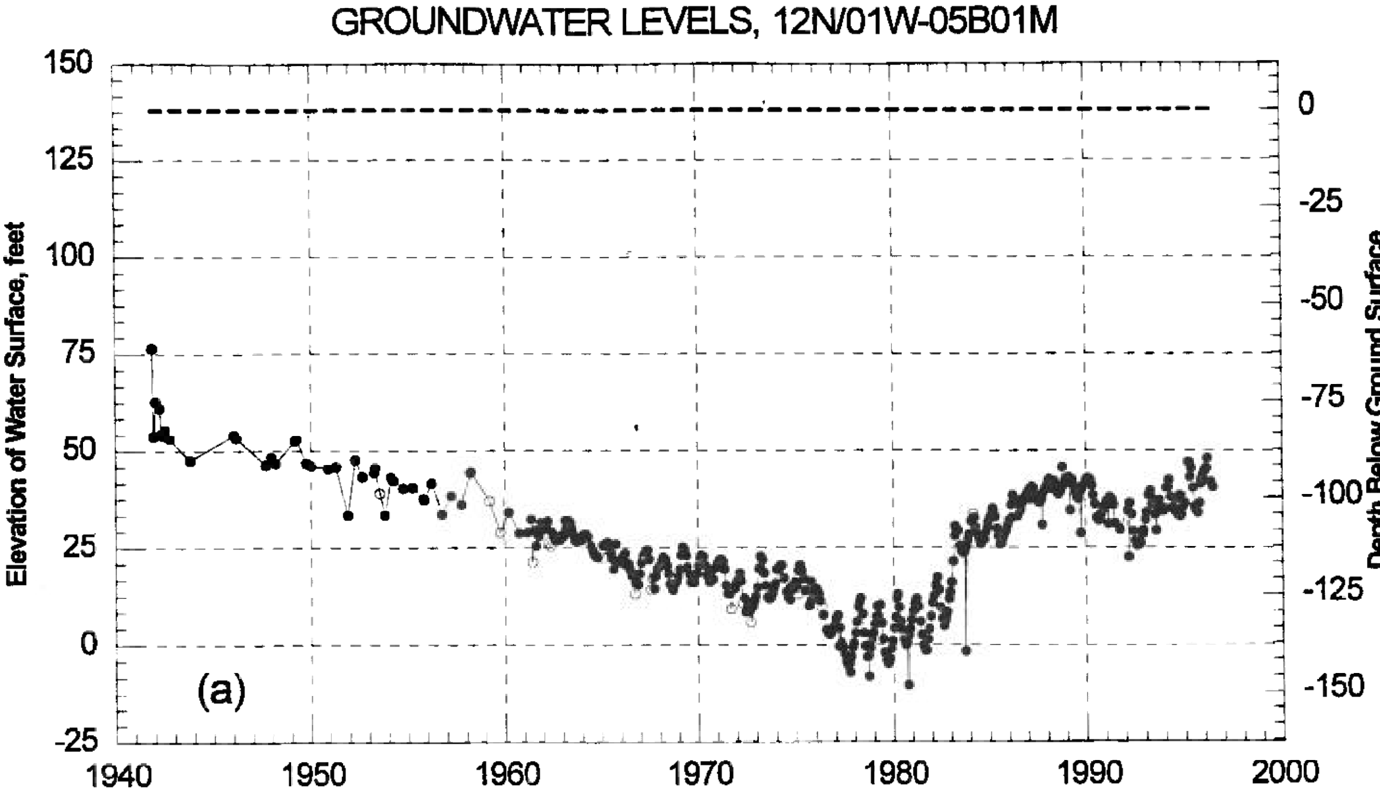
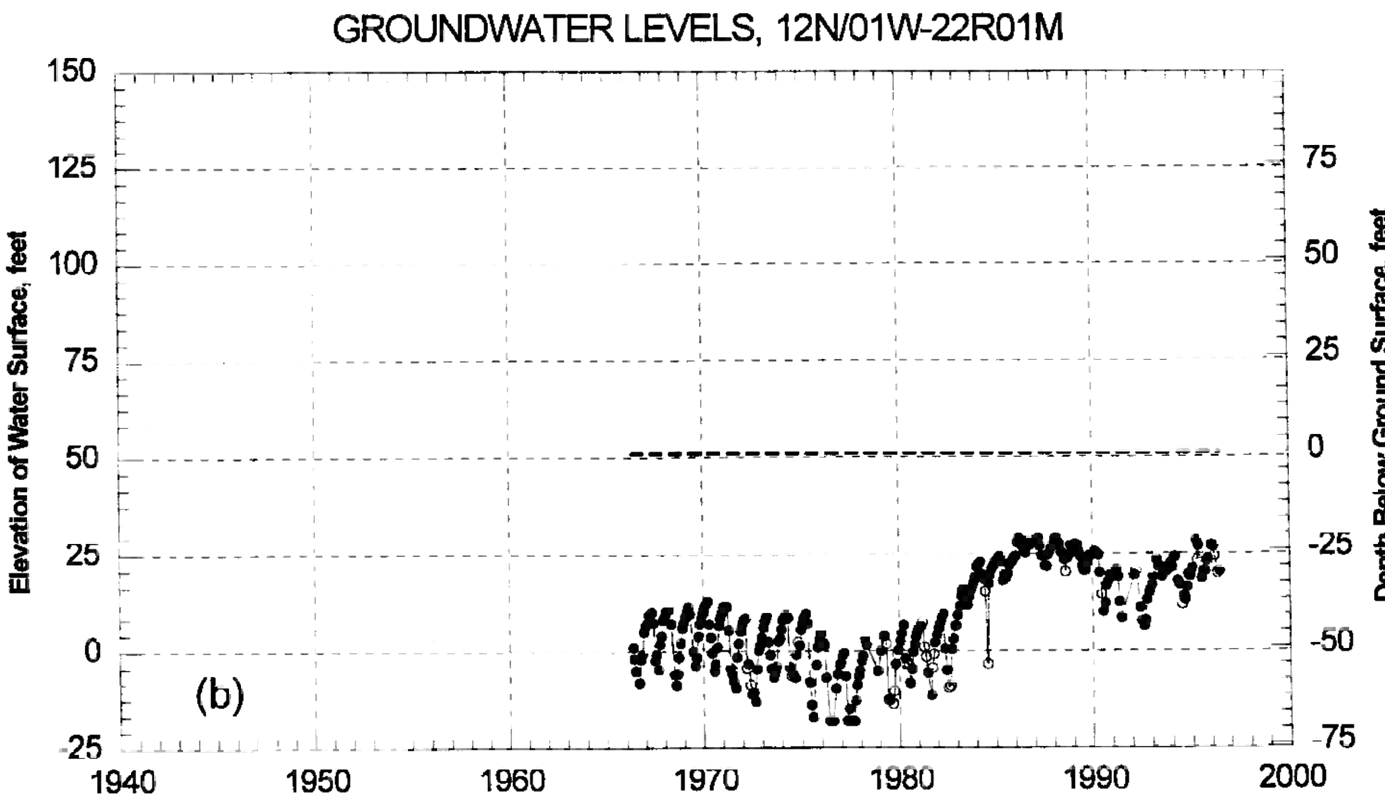


Figure 42. Hydrographs of Wells 11N/01E-16P01M and 11N/02E-20K04M



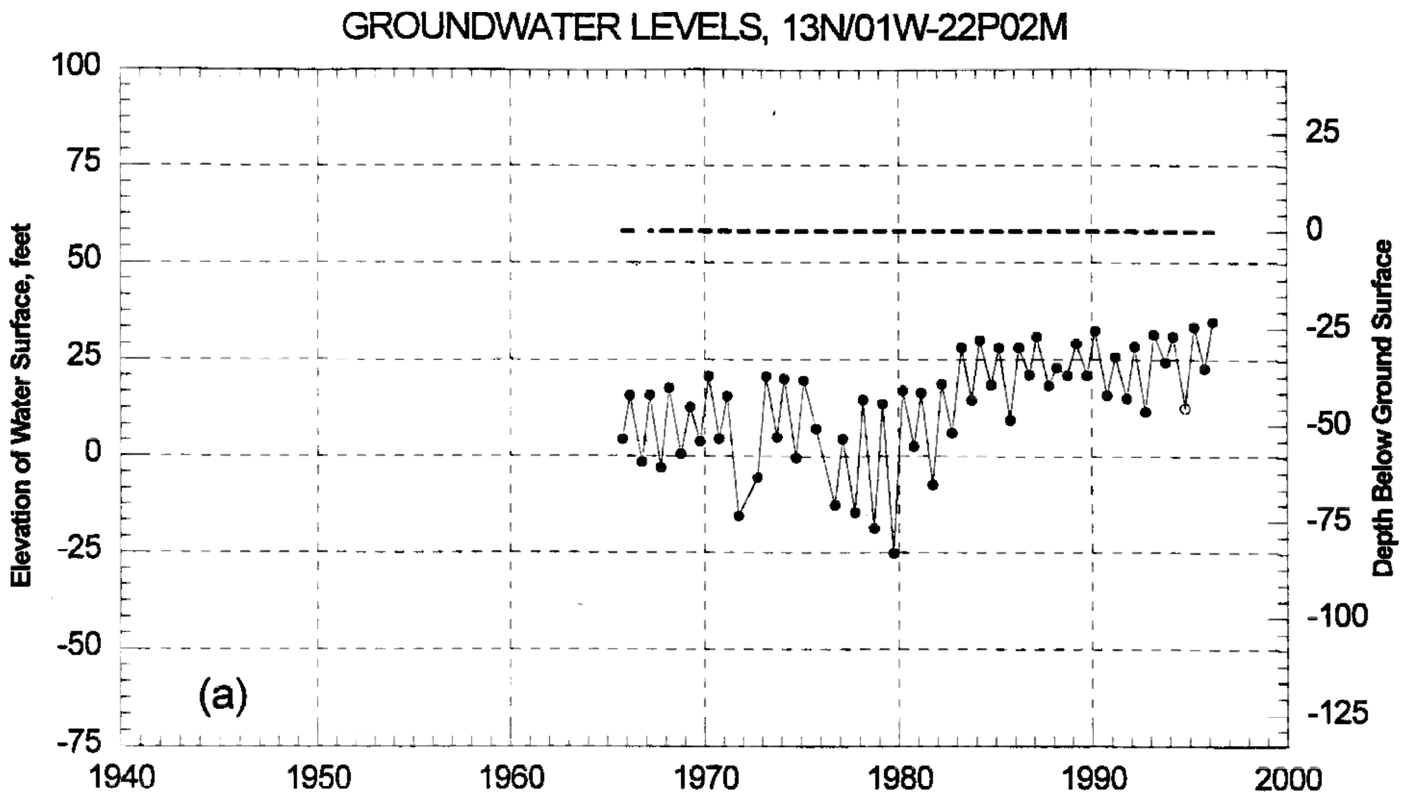


Tick mark shows beginning of calendar year

● Water surface elevation in well ----- Ground surface elevation at well

○ Questionable measurement

Figure 43. Hydrographs of wells 12N/01W-05B01M and 12N/01W-22R01M



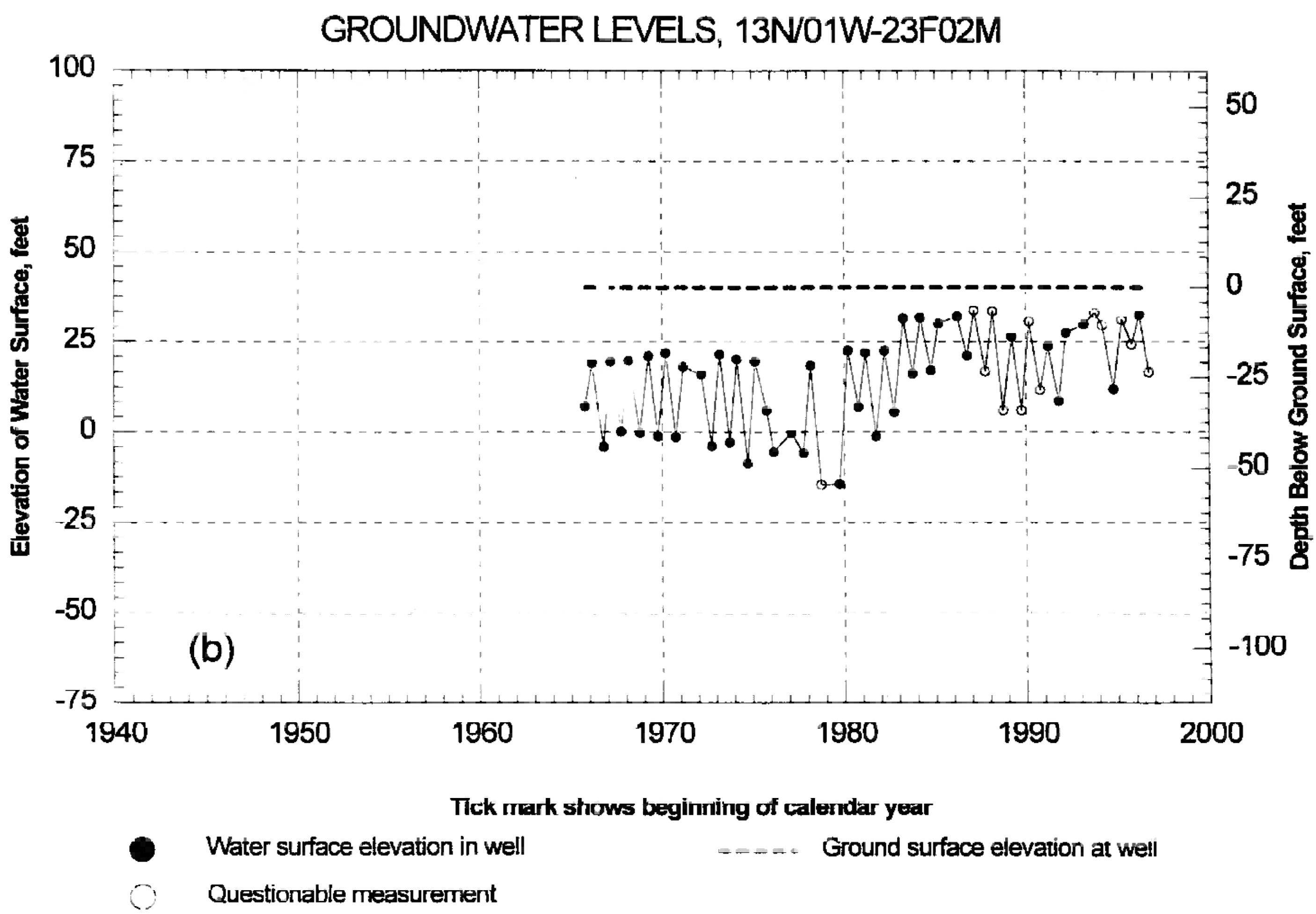


Figure 44. Hydrographs of Wells 13N/01W-22P02M and 13N/01W-23F02M

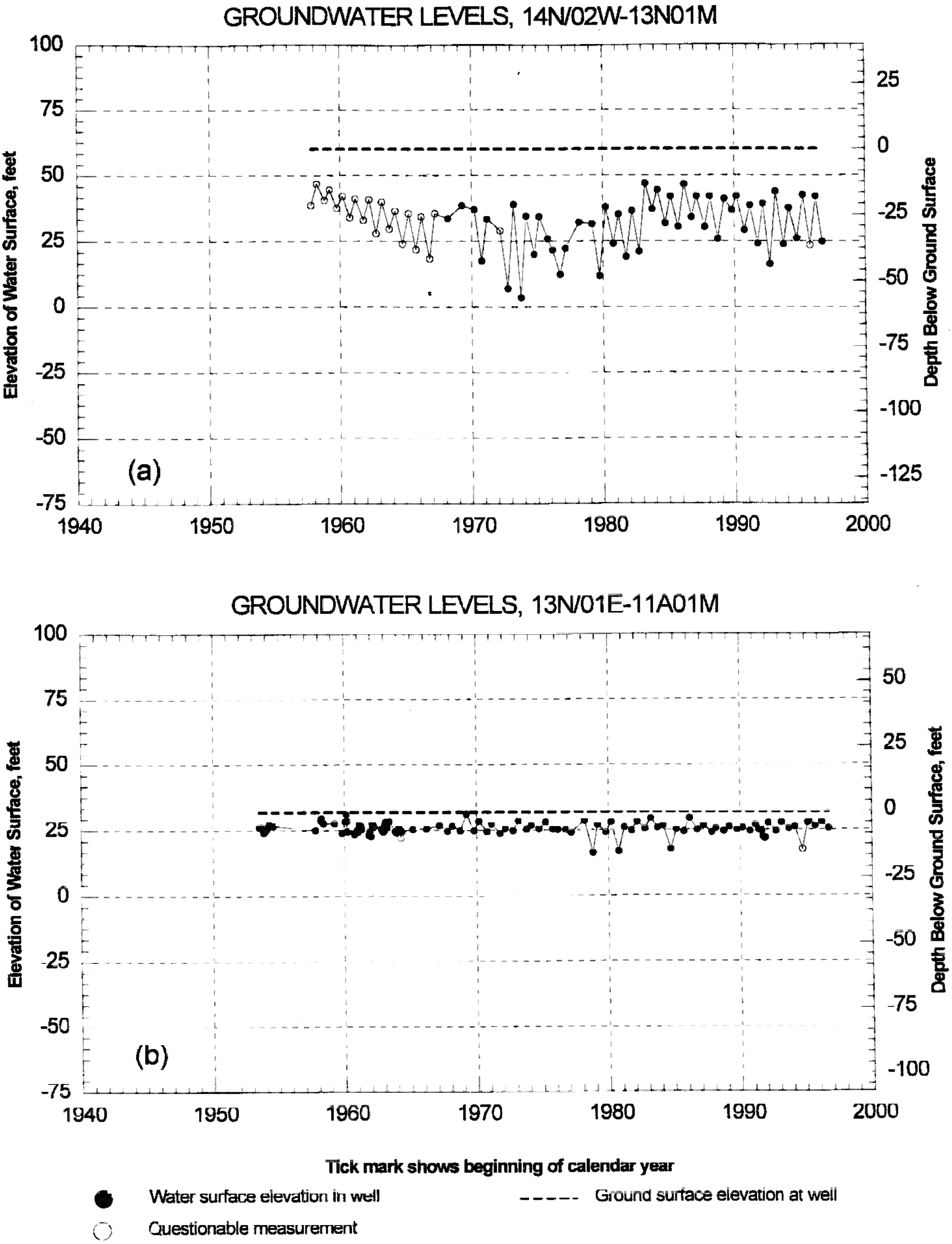


Figure 45. Hydrographs of Wells 14N/02W 13N01M and 13N01E-11A01M

the river.

DWR Monitoring Wells

As part of the study of the Lower Colusa Basin DWR has constructed two multi-completion monitoring wells and five exploration holes. Ten more wells planned. Figure 46 shows the locations of existing and planned monitoring wells. The wells are completed at discrete depth intervals to observe groundwater elevations within different aquifer zones. The wells have also been sampled to observe potential changes with depth in water chemistry.

The two existing monitoring wells, LCB-11 and LCB-13, have been monitored monthly for water levels since October 1996. A hydrograph of the two wells is shown on figure 47. In April and May of 1997, both wells are beginning to show signs of being stressed by groundwater production from wells to the south of the Colusa Basin Drain. The hydrographs suggest that groundwater is being produced primarily in the 400-500 foot depth range and that there is some degree of confinement between the monitored zones resulting in differential drawdown as water leaks between the zones in response to head changes resulting from pumping. During the winter recharge period the heads in all zones appear to equilibrate.

Subsidence

Subsidence has little effect on land use or the overall landscape. However, it has the potential to pose flood control problems if allowed to occur undetected and unmitigated. Subsidence reduces the freeboard of levees and can change the grade, or even the direction of flow, in drainage canals and other hydrologic facilities. It can also damage wells and impair the functioning of conveyance and drainage facilities. There is documented evidence of historical land subsidence in the southern part of the study area (Lofgren and Ireland 1973; Blodgett et al 1990; Ikehara 1995).

Lofgren and Ireland (1973) noted up to two feet of subsidence in an area about two miles east of Zamora in the southern part of the study area. The subsidence occurred during a period from 1949 to 1973 and is likely related to the compaction of water-bearing clay and silt bodies as groundwater is withdrawn from the aquifer. Blodgett et al (1990) used Global Positioning System survey technology to record approximately two additional feet at that location through 1988.

Ikehara (1995) provided data from a monitoring station constructed by the United States Geological Survey in 1987 to monitor land subsidence between Zamora and Knight's Landing. The location of the station, referred to as the Zamora extensometer,

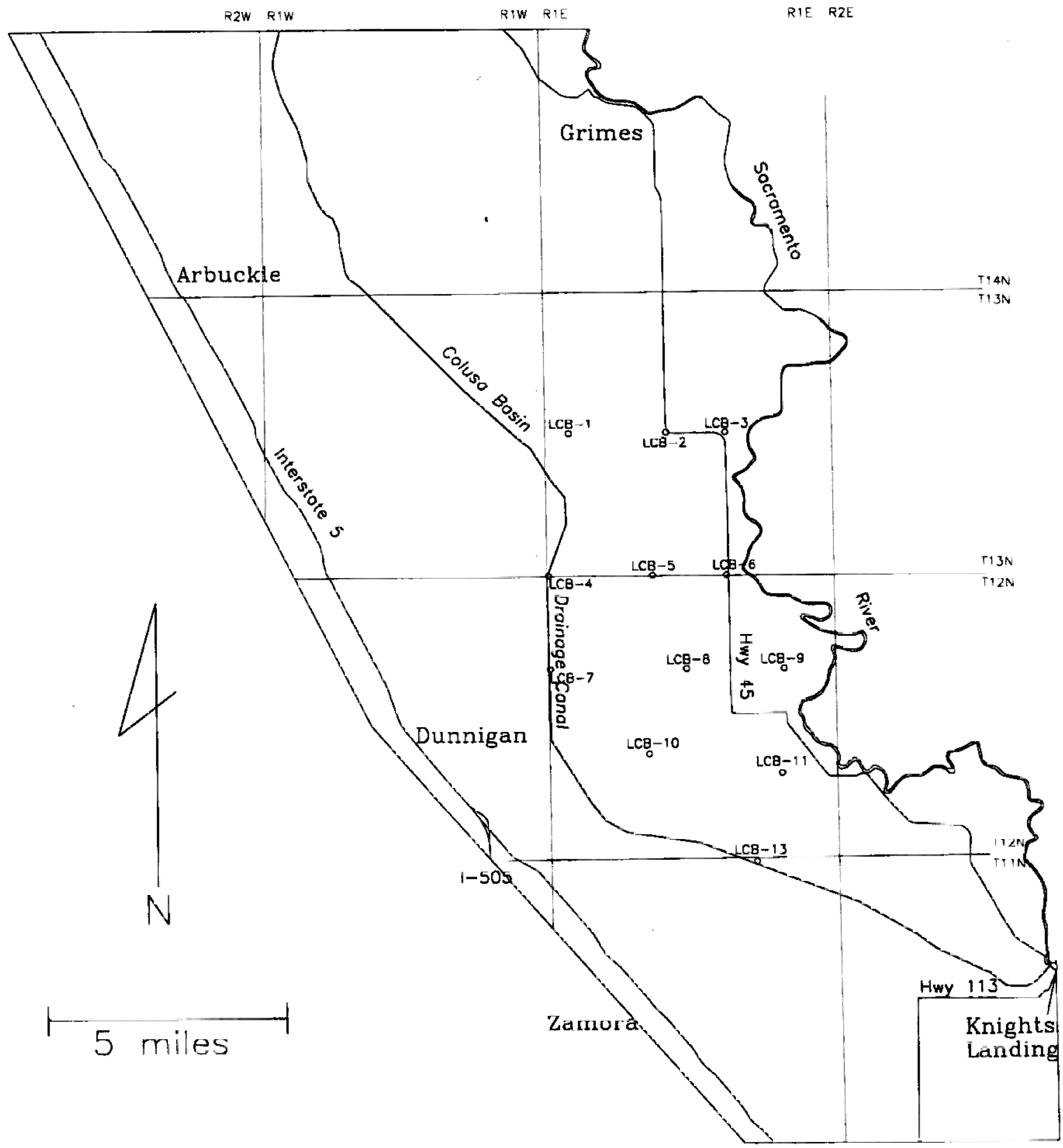


Figure 46. Locations of Proposed and Existing Multicompletion Monitoring Wells in the Lower Colusa Basin Study Area

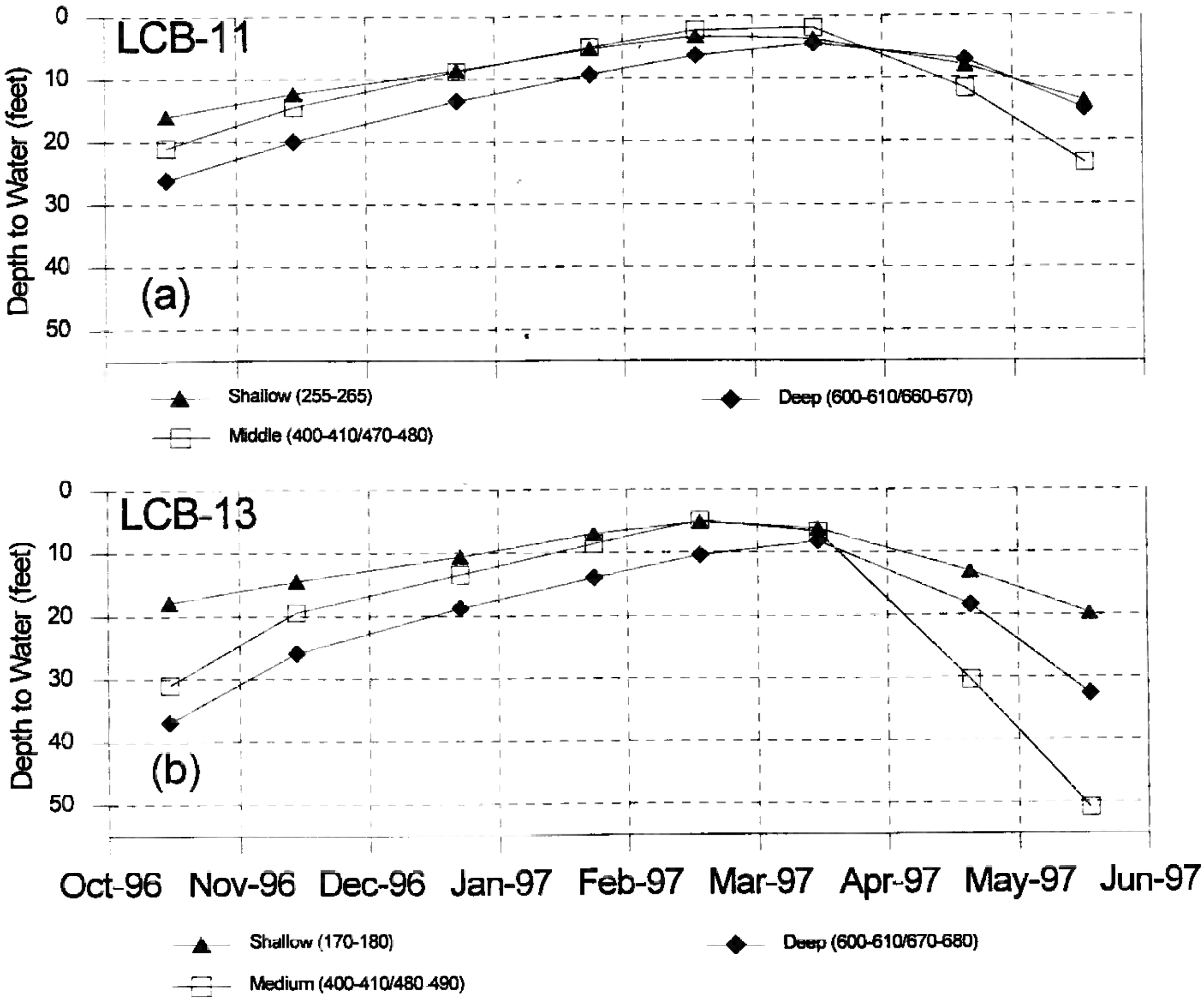


Figure 47. Hydrographs of Existing DWR Multicompletion Monitoring Wells

is shown in figure 48. The report documented approximately 0.78 feet of subsidence from December 1987 through September 1992. This station was monitored by the United States Geological Survey only during the 1987 to 1992 drought.

The Department of Water Resources has monitored the Zamora extensometer continuously since October 1992. From October 1992 through January 1997, there has been little net subsidence at the extensometer. Figure 49 shows groundwater hydrographs of four monitored depths along with relative ground surface displacement. The ground surface displacement closely mimics the trend in water surface elevation in the upper three zones of the aquifer. Compaction of water-bearing sediments occurs as water levels are drawn down and rebound occurs as water levels recover. Inelastic subsidence would not be expected to occur again unless historical groundwater level lows are exceeded. The record for the post-October period shows a greatly reduced rate of subsidence when compared to the earlier record from July 1988 through July 1992. Figure 50 shows subsidence recorded during the earlier period. During this earlier period, characterized by drought conditions, subsidence of up to 0.3 feet per year was experienced.

Lithology and spontaneous potential logs for the Zamora extensometer are presented in Ikehara (1995). The spontaneous potential log appears "spiky" indicating thinly inter-bedded sands and clays. Thinly interbedded sands and clays are also supported by the lithologic log; many of the clays are described as having sand or sand and gravel in the sample.

The documented subsidence in the southern part of the study area and the potential serious consequences of additional induced subsidence necessitate a detailed evaluation of possible subsidence before project development can proceed. Furthermore, project development should incorporate a monitoring system designed to detect early evidence of any subsidence induced by project operations.

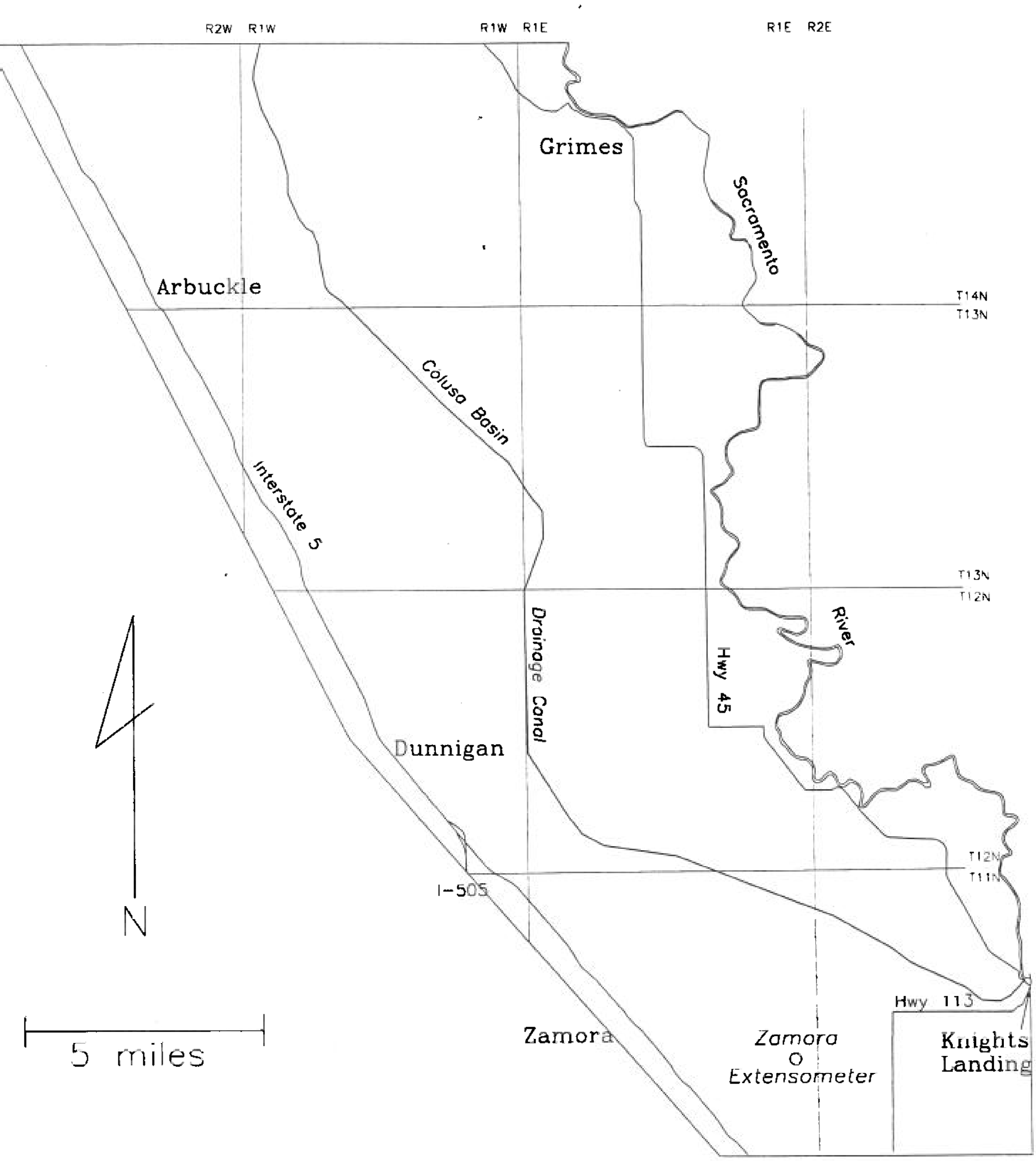


Figure 48. Location of Zamora Extensometer

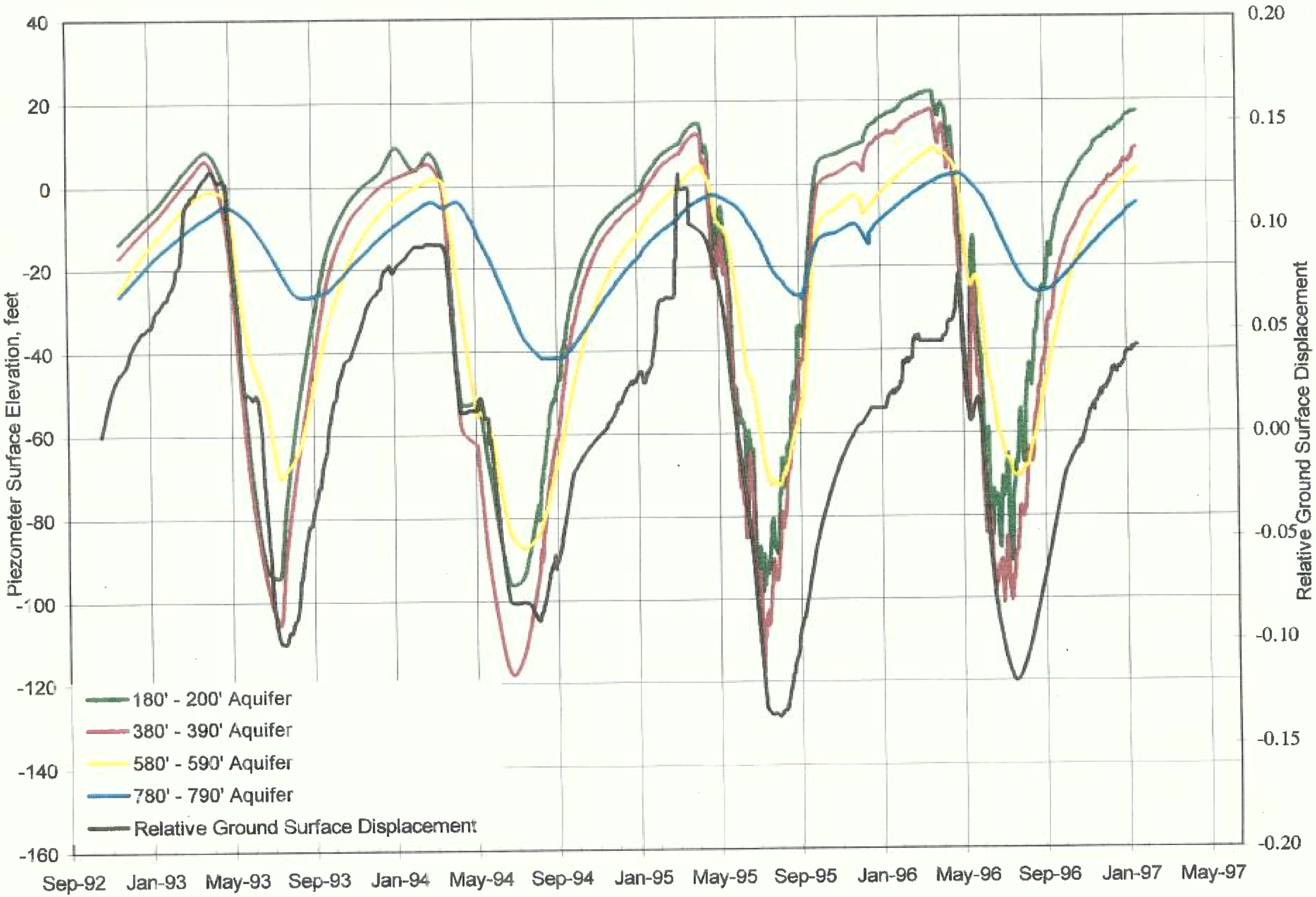


Figure . Elevation of piezometric surfaces and relative ground surface displacement at Zamora extensometer.

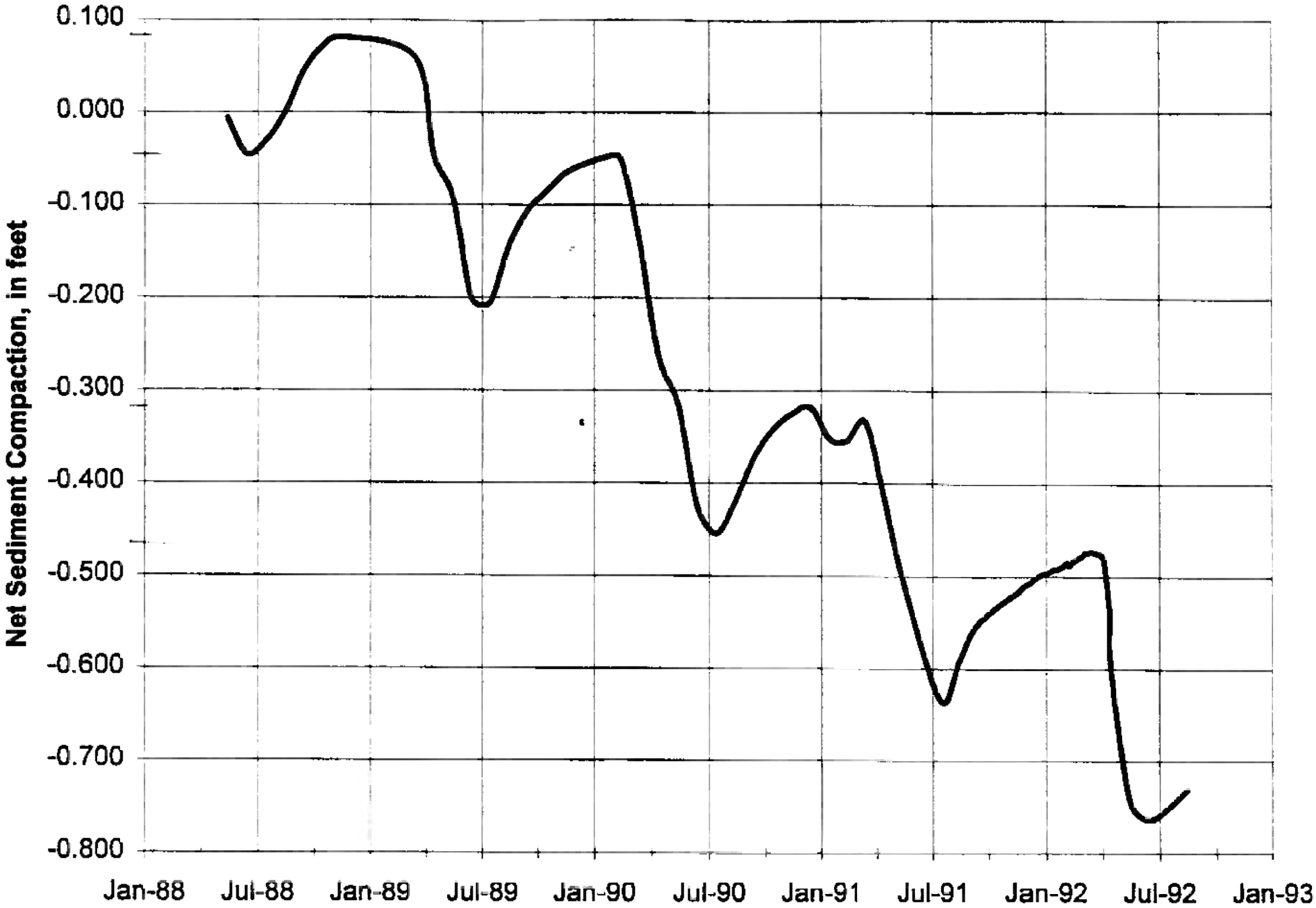


Figure 50. Compaction at Zamora Extensometer, 1988-1992

Chapter 4

Water Quality

A preliminary assessment of water quality indicates that groundwater should be suitable for most purposes. Elevated concentrations of boron in the southern part of the study area should be studied further for potential impacts to crops. During recharge years some use of high boron groundwater in YZWD will be displaced by surface water delivered for recharge providing water quality benefits. The potential impact of groundwater quality within the extraction area of RD-108 cannot be determined until additional wells are available for sampling. The proportion of groundwater acceptable in the distribution system will be determined by the groundwater quality in the area. Preliminary data is presented below, while additional groundwater quality data will be collected in the near future.

WATER QUALITY

Water quality analyses from 53 wells are discussed in this Chapter. The groundwater chemistry is highly varied in the study area and there is no clear trend with respect to water quality and well depth. Specific constituents of concern in groundwater are discussed.

Groundwater Quality

The assessment of groundwater quality data is limited to a preliminary review of readily available water quality data. Additional sampling and analysis of groundwater for the proposed project will occur as monitoring wells are constructed in the study area.

Water quality analyses for more than 100 wells in the study area have been collected from Department of Water Resources and U.S. Geological Survey records. Most of the data for inorganic constituents is from sampling conducted in the mid-1970's through early 1980's. Limited data is available since that time. Data on pesticide contamination was obtained from the Department of Pesticide Regulation. Data on organic and radiological constituents was obtained from the Departments of Health Services and Pesticide Regulation.

The project under consideration involves the use of groundwater for agricultural supply. However, groundwater in the study area is also used for drinking water supply. Because extraction in the project area could potentially induce the movement of groundwater into areas used for domestic supply, it is necessary to evaluate the suitability of groundwater from both an agricultural and drinking water perspective.

The assessment of study area groundwater for agricultural use is based on guidelines for irrigation of crops presented in Ayers and Wescott (1985) and ASCE (1996). Water quality guidelines for irrigation serve to help avoid potential negative impacts from the use of poor quality irrigation water. These impacts include toxicity to crops, salt buildup in plant root zones, and the reduction of soil infiltration rates.

There are many constituents in water that could potentially impact agricultural operations. The relationship amongst these constituents is complex, so any potential impacts need to be considered on a case by case basis. This analysis looks at general guidelines for acceptable concentrations of individual constituents.

The assessment of groundwater for drinking water is based on State and Federal drinking water standards (California Regional Water Quality Control Board 1995). The standards are in the form of Maximum Contaminant Levels (MCL's). Primary health standards are based on health risks, while secondary standards are based on esthetics. The criteria is presented, where appropriate, in the discussion of individual constituents in groundwater.

Figure 51 shows the approximate locations of water supply and monitoring wells with analyses of groundwater in the study area. Not every well has complete analyses of each constituent. The subsequent figures show concentrations of individual constituents or parameters at levels related to agricultural and drinking water standards. Where an analysis of a given constituent or parameter is not available, the well has been left off of that figure.

Comparison of groundwater quality data with applicable water quality standards and guidelines indicate that elevated levels of total dissolved solids (TDS), chloride, sodium, boron, fluoride, nitrate, iron, manganese, and arsenic exist in portions of the study area. Each of these constituents is discussed below.

Total Dissolved Solids. Figure 52 shows wells where concentrations of TDS in groundwater may be excessive for irrigation or drinking water uses. Well T12N/R1E-02D2 had the highest concentration of TDS at 2,140 mg/l. This well is in the middle zone of a DWR triple-completion monitoring well. The intervals above and below this zone have significantly lower concentrations.

Total dissolved solids above 450 mg/l can be undesirable for irrigation supply under certain conditions. These problems can be more pronounced where low-volume irrigation practices are used in low-permeability soils in areas with high evapotranspiration rates. A total of 19 wells exceed 450 mg/l TDS. These wells are found throughout the study area, and are in both shallow and deep wells.

There is only a secondary drinking water standard for TDS of 500 mg/l. Concentrations exceeding 1,000 mg/l are generally considered undesirable for drinking water supply. Only five wells had TDS concentrations of greater than 1,000 mg/l. These wells are mostly found in the southern part of the study area, and are used as agricultural supply wells.

<u>Chloride</u>. Figure 53 shows wells where concentrations of chloride may be excessive for irrigation and drinking water uses. Well T12N/R1E-02D2 also had the highest concentration of chloride at 681 mg/l.

Chloride at concentrations of 106 mg/l and greater can be undesirable under certain irrigation conditions. Excessive chloride can be injurious to some fruit crops where irrigation practices result in accumulation of salts in the root zone. Damage can occur where irrigation water with elevated chloride is applied by sprinklers to citrus, stone fruit, and almond orchards. The possibility of chloride damage is increased when sprinkler irrigation occurs under conditions of high evapotranspiration.

Relatively few of the wells had concentrations of chloride exceeding 106 mg/l. There is no clear spatial distribution of the elevated chloride, but a small cluster exists just east of the town of Arbuckle. Several wells also have elevated chloride south of the Colusa Basin Drain and between Zamora and Knights Landing.

Chloride has a secondary MCL of 250 mg/l for drinking water supplies. Only five wells in the study area have concentrations of chloride exceeding 250 mg/l. None of these wells appear to be directly located where public drinking water supplies are extracted from the aquifer.

<u>Sodium</u>. Sodium concentrations were elevated in the northern portion of the study area east of Arbuckle and west of Grimes, and in the southern part just north and south of the Colusa Basin Drain. The highest concentration of sodium was found in well T12N/R1E-02D2. Elevated dissolved sodium concentrations are shown in figure 54. There is no MCL for sodium in drinking water supplies.

Sodium in irrigation water above a concentration of 69 mg/L may be injurious to some crops if applied by sprinklers. Figure 54 depicts a portion of the study area where concentrations of sodium in groundwater may be excessive for sprinkler application of irrigation water for some crops.

Irrigation water with elevated concentrations of sodium in

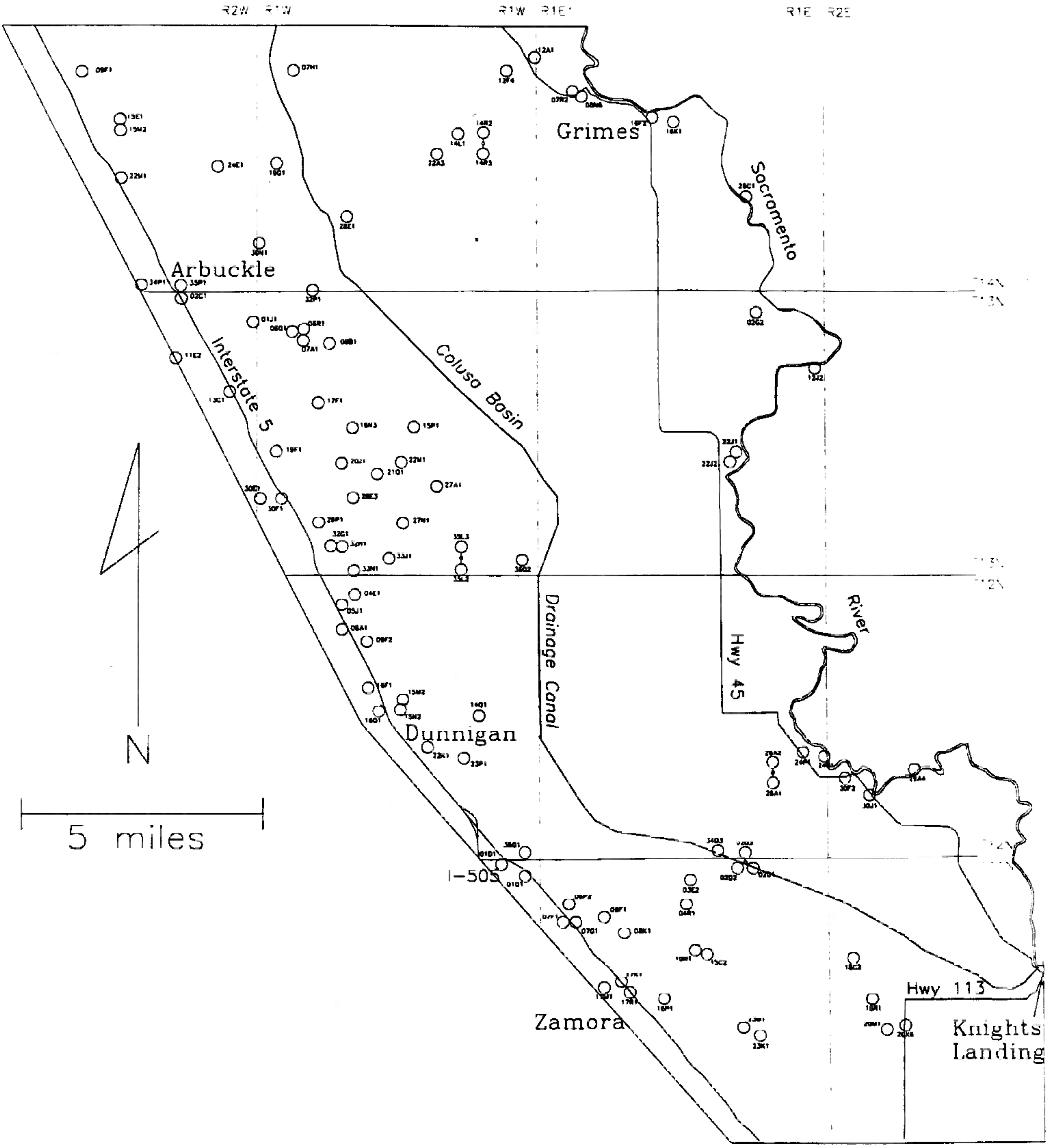


Figure 51. Location of Wells with Water Quality Analyses in the Lower Colusa Basin Study Area

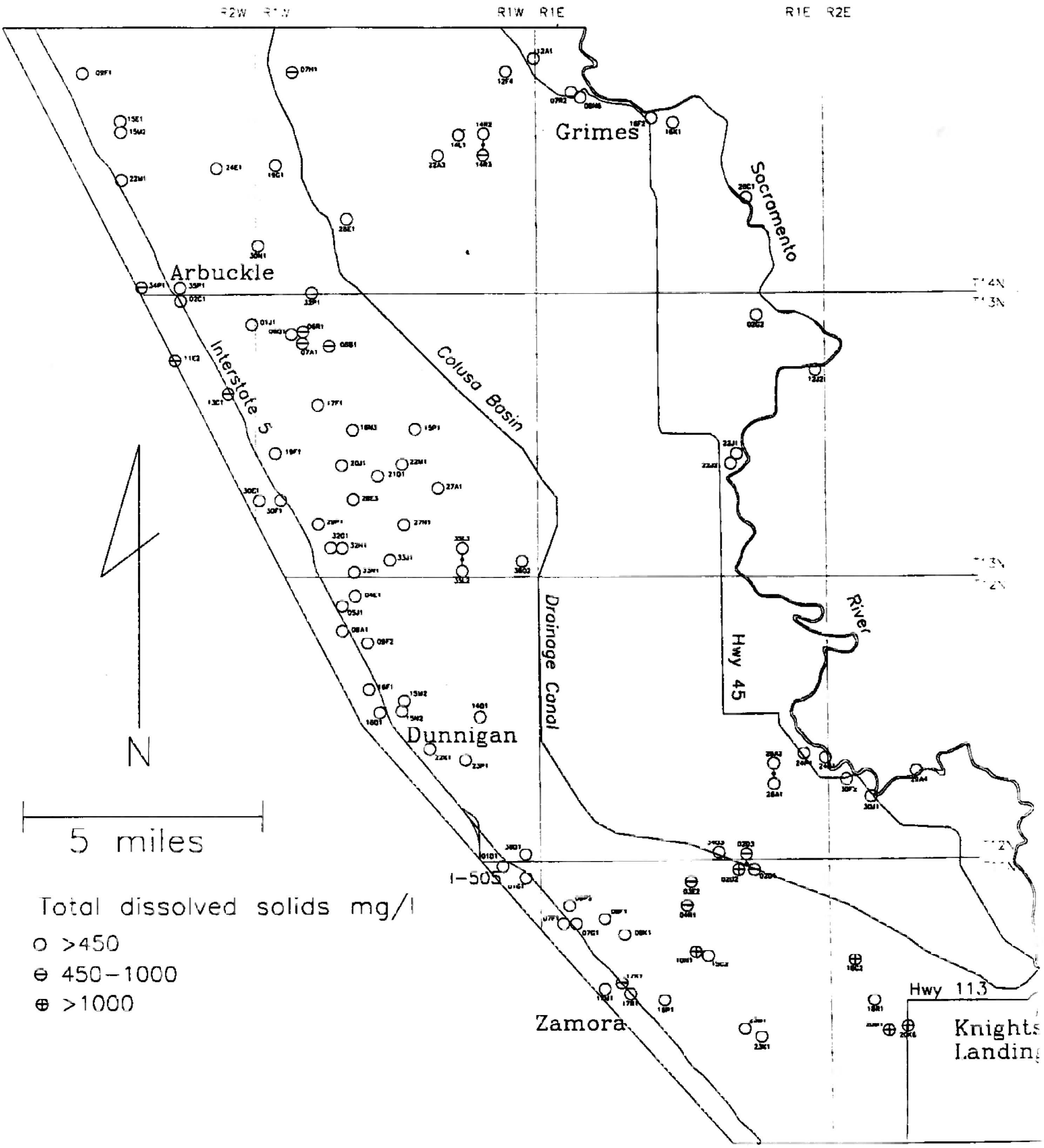


Figure 52. Total Dissolved Solids Concentrations in the Lower Colusa Basin Study Area

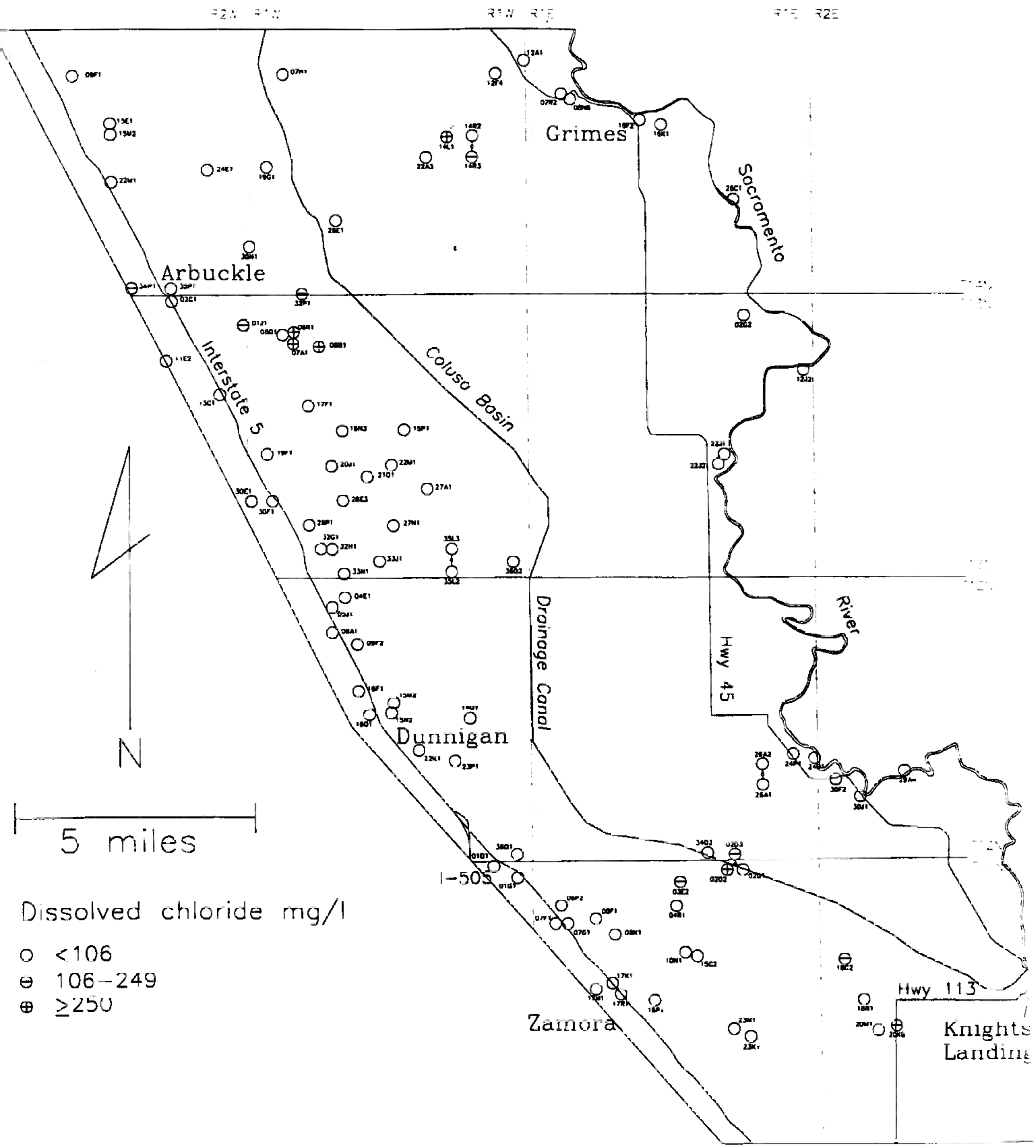


Figure 53. Dissolved Chloride Concentrations in the Lower Colusa Basin Study Area

relation to calcium may be injurious to some crops, including deciduous fruits. The sodium adsorption ratio (SAR) of irrigation water is sometimes used as an indicator of the toxicity potential of sodium for some crops, because the toxicity of sodium is partly dependent on calcium availability. Irrigation water with a SAR greater than 3 may be injurious to some crops. The SAR for irrigation water is defined as:

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$

Where:

	SAR	=	Sodium Adsorption Ratio (unitless)
	Na	=	Concentration of sodium in irrigation water in milliequivalents per liter.
	Ca	=	Concentration of calcium in irrigation water in milliequivalents per liter.
	Mg	=	Concentrations of magnesium in irrigation water in milliequivalents per liter.

Figure 55 illustrates portions of the study area where the SAR exceeds 3.

Sodium in irrigation water can be detrimental to soil structure and can serve to reduce infiltration rates in surficial soils. The potential impact of sodium in irrigation water on infiltration rates can be evaluated based on the concentration of calcium, magnesium, bicarbonate and TDS in the water, and on the partial pressure of carbon dioxide gas in surficial soils. The impact of sodium concentrations on soil infiltration rates of a particular field is dependent on a variety of factors as discussed earlier and should be evaluated on a field-by-field basis.

Boron. Figure 56 shows areas with elevated concentrations of dissolved boron. The highest concentration of boron at 11 milligrams per liter was found in well T12N/R1E-02D2. Clusters of wells with elevated dissolved boron were observed within and east of the town of Arbuckle and throughout the southern part of the study area around the Colusa Basin Drainage Canal.

Boron concentrations above 0.5 mg/l in irrigation water may be injurious to sensitive crops. More tolerant crops may be injured at concentrations above 1 mg/l. The sensitivity of various crops to boron in irrigation water is discussed in Ayers and Wescott (1985) and ASCE (1996).

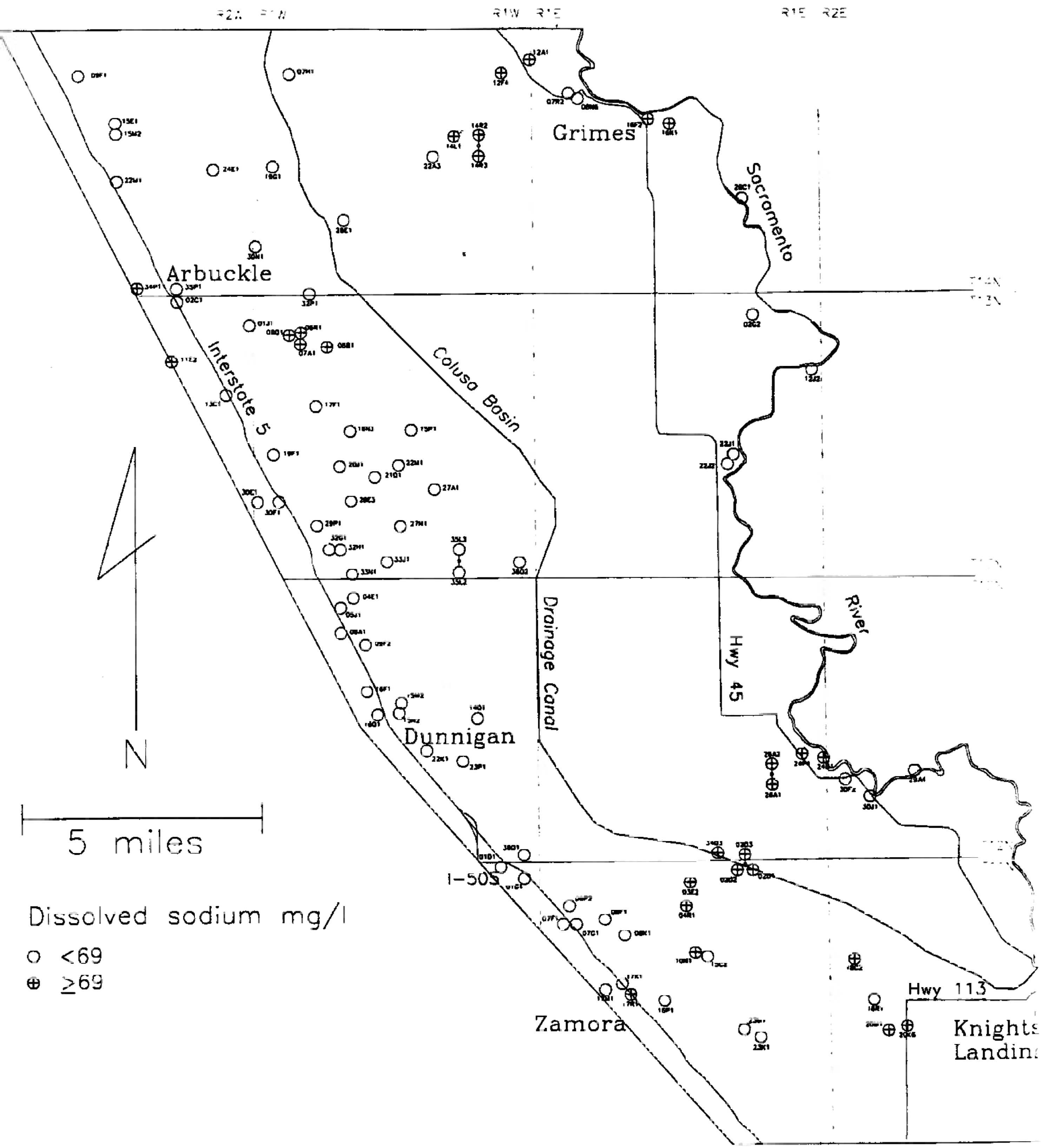


Figure 54. Dissolved Sodium Concentrations in the Lower Colusa Basin Study Area

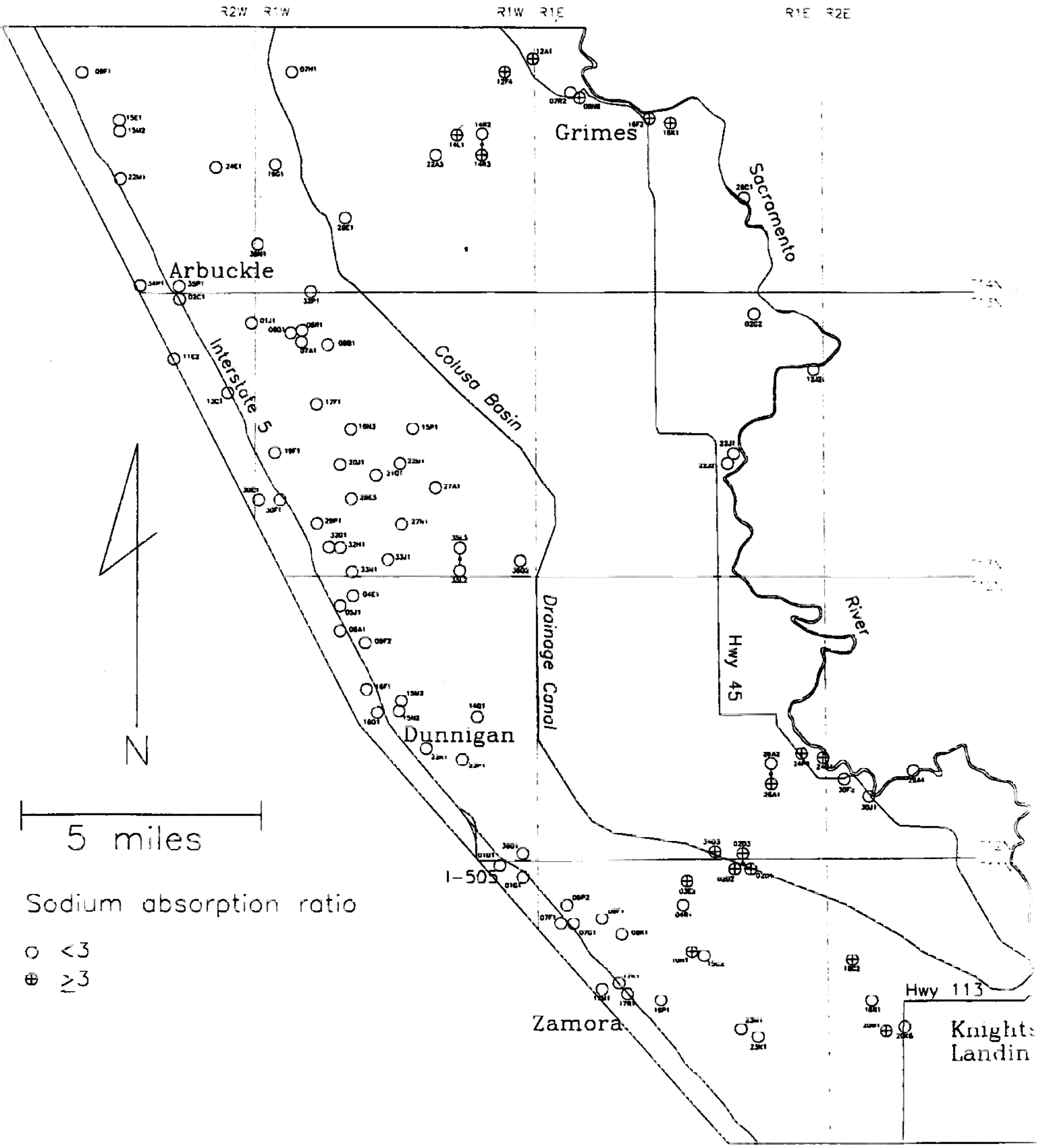


Figure 55. Sodium Adsorption Ratios in the Lower Colusa Basin Study Area]

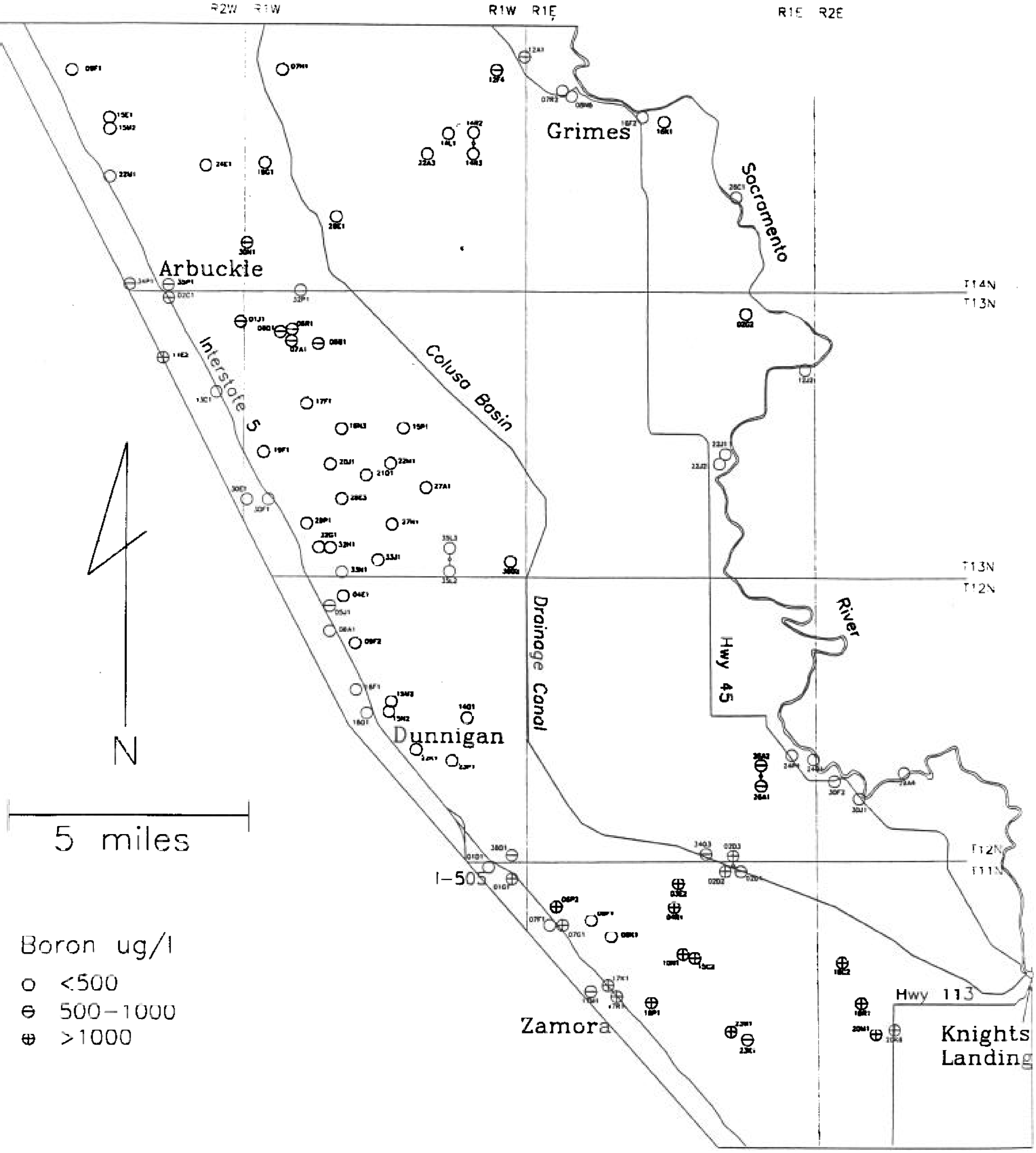


Figure 56. Dissolved Boron Concentrations in the Lower Colusa Basin Study Area

Nitrate. The state primary MCL for nitrate in drinking water is 45 mg/l. Concentrations of 22 mg/l can, under some circumstances, be injurious to crops. Only seven wells in the study area had concentrations exceeding 22 mg/l with two of these exceeding 45 mg/l. There is no clear spatial distribution of the elevated nitrate concentrations. However, the shallow aquifer beneath the town of Dunnigan contains elevated levels of nitrate, probably relating from on site waste disposal.

Iron. The state and federal secondary MCL for iron is 0.3 mg/l. For irrigation purposes, concentrations of iron above 5.0 mg/l may be injurious to some crops in saturated acidic soils. Only three wells in the study area had iron concentrations exceeding 0.3 mg/l while no wells exceeded 5.0 mg/l.

Manganese. Figure 57 shows the locations of wells with elevated concentrations of manganese. The state and federal secondary MCL for dissolved manganese is 0.05 mg/l. A total of 14 wells exceed this concentration in the study area. The highest concentration of dissolved manganese of 2.0 mg/l was found at well T13N/R1E-22J2.

Irrigation water containing manganese at concentrations above 0.20 mg/L may cause damage to some crops, especially in acidic soils. The phytotoxic properties of manganese are less pronounced in fine-grained soils that are neutral to alkaline in pH, although the effect of soil on manganese toxicity is complex. Eight of the 14 wells with elevated manganese exceed 0.2 mg/l.

Arsenic. Several wells have concentrations of dissolved arsenic of up to 0.03 milligrams per liter. The current maximum contaminant level (MCL) of 0.05 milligrams per liter for drinking water is under review and is expected to be lowered.

Organic and Radiological Constituents. Figure 58 shows the location of wells with analyses for pesticide constituents from the Department of Pesticide Regulation. A total of 40 wells had pesticide data within the study area. Of these, nine wells had detectable levels of pesticide constituents. Bentazon, chlorthan-dimethyl, paraquat dichloride, prometon, simazine, and tetrachloroethylene had concentrations above the method detection levels, but not above state or Federal drinking water standards. The concentrations of these constituents are shown in figure 58.

Figure 59 shows the location of wells with analyses for organic and radiological constituents. Ten wells had detectable levels of organic constituents. Three wells had analyses for the radiological parameter gross alpha. The wells with detectable organic constituents and radiological data are shown with their concentrations and state and Federal MCL's in table 12, Where more than one concentration is shown for a given constituent on the same sampling date, a sample was either analyzed at an

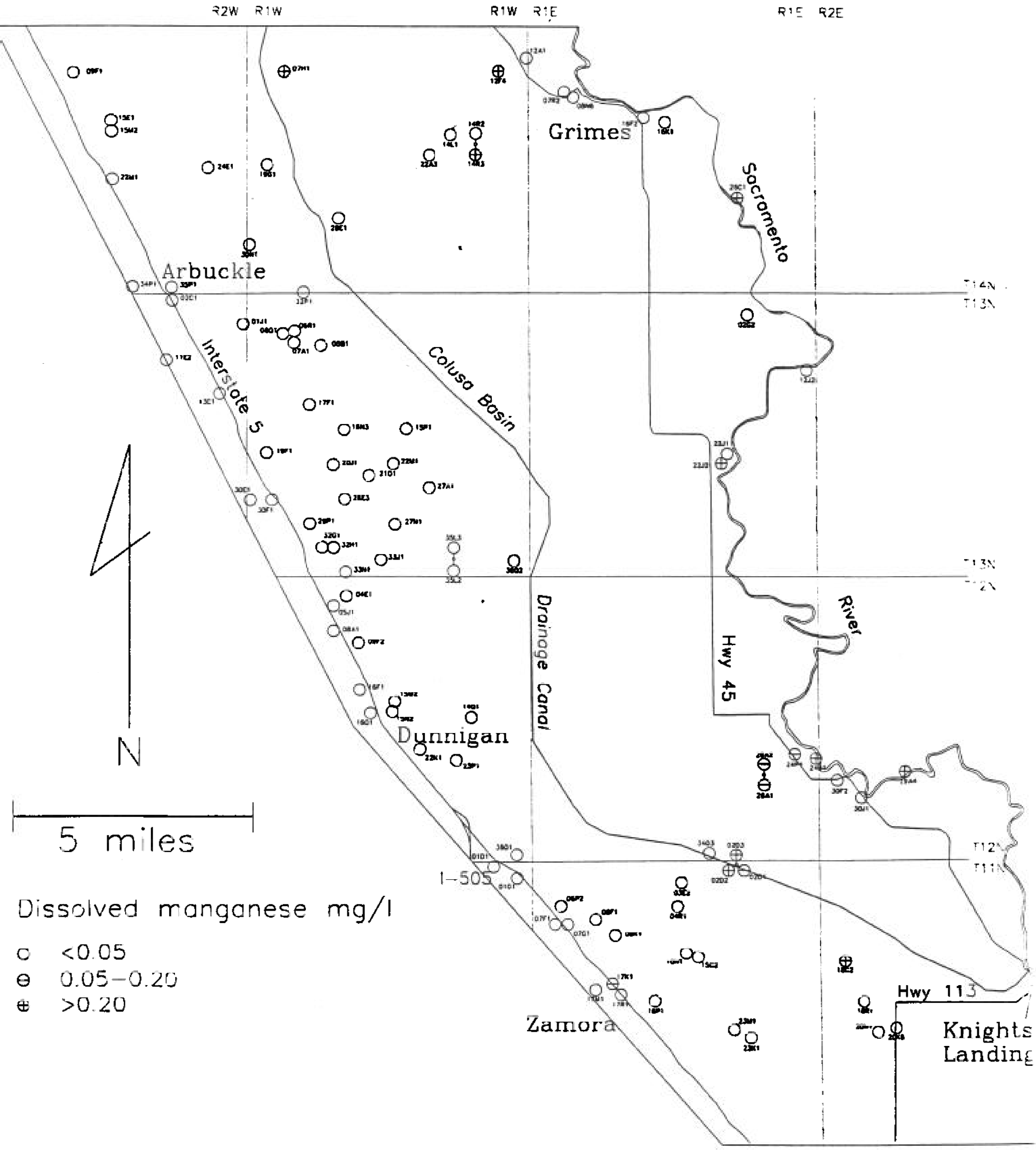


Figure 57. Dissolved Manganese Concentrations in the Lower Colusa Basin Study Area

Table 12. Organic and Radiological Constituents Detected

State Well Number	Sample Date	Chemical	Measured Concentration	EPA MCL	DHS MCL	Units	Data Source
12N/01E-24P01 M	2/23/89	BENTAZON, SODIUM SALT	0.24		18	UG/L	DPR
12N/01E-24P01 M	2/23/89	BENTAZON, SODIUM SALT	0.5		18	UG/L	DPR
12N/01W-15N02 M	4/27/87	1,1-DICHLOROETHYLENE	1.10	7	6	UG/L	DHS
12N/01W-15N02 M	6/2/87	1,1-DICHLOROETHYLENE	1.40	7	6	UG/L	DHS
12N/01W-15N02 M	1/25/89	1,1-DICHLOROETHYLENE	5.10	7	6	UG/L	DHS
12N/01W-15N02 M	4/27/87	CARBON TETRACHLORIDE	2.10	5	0.5	UG/L	DHS
12N/01W-15N02 M	6/2/87	CARBON TETRACHLORIDE	6.20	5	0.5	UG/L	DHS
12N/01W-15N02 M	1/25/89	CARBON TETRACHLORIDE	4.20	5	0.5	UG/L	DHS
12N/01W-15N02 M	4/27/87	CHLOROFORM (THM)	1.60	100		UG/L	DHS
12N/01W-15N02 M	6/2/87	CHLOROFORM (THM)	2.80	100		UG/L	DHS
12N/01W-15N02 M	1/25/89	CHLOROFORM (THM)	2.70	100		UG/L	DHS
12N/01W-15N02 M	4/27/87	TETRACHLOROETHYLENE	0.7	5	5	UG/L	DPR
12N/01W-15N02 M	6/2/87	TETRACHLOROETHYLENE	0.5	5	5	UG/L	DPR
12N/01W-15N02 M	1/25/89	TETRACHLOROETHYLENE	0.9	5	5	UG/L	DPR
12N/01W-15N02 M	1/25/89	TOTAL TRIHALOMETHANES	2.70	100	100	UG/L	DHS
12N/02E-30R01 M	2/23/89	BENTAZON, SODIUM SALT	0.16		18	UG/L	DPR
12N/02E-30R01 M	2/23/89	BENTAZON, SODIUM SALT	0.36		18	UG/L	DPR
12N/02E-30R01 M	2/23/89	BENTAZON, SODIUM SALT	0.28		18	UG/L	DPR
13N/01E-22J01 M	6/22/90	PARAQUAT DICHLORIDE	16			UG/L	DPR
13N/01E-27A02 M	4/13/94	PROMETON	0.071			UG/L	DPR
13N/01E-27A02 M	4/13/94	PROMETON	0.085			UG/L	DPR
13N/01W-06Q01 M	6/28/90	CHLORTHAL-DIMETHYL	1.2			UG/L	DPR
13N/01W-06R02 M	4/26/94	SIMAZINE	0.1	4	100*	UG/L	DPR
13N/01W-06R02 M	4/26/94	SIMAZINE	0.11	4	100*	UG/L	DPR
13N/01W-36Q02 M	6/27/90	CHLORTHAL-DIMETHYL	1.6			UG/L	DPR
13N/02W-02C01 M	1/14/92	CHLOROFORM (THM)	0.65	100		UG/L	DHS
13N/02W-02C01 M	12/14/93	GROSS ALPHA	0.00	15	15	PCI/L	DHS
13N/02W-02C01 M	1/14/92	TOTAL TRIHALOMETHANES	0.65	100	100	UG/L	DHS
13N/02W-26A01 M	6/21/90	PARAQUAT DICHLORIDE	7.9			UG/L	DPR
14N/01W-32N02 M	4/26/94	SIMAZINE	0.05	4	100*	UG/L	DPR
14N/01W-32N02 M	4/26/94	SIMAZINE	0.071	4	100*	UG/L	DPR
14N/02W-34J01 M	3/23/89	GROSS ALPHA	1.00	15	15	PCI/L	DHS
14N/02W-34J01 M	12/14/93	GROSS ALPHA	1.00	15	15	PCI/L	DHS
14N/02W-35M03 M	12/14/93	GROSS ALPHA	2.00	15	15	PCI/L	DHS

Where no MCL has been established, the MCL is left blank

The state MCL for simazine is expected to be lowered to near federal MCL additional lab or re-analyzed for quality control purposes. The only well with an organic constituent exceeding an MCL for drinking water was well 12N/01W-15N02M. The concentration of carbon tetrachloride exceeded the MCL in June 1997, but was just below the MCL in April 1987 and January 1989. Carbon tetrachloride has commonly been used as an industrial solvent with other uses including grain fumigation, and formerly, as a dry cleaning agent and fire extinguisher (Budavari, 1989).

Overall, a preliminary assessment of water quality indicates that most groundwater extracted from the central portion of the basin should meet criteria for application on crops.

One of the notable constituents of concern is boron in the southern part of the study area. Many groundwater wells extract water for use on crops with elevated boron south of the Colusa Basin Drainage Canal. The groundwater high in boron in this vicinity is believed to be from recharge associated with Cache Creek which would be just south of the depicted study area. Elevated boron in this area is also associated with deeper groundwater below the base of fresh water. If Cache Creek recharge is the source of elevated boron, concentrations should decrease to the north as is observed at well T12N/R1E-26A.

Colusa Basin Drain Quality

The Department has collected water quality samples on a monthly basis, with some interruptions, from the Colusa Basin Drain near Knight's Landing since 1957. The data on electrical conductivity (EC), boron, and chloride were reviewed for this study as they are indicators of suitability for irrigation. The EC values are occasionally high enough to reduce yields of sensitive crops if used as the sole irrigation source. Boron was rarely high enough to pose a problem. Most of the samples indicate that the drain would be a suitable source of irrigation supply for a wide range of crops. Little information is currently available on the organic quality of the drain water. Anecdotal evidence suggests that, at times, the pesticide (particularly rice herbicide) content of the drain water adversely affected crops irrigated with it. However, efforts to limit the discharge of rice herbicides have likely eliminated this potential problem. Nevertheless, the organic content of the drain should be monitored if it is used to convey project water. This is particularly the case if return flows from RD-108 are a portion of project supply. The U. S. Geological Survey is collecting pesticide samples from the drain as part of National Water Quality Assessment Program. These data were unavailable for review.

Electrical Conductivity. The median value of electrical conductivity from 350 sample analyses was 610 micromhos per centimeter (umhos/cm), which is roughly the equivalent of 400 milligrams per liter of total dissolved solids. The EC values ranged from 160 to 1,560 umhos/cm.

Water with high electrical conductivity can reduce crop yields if used as an irrigation source. Crops vary in their sensitivity to water with elevated EC. Ayers and Westcot, 1985, provide the following ranges for "Degree of Restriction on Use" for irrigation:

No restriction on use - EC < 700 umhos/cm
Slight to moderate restriction - 700 < EC < 3,000 umhos/cm
Severe restriction - EC > 3,000 umhos/cm

The highest EC values generally occurred during the winter months, December through March, when water would not be delivered under the proposed conjunctive use project. Water from the drain had EC values less than 700 umhos/cm during most of the irrigation season in most years. Occasionally, the EC, during the irrigation season, is greater than 700 umhos/cm making it undesirable for use on sensitive crops.

<u>Boron</u>. Boron can be toxic to plants in relatively low concentrations. General guidelines for determining the suitability of irrigation supplies containing boron are:

No restriction on use - < 0.7 boron milligram/liter (mg/l)
Slight to moderate restriction - 0.7 < boron < 3.0 mg/l
Severe restriction - boron > 3.0 mg/l

Boron concentrations in the Colusa Basin Drain are usually below 0.7 mg/l. During the period between June 1975 and May 1995 only three samples exceeded that level: 0.9 mg.l on July 26, 1977, 1.1 mg/l on May 31, 1979 and 1.1 mg/l on July 19, 1994.

Boron concentrations in water entering the drain in the project area can be greater than those measured near Knights Landing. Boron concentrations from samples representing Reclamation District No. 787 drainage for two of the five known samples. On June 28, 1957 it was 1.0 mg/l while the corresponding concentration at Knights Landing was 0.23 mg/l. On July 9, 1957 the corresponding values were 0.82 mg/l and 0.30 mg/l.

Groundwater in the areas to be served within the Yolo Zamora Water District often exceeds 2 mg/l of boron. Therefore, water diverted from the drain is unlikely to adversely affect crops and will indeed often provide a water supply benefit.

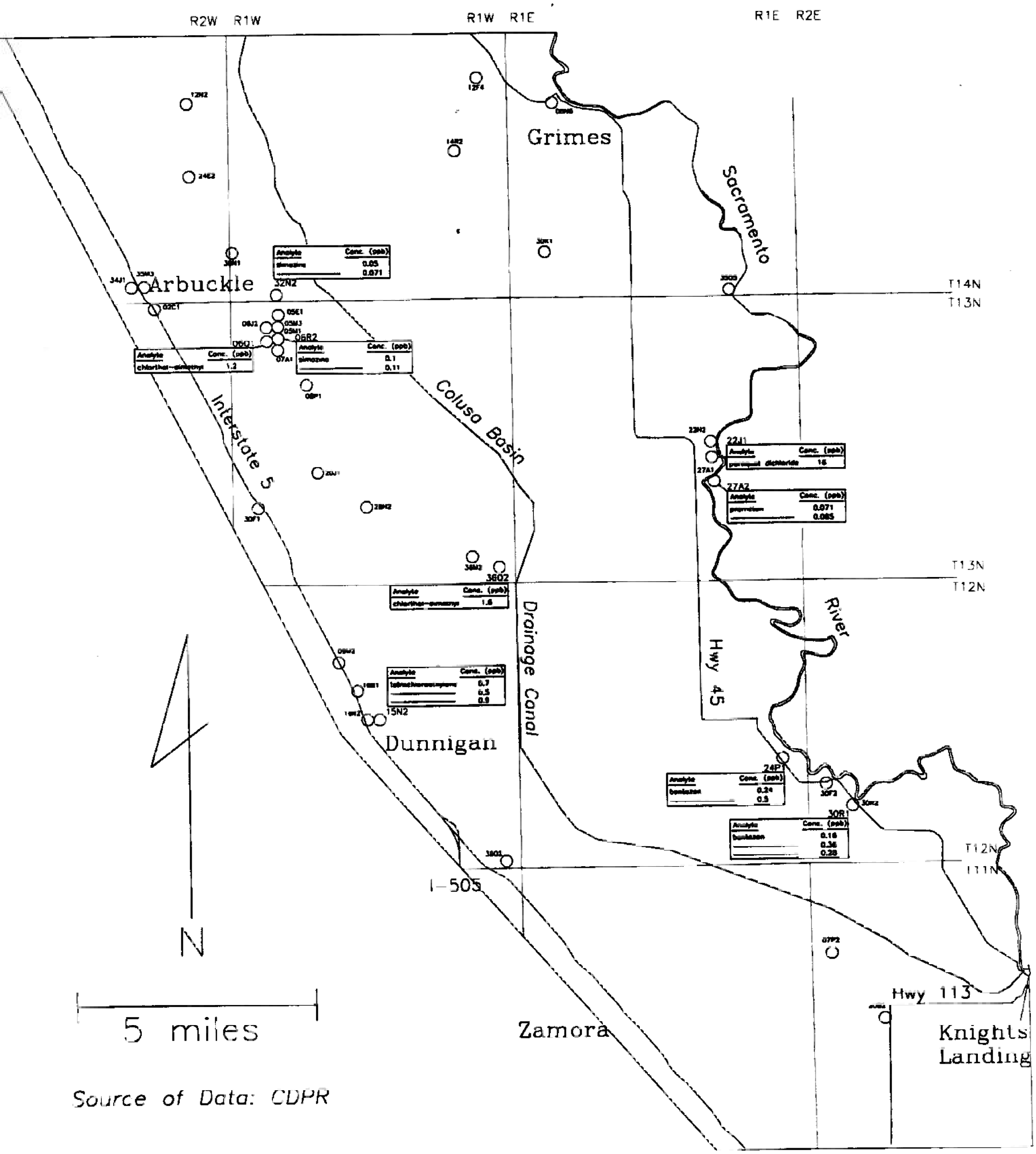


Figure 58. Locations of Wells with Pesticide Constituent Analyses and Concentrations of Constituents above the Detection Limit in the Lower Colusa Basin Study Area

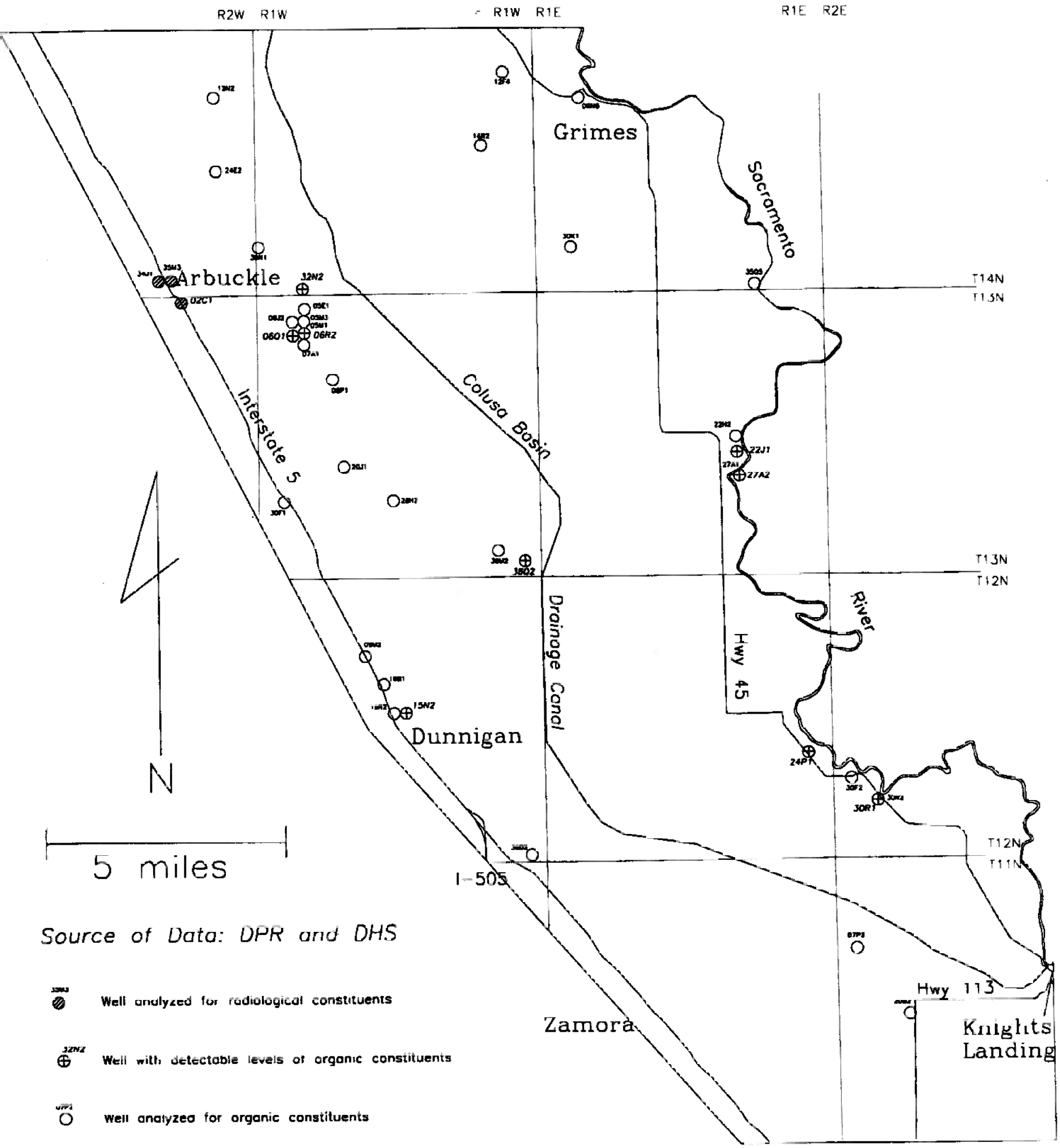


Figure 59. Wells with Organic and Radiological Constituent Analyses in the Lower Colusa Basin Study Area

Chapter 5

Water Rights

Three options for supplying water to the inlieu recharge area are evaluated in this Chapter. Each of the options evaluated appears to be potentially feasible.

The most costly alternative, diverting water at the RD-108 Sacramento River diversion facilities and transporting that water to Yolo-Zamora Water District through a combination of RD-108's existing facilities and new facilities as required, has the fewest water rights issues associated with its implementation. The second option, similar to option one except it involves use of the Colusa Basin Drain as a transportation facility, has a lower cost but introduces concerns relating to water supply and water quality within the Drain. The third option, direct diversion from the Colusa Basin Drain, is the least costly. However, it also has the greatest number of water rights issues which must be dealt with prior to receiving approval from the SWRCB for implementation.

Background

The Colusa Basin is an area bounded generally by the Sacramento River on the east, the foothills on the west, Stony Creek on the north, and Cache Creek on the south. The Colusa Basin Drain extends approximately 70 miles from an area near the Tehama-Colusa Canal northeast of Willows to the outfall gates at Knights Landing. Approximately one quarter mile upstream of the outfall gates is the bifurcation where the Knights Landing Ridge Cut flows south into the Yolo Basin. The canal provides drainage for an area of approximately 1600 square miles. The area primarily considered in this study is the southern portion of the Drain, an area extending from the northern boundary of Reclamation District 108 (near College City) to the Knights Landing Outfall gates.

Flow within the Drain results from natural runoff during spring, fall and winter, and return flow during spring, summer and fall. Return flows originate from diversions from the Sacramento River, local surface supplies and groundwater pumping within the Colusa Basin. The amount of natural runoff is closely tied to rainfall, and little natural runoff exists by late spring and early summer. Throughout the irrigation season, the majority of the flow within the drain and its extensions is "foreign water", primarily return flow from Sacramento River diversions.

The Colusa Basin Drain is used both as an agricultural drain and a water supply. The lower portion of the Drain has little slope, and the water level in this section can be maintained at desired levels for water supply pumping by controlling the outfall gates at Knights Landing. The pool which is created by manipulating the outfall gates can extend nearly to College City.

Several studies focusing on the Colusa Basin Drain have been conducted. The focus of the studies has included water rights, flood control and irrigation season drainage. The major studies include "Colusa Basin Investigation" DWR Bulletin 109, May 1964; "Colusa Basin Drain System Determination of Project Water," USBR November 1967; "Colusa Basin Study Water Supply and Water Rights," USBR December 1973; and "Colusa Basin Appraisal" DWR Northern District May 1990. Information contained in those studies has been evaluated and is incorporated here where appropriate.

Current Study

Yolo-Zamora currently relies on groundwater for its irrigation. It has no surface supply. Under a conjunctive use program, SWP water would be delivered to YZWD during wet and above normal years for inlieu recharge. During the recovery portion of the program no surface water would be delivered to YZWD. A similar although smaller recharge program was evaluated for Colusa County Water District. In addition, RD 108 (a Bureau contractor with a Sacramento River water rights settlement contract) would switch to groundwater pumping for a portion of its demand, and allow an equal amount of its Bureau base supply to be transferred to the Department. YZWD and CCWD are located directly across the Colusa Basin Drain from RD 108, and overlies the same groundwater basin.

One delivery option involves diverting surface water from the Sacramento River at the current RD-108 facilities, conveying it through RD-108 to a point where it would be conveyed across the Drain through a new siphon or released into the Drain for conveyance to the new pumping plant that would lift water into YZWD. A second option would entail construction of a new pumping plant at the Knights Landing outfall gates to pond additional water in the Colusa Basin Drain. Water from this source could be used to supply both YZWD and CCWD diversion points. The water would then be rediverted from the Drain to Yolo-Zamora through new facilities to be constructed on the Drain and to CCWD through reinstallation of a pumping plant drawing water from the Drain.

Under the third option, the Department, CCWD or YZWD could appropriate water directly from the Drain.

The first two proposals involve diverting water from the Sacramento River during the recharge phase, and exchanging RD-108 base supply for groundwater pumping during the recovery phase. Implementation of these proposals will require execution of an exchange agreement with the Bureau.

Water Rights

RD 108 has a Sacramento River water rights settlement contract with the Bureau (contract no. 14-06-200-876A, expires March 31, 2004) which includes both Base Supply and Project Water. Under the contract, RD 108 may divert up to 199,000 af/yr of Base Supply and 33,000 af/yr of Project Water. The Bureau contract governs all Sacramento River diversions by RD 108 during the period April through October. In addition to its Bureau contract supply, RD 108 retained the right to divert from the Colusa Basin Drain under its water rights permit (Application 11899, up to 75 cfs April through September). The Schedule of Monthly deliveries contained in RD 108's contract is shown in table 13.

Table 13. Schedule of Deliveries to RD-108 (acre-feet)

Month	Base Supply	Project Supply	Total
April	34,000	0	34,000
May	50,500	0	50,500
June	49,000	0	49,000
July	31,500	16,000	47,500
August	16,500	15,000	31,500
September	16,000	2,000	18,000
October	1,500	0	1,500
TOTAL	199,000	33,000	232,000

The quantities shown in table 13 may be reduced by 25 percent in a critical year. Contract terms and conditions could change following the contract renewal process. Since the contract expires in 2004. This process will effect any proposed conjunctive use proposal.

The water supply within the Colusa Basin Drain and its extensions during the spring, summer and fall consists primarily of return flows from Sacramento River, groundwater pumping and, to a limited extent, diversions from local sources. Natural runoff is rainfall dependent, and therefore by late spring very little riparian water exists within the basin. There is virtually no riparian water during the summer and fall. Therefore, the vast majority of diversions within the basin are made under a claim of appropriative rights. There has been substantial development along the Colusa Basin Drain since early this century.

Numerous agencies and individuals use the Colusa Basin Drain as a primary water supply, supplemental water supply, transportation or drainage facility. The major water agencies using the Drain as either a source of water or a conduit include, the Glenn-Colusa Irrigation District (GCID), the largest user on the drain and the single largest contributor to return flows in the drain, Provident Irrigation District, Princeton-Cordura-Glenn Irrigation District, Willow Creek Mutual Water Company, Maxwell Irrigation District, Colusa County Water District, Dunnigan Water District, Reclamation Districts No. 478, 108 and 787, Yolo Zamora Irrigation District, and the Colusa Drain Mutual Water Company. Many of these agencies also have water rights settlement contracts with the USBR. Of the above agencies, only RD 108 and 787, CCWD, DWD, YZWD and CDMWC are within the study area, and of these six agencies only RD 108, and CDMWC use the Drain for direct diversion or rediversion of their irrigation supply.

There are 102 permits and licenses and 7 statements for diversion of water from the Colusa Basin Drain and its tributaries on file with the State Water Resources Control Board (SWRCB) (Appendix A). The Colusa Basin Drain is also tributary to the Knights Landing Ridge Cut, and the Yolo Bypass including the Tule Canal and downstream channels. Only those applications or statements which are within the Colusa Basin Drain and its tributaries are shown here. Those rights downstream of the bifurcation at the Knights Landing Ridge Cut are not part of this study. However, any project implemented as part of the conjunctive use project would not be able to diminish the flow within the Drain or to the Ridge Cut without prompting protests from downstream diverters.

There are 37 licenses and permits and 4 statements for diversion of water from the Colusa Basin Drain within the study area (from the northern boundary of RD 108 to Knights Landing). The diversions on file with the SWRCB within the study area are shown in table 14. Nine of the permits and licenses exclude the months of July and August from the authorized season of diversion, and one permit is for the winter season only.

Table 14. Water Rights Along Colusa Basin Drain

Full Season Supply

Apl No.	Lic/Per	Date	Owner	Diver (cfs)	Season
735	L535	7/14/17	Schaad	2	5/15-10/1
1725	L1538	3/15/20	Knaggs	27.42	5/1-9/30
3423	L9994	5/17/23	Mormon Church	7.25	4/1-10/1
4351	L9995	1/28/96	Mormon Church	22	4/1-10/31
4901	L9996	1/28/26	Mormon Church	8.12	4/1-10/31
4902	L9997	2/17/27	Mormon Church	4.26	4/1-10/31
5359	L9997	2/17/26	Mormon Church	4.26	4/1-10/31
9554	L2766	4/10/39	Youngmark	12.96	4/1-10/1
11011	L4131	3/20/45	Balsdon Ranch	28	3/15 10/1

11854	L4061	5/5/47	Ridge Cut Farms	13.7	4/15-9/15
11855	L4062	5/5/47	Ridge Cut Farms	13.7	4/15-9/15
11863	L4329	5/8/47	Kalfsbeek et al	8	4/15-9/15
11864	L4330	5/8/47	Kalfsbeek et al	8	4/15-9/15
11865	L5428	5/8/47	Mafrici et al	6.4	4/1-11/1
11875A	L4339A	5/12/47	Kalfsbeek et al	3.5	4/15-9/15
11875B	L4339B	5/12/47	Kalfsbeek et al	4.5	4/15-9/15
11885	L3654	5/22/47	Cooling	7.5	4/1-10/1
11899	L7060	5/26/47	RD 108	75	4/1-10/1
11910	L4636	5/29/47	River Garden Farm	19	4/1-9/15
12256	L4303	1/23/48	Knaggs	9	4/1-10/1
12889	L7061	1/4/49	Doherty	3	3/15-10/1
12995	L3688	3/23/49	Knaggs	1.72	4/1-10/1
12996	L4304	3/23/49	Knaggs	2.11	4/1-10/1
12997	L4305	3/23/49	Knaggs	2.98	4/1-10/1
13003	L4208	3/28/49	Smith Co. DC Farm	5	4/15-10/1
13006	L5436	3/28/49	Anderson	6.5	4/15-9/15
17853	L7126	10/17/57	Schaad	50	4/15-9/15

No July/August Water

Apl No	Lic/Per	Date	Owner	Diver (cfs)	Season
16185	L8151	12/21/54	Whitmire	9.3	4/1-6/30 9/1-10/31
16305	L12087	4/7/55	Colusa Drain MWC	36	4/1-6/30
16361	P13861	5/5/55	Knaggs	65.36	4/1-6-30
16362	P13862	5/5/55	Ridge Cut Farms	14.52	4/1-6/30 9/1-9/30
16442	L8527	6/27/55	Mafrici et al	3.24	4/1-6/30 9/1-10/31
16515	L8209	8/11/55	Daniels	1.1	4/15-6/30 9/1-10/31
16516	L8210	8/11/55	Tolson	2.1	4/1-6/30 9/1-10/15
26141	P19426	11/29/79	Buck Horn Ranch	11	3/1-6-30 9/1-9/30
26604	P19117	11/5/80	Mumma Brothers	2.5	4/20-6/15

Winter Season Only

Apl No	Lic/Per	Date	Owner	Diver (cfs)	Season
28985	P20401	3/12/87	Schaad	2.7	11/1-1/15

Statement

No.	Owner	Season	Notes
S365	McCullough	Apr-Nov	1700-3400 af/year
S8442	Anderson Farms	Irrig. Sea.	Maximum 2600 af/year
S8443	Knaggs	Irrig. Sea.	Closed 1-9-89
S8444	Knaggs	Irrig. Sea.	Closed 1-9-89

Diversion from either Sacramento River or Drain

L994	L997
L995	L12087
L996	P13861

Seven of the 37 within the study area include the Sacramento River as an alternate source. Each of these 7 permits/licenses allows the diversion of Sacramento River water at the outfall gates. Under certain conditions depending on the water levels in the drain and the river stage, water can be diverted at the outfall gates by gravity or pumping and rediverted at various points along the drain.

Within the study area, Bureau contractors include RD-108, CCWD, DWD and CDMWC. CCWD and DWD are Tehema-Colusa Canal contractors. RD-108's Bureau contract was discussed earlier in this section.

CDMWC was formed to represent numerous individual water users along the Drain which were not within organized water districts. CDMWC signed a contract with the USBR on July 12, 1988 (contract no. 8-07-20-W0693, expires December 31, 2004). Unlike most Bureau contracts, CDMWC's contract has no provisions for a physical water supply. The purpose of the contract is to allow appropriators along the Drain to continue diverting during periods when diversion is not permitted in the license or permit, or when the SWRCB declares that insufficient water exists for diversion. Under its Bureau contract, CDMWC is entitled to divert up to 100,000 acre-feet per year from the drain. To replace the depletion within the Sacramento River system from the diversions on the Drain, the Bureau releases supplemental water from Shasta.

Intensive use of the supply available in the Drain has resulted in numerous complaints and protests filed with the SWRCB. Several have led to SWRCB Decisions regarding water diversion and use from the drain. The most significant are D683 (11-27-50), D1045 (11-13-61) and D1190(amended 10-29-64). D683 addressed the issue of the nature of Drain as a watercourse and the need to get a permit to appropriate water from the Drain. Some Protestants had argued that the Drain was not a natural watercourse and therefore not within the jurisdiction of the Division of Water Resources (predecessor to the SWRCB). The Division rejected this argument and declared that appropriations from the Drain were within its jurisdiction and required an application to appropriate water in conformance with the water code.

In D1045, the SWRCB found that water in excess of the downstream rights along the Colusa Basin Drain was physically available during the months of July and August. However, diversions at this time would require that an alternate source be made available to satisfy senior rights along the Sacramento River downstream of the Drain. All applications approved as part of and subsequent to D1045 have excluded July and August from the permitted season of diversion. This position was reaffirmed in D1190.

The Board is currently investigating a complaint filed by the CDMWC over diversions from the drain. The substance of the current complaint is that there are diversions occurring from the Drain which are not covered by a valid water right or a contract with the Bureau for a replacement water supply. CDMWC's contract provides for a supplemental water supply to cover deficiencies in the members permitted diversions, allowing them to continue diverting throughout the irrigation season. The contract is of benefit only to the extent that sufficient water is physically available.

Historically there has been sufficient water physically in the Drain to meet the demands of all the appropriators along the Drain except for short periods of time. Recent drought conditions and changes in the environmental requirements governing Tehema-Colusa Canal and Sacramento River diversions have diminished the physical supply in the Drain, diminishing the ability of the members to divert water during the contract period and reducing the value of CDMWC's contract. According to a report titled Colusa Basin Mutual Water Company dated October 1994 by Murray, Burns and Kienlen (MBK) flows have been reduced enough during certain periods that some pumps have become inoperable. This has increased the reliance on groundwater in some areas. The report also states that water flowed over the Davis Weir only 50% of the time during June and July 1994. The Davis weir is the most downstream control facility of GCID, historically a major contributor to the flow in the Drain. Problems with increased salinity levels in the Drain are noted as a problem as well.

The SWRCB responded to CDMWC's complaint in a letter dated October 21, 1996. SWRCB staff indicated that it will be monitoring diversions from the Drain by all parties which do not have a full season supply, and possibly all diverters if the year is declared critically dry.

Options

One option being considered is to divert SWP water from the Sacramento River under an exchange agreement with the USBR. The water would be transported through RD-108 using existing facilities, diverted through a new pumping plant at the Knights Landing outfall gates on the Colusa Basin Drain or a combination thereof.

A second option is for the Department, CCWD, or YZWD to apply for water right on the Drain. As discussed earlier, there is no unappropriated water available during the irrigation season. Since D1045 and D1190 were issued, all permits issued for appropriation from the Drain have excluded the months of July and August from the allowable season of diversion. Post D1045 appropriators are allowed to divert during July and August only if an alternate source is made available to satisfy the senior rights along the Sacramento River and in the Delta below the mouth of the Colusa Basin Drainage Canal.

A petition to the SWRCB to appropriate water from the Drain would have to contain information showing that there is still water physically available for appropriation in the lower drain, and that the Department would supply replacement water from the SWP or CVP by exchange. In light of the current complaint regarding the diminished water supply and water quality concerns in the Drain, this may be more difficult than it has been in the past. Additional flow and water quality monitoring of the Drain may be required.

The Department is in the position to assure that all downstream water rights holders are protected, since it is jointly responsible for meeting in basin demands making this option at least potentially feasible. Numerous protest will likely be filed. An agreement with the Bureau would need to be drafted to account for the water under the Coordinated Operating Agreement.

As an alternative to the SWP, CCWD, or YZWD applying for a permit for the entire amount of water proposed for the conjunctive use project, the Department could try to secure a transfer of water from a current appropriator on the drain. Within the study area RD 108 is the only major diverter from the Drain. RD-108 has a right to divert up to 75 cfs from the drain April through September under license 7060. RD-108's diversions from the Drain under its license are shown in table 15. RD-108's maximum diversion from the drain was 19,800 af in 1959. The last large diversion (15,342 af) was in 1968. Diversions within the past 20 years have not exceeded 6000 af, and very little water was available during the drought. This may be an option for supplying a portion of the wet and above normal year supply, but it is not adequate during even normal years.

Table 15. RD 108 Water Use Under L7060 (acre-feet)

Year	Apr	May	Jun	Jul	Aug	Sep	Total
Under P8251							
1954							3,210
1955							2,432
1956							0
1958							-
1959							19,800
1960							16,062
1963							14,635
1964							9,230
Under L7060							
1965							10,919
1966	603	263	0	2,576	1,619	0	5,061
1967	1,240	248	95	2,887	2,790	720	7,980
1968	1,705	3,236	3,270	3,462	3,000	669	15,342
1969	1,678	0	0	2,246	0	0	3,924
1970	421	738	835	671	937	513	4,115
1971	0	0	0	2,765	2,799	468	6,032
1972		1,191	1,438	1,866	2,430	217	7,870
1973		1,273	0	2,406	2,392	225	6,296
1974		605	114	1,593	2,024	437	4,773
1975	213	1,406	146	1,473	2,173	1,026	6,437
1976		1,344	140	1,414	2,086		4,984
1977		1,360	509				1,869
1979		351	1,808	0	1,071	496	3,726
1980		0	0	0	0	0	0
1981		1,900	1,061	0	245	573	3,779
1982		430	479	106	1,004	434	2,453
1983				186	905	746	1,837
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0
1989		4,450	375				4,825
1990		775	4,320				5,095
1991							0
1992							0
1993							0
1994							0

Notes: 1958 - Broken Meter
1979 - Diversion stopped 6-1 per SWRCB letter

1989 - No Jul Aug diversion due to drought
1990 - No Jul Aug diversions due to drought
1992 - No water available
1993 - No water available after June
1994 - No water available To: Dwight Russell, Acting

The only other large diverters from the drain with a year round supply are Provident ID (350 cfs under L7205 and L7206; A462 and A640) and Maxwell ID (65.5 cfs under L4644, A11957). Both districts could be supplied with an exchange supply from the Sacramento River. However, both districts divert water well upstream of the project area, and it questionable whether the transferred supply would reach YZWD or CCWD.

Water Supply Availability

The recharge phase of the project in the first two options relies on the Sacramento River as the surface water supply. Deliveries would be limited only by availability of SWP or CVP supplies, any permit conditions imposed by the SWRCB in approving the change petitions, and any pumping restrictions placed on the operation of the RD-108 diversion facilities. During wet or above normal years, there should not be significant restrictions placed on deliveries from the Sacramento River.

Issues relating to the Colusa Basin Drain effect the options which include using the Drain as either a conduit or a surface water supply. In recent years, the lower drain in particular has experienced problems with both water supply and water quality. The problems noted in the October 1994 report by MBK include diminishing supplies and reduced water quality. The reduction in return flow to the drain can be attributed to several factors including pumping restrictions placed on major Sacramento River diverters by Endangered Species concerns, changes in rice culture and pesticide residue requirements which have resulted in longer holding times and more reuse, and the recent drought. The statements in the MBK report are accompanied by photographs but no flow records or water quality sampling data. Flow records for the Drain at Knights Landing and Highway 20 are shown in table 16 and table 17, respectively. These records show a reduction in the flow during the recent drought period. Verification of the water supply and water quality problems noted will require further evaluation of he existing records and some additional monitoring.

Table 16. Colusa Basin Drain Monthly Flow at Knights Landing (CFS)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Type
1960	326	1248	262	566	864	1050	438	Below Normal
1961	430	1164	695	460	877	1059	366	Dry
1962	361	1048	404	390	727	1024	274	Below Normal
1963	0	131	597	409	614	1145	309	Wet
1964	99	924	449	99	384	847	265	Dry
1965	106	538	406	204	714	1009	266	Wet
1966	233	699	328	218	679	813	162	Below Normal
1967	0	0	105	272	500	810	262	Wet
1968		931	188	232	986	921	125	Below Normal
1969	0	206		275	699		129	Wet
1970	208	885	371	367	661	794	188	Wet
1971	54	707	203	108	462	655	161	Wet
1972	190	804	204	181	432	840	194	Below Normal
1973	323	481	316	309	774	970	242	Wet
1974	38	492	233	474	698	853	182	Wet
1975	134	415	191	509	933	1153	228	Above Normal
1976	222	414	32	111	920	1163	141	Critical
1977	10	484	1.4	2.4	302	470	13	Critical
1978	45	517	177	351	917	1313	128	Wet
1979	264	548	172	431	1126	1340	190	Dry
1980	329	998	387	485	1220	1398	275	Wet
1981	280	807	203	707	1462	1562	423	Dry
1982	0	295	786	1024	1344	1395	468	Wet
1983	0	0	91	674	1035	1335	488	Wet
1984	449	1061	745	1219	1537	1268	572	Wet
1985	411	924	671	1120	1429	1645		Dry
1986	496	1061	945	1130	1666	1698	484	Wet
1987							470	Critical
1988	719	938	377		998	1356	477	Critical
1989	334	323		625			457	Dry
1990	229	447	363	395	916	945	207	Critical
1991	292	282	190	268	472	383	90	Critical
1992	96	4	69	19	128	514	118	Critical
1993			40	107	404	1020		Above Normal
1994	233	118	61	94	442	744	251	
1995	21	0	125	233	311	890		
Ave	194	481	364	379	664	903	288	

Notes: Average shown above is for period 1924 through 1995. Gage at Knights Landing measures the flow from the Colusa Basin Drain to the Sacramento River at the outfall gates. Flow also is discharged to the Yolo

Bypass through the Knights Landing Ridge Cut. The Ridge Cut is not measured, therefore, the total discharge from the drain is not measured. During periods of high flow in the River, water cannot flow by gravity from the drain through the outfall gates. Frequently during the winter and spring, records show no flow at Knights Landing. Daily flows at Knights Landing can fluctuate significantly depending in the level of the Sacramento River and manipulation of the pool behind the outfall gates.

The level of the pool behind the drain is maintained at an optimum level for irrigation pumping during the irrigation season. Flow can back up behind the outfall gates nearly to College City.

The problems being noted on the Drain with diminishing supplies are more acute in dry years. The situation may not be as severe in wet or above normal years if pumping from the river and State and Federal Endangered Species Acts restrictions are not a problem.

The groundwater substitution phase of the program, as currently proposed, is accomplished by increasing the amount of groundwater pumping in RD-108 and transferring a like quantity of RD-108's base supply to the SWP. A review of RD-108's Schedule of Diversions indicates that a significant amount of base supply is available, even in summer. It is important to note that the quantities shown in the schedule of diversions may be reduced by 25 percent during critical years. The quantity available may be more dependent on the groundwater supply which can be developed.

Implementation

The study area is not within the current place of use of the SWP. Therefore, the Department will be required to apply to the SWRCB for a change in point of diversion and place of use. Compliance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA) will be required prior to approval by SWRCB. Given the problems being experienced along the Drain, it is likely that the proposal will generate a considerable amount of interest.

Implementation will also require the approval of the USBR. If the delivery of SWP water from the Sacramento River is accomplished through an exchange with the Bureau, an exchange agreement will be necessary. In addition, the recovery phase of the program involves groundwater pumping in RD-108 in exchange for the transfer of a portion of RD-108's base supply under its water rights settlement contract with the Bureau. The transfer of base supply to the Department may require that the Bureau file a change petition with the SWRCB as well to allow diversion of the water at Banks and delivery to the SWP place of use.

If the Drain is used as a conduit, DWR's petition to the Board would require inclusion of a change in point of rediversion. If the Drain is to be used as a water supply, the Department, CCWD, or YZWD would apply for a permit to appropriate water from the Drain. That application would have to contain information showing that a physical supply is available in the lower drain, and that the SWP would provide replacement water to downstream appropriators either through exchange with the USBR or directly from the SWP. If this option includes a transfer from another diverter on the drain for a portion of the supply, that diverter would have to petition the SWRCB for a change in place of use and point of diversion.

Diversion of water from the Sacramento River provides the most reliable and best quality water supply. With careful monitoring of the quantity of water discharged to and rediverted from the Drain, issues of damage to other appropriators on the Drain should be minimized. The primary issues of concern with this option are the water supply and water quality in the Drain.

The second option which involves petitioning the SWRCB for a permit to divert from the Drain, or a transfer from another Colusa Basin Drain appropriator appears to be feasible. It would require the least number of new facilities. However, a number of water rights and water supply availability issues will need to be dealt with in order to implement this option. Although physical supply and water quality were not problems in the past, recently both appear to have become problems, particularly in the lower portion of the Drain. The extent of the water quality problems in the lower section of the Drain should be investigated carefully to determine what detrimental effects it may have on the feasibility of incorporating use of the Drain into the conjunctive use program.

Table 17. Colusa Basin Drain Monthly Flow at Highway 20 (CFS)

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Year Type
1960	421	1202	457	744	965	838	356	Below Normal
1961	391	1188	783	660	1006	881	319	Dry
1962	422	1098	584	623	885	977	NR	Below Normal
1963	568	726	747	576	761	1094	346	Wet
1964	NR	915	427	447	NR	NR	224	Dry
1965	491	801	512	420	759	865	233	Wet
1966	327	860	461	496	796	680	171	Below Normal
1967	608	440	1093	554	778	861	283	Wet

1968	256	1059	441	565	1036	821	210	Below Normal
1969	402	973	740	589	902	769	204	Wet
1970	369	957	525	604	785	761	217	Wet
1971	374	1317	444	423	693	737	186	Wet
1972	368	964	409	454	652	892	244	Below Normal
1973	317	727	533	561	894	897	286	Wet
1974	307	753	491	910	1036	974	229	Wet
1975	356	920	461	828	1076	1024	237	Above Normal
1976	312	679	239	434	926	904	169	Critical
1977	90	642	121	121	424	388	116	Critical
1978	365	684	469	711	1056	1028	201	Wet
1979	328	802	424	803	1211	1029	200	Dry
1980	326	1048	603	805	1307	1160	275	Wet
1981	342	1039	446	1057	1464	1182	285	Dry
1982	682	743	908	902	1338	1334	467	Wet
1983	990		1050	908		1198	305	Wet
1984	547	1191	851	1311	1580	1041	376	Wet
1985	409	1048	768	1237	1442	1473	316	Dry
1986	449	921	834	1052	1338	1289	318	Wet
1987	495	913	707	907	1175	1079	341	Critical
1988	666	849	515	586	972	966	345	Critical
1989	438	572	587	800	995	1275	303	Dry
1990	NR	583	439	533	913	777	247	Critical
1991	423	477	353	371	535	724	159	Critical
1992	256	167	250	149	186	517	116	Critical
1993	322	279	290	201	489	776	203	Above Normal
1994	300	191	147	61	418	579	NR	
1995	591	551	364	297	416	848		
Ave	419	731	549	550	759	812	248	

Notes: Average shown above is for period 1924 through 1995
Gage is located at bridge on Highway 20 approximately 3 miles from Colusa

Chapter 6

Proposed Conjunctive Use Project

This chapter describes the potential for a conjunctive use project involving Reclamation District 108, Colusa County Water District, and the Yolo-Zamora Water District. It also documents the development of preliminary designs and cost estimates for facilities required to implement the proposed project. Additional delivery alternatives involving the Tehama-Colusa Canal or use of existing diversions on the Sacramento River north of the study area may be reasonable and cost effective but were not explicitly evaluated as part of this study. These alternatives should be considered at the feasibility level.

Project Description

This report evaluates two conjunctive use project alternatives. Alternative I is a conjunctive use project utilizing 12,300 acres of irrigated agricultural land within YZWD for in-lieu groundwater recharge. Alternative II is a project utilizing CCWD for recharge operations. Both alternatives involve RD-108 for groundwater extraction.

The project is comprised of two components: project recharge and project recovery. Project recharge would occur during wet and above normal water years as defined by the Sacramento River Index. Based on historical data, there would average 20 recharge occurrences during a forty year project life. To facilitate in-lieu recharge operations, the feasibility of the two alternatives were evaluated. Alternative I involves development of a surface water conveyance system with the capability for an annual delivery of approximately 38,300 af to YZWD. Alternative II involves developing a separate surface water conveyance system capable of delivering approximately 15,600 af per year to CCWD. These annual deliveries were determined by estimating groundwater demand that can be offset by a surface water supply with cost effective delivery facilities.

The second component involves recovery of the recharged water. Project recovery would occur during below normal, dry and critical water years (20 out of 40 years). This would be accomplished by groundwater substitution. RD-108 would reduce diversions from the Sacramento River which would make the water available to the State Water Project. RD-108 would pump an equivalent amount of groundwater to obtain maintain deliveries.

There is essentially no opportunity for direct groundwater recharge because all of the land within the project area is being used for agriculture and the soils in the area are generally unsuitable for percolation. The proposed in lieu recharge system could be expanded to serve additional areas if necessary. Also, the area served could be selectively reduced which would result in a lower unit cost as the less efficient portions of the system would be eliminated. The flexibility in the of area served provides an opportunity to control the proposed project yield and optimize the annual cost/project yield ratio.

Project Recharge Facilities

Alternative I - Yolo-Zamora Water District

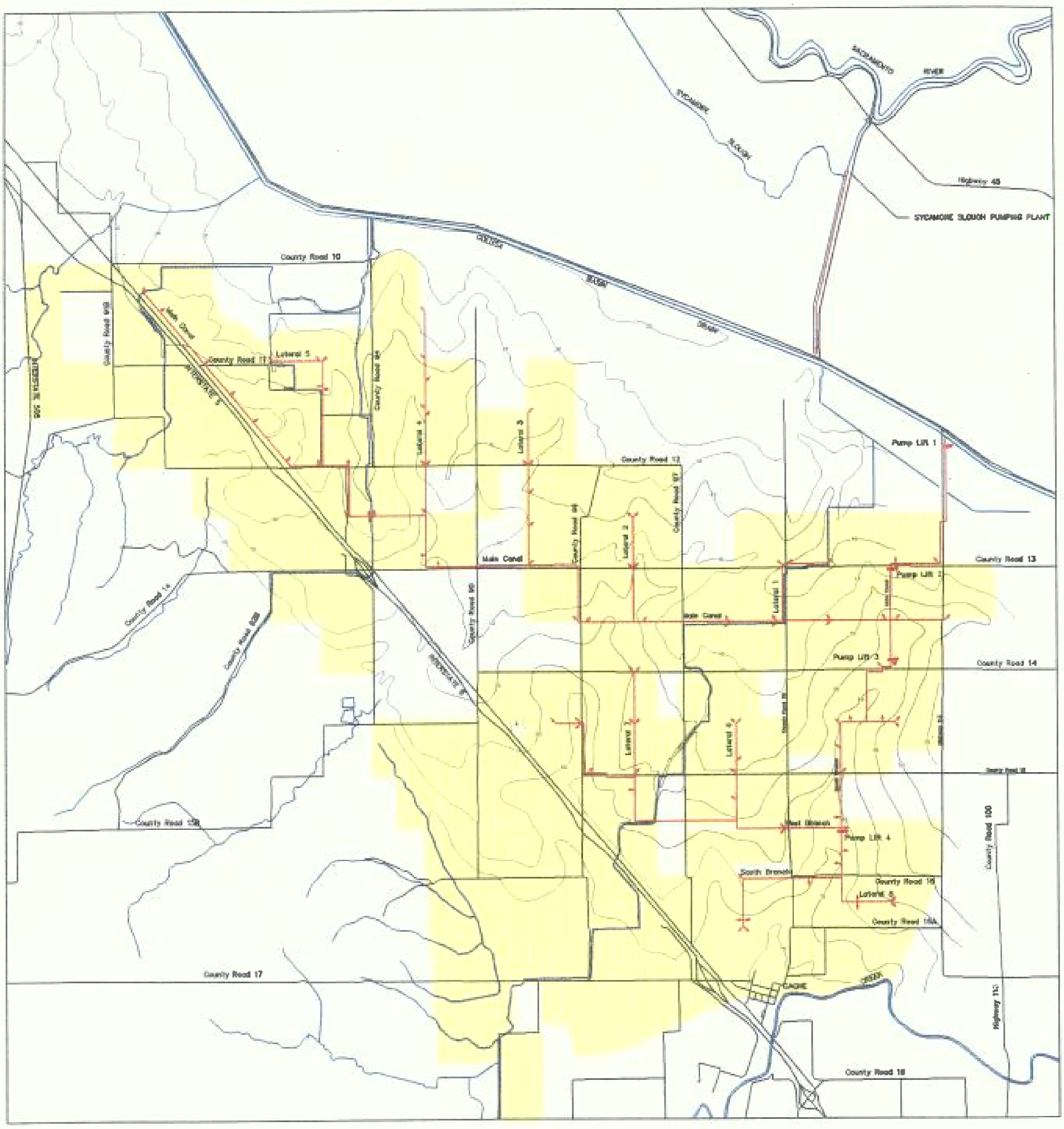
This section describes the proposed surface water delivery facilities required to facilitate in-lieu recharge in Yolo-Zamora Water District. YZWD is composed of numerous land owners with individual irrigation and drainage patterns and methods. Therefore, no existing facilities are available for incorporation into the proposed distribution system.

The design flow rates, conveyance facilities, and pumplifts were designed using the criteria outlined in this section. The proposed delivery system is designed to convey 350 cfs from the Sacramento River to the Colusa Basin Drain and ultimately to the YZWD for distribution. The proposed surface water delivery system for Alternative I is shown in figure 60.

An alternative delivery system configuration was also developed and evaluated for YZWD (Figure 61). Although these systems serve the same proposed areas, the alternative configuration is based on a Colusa Basin Drain diversion near the northern boundary of the District while the proposed system is based on diversion near the southern boundary.

Design Flow Rates. The design flow rates used to design the conveyance facilities are based on the following criteria and assumptions: (1) The smallest increment of area served by the system is 160 acres. If an individual's acreage is less than 160 acres however, a turnout (field headgate) was provided. (2) Open channel capacities were determined by assuming 12.5 gpm per acre for segments of the system that serve more than 4,000 acres; 22 gpm per acre for areas less than 2,500 acres; and for areas in between the flow rate varies linearly with the area served. (3) Pumplift capacities were determined using the same assumptions applied to the acreage downstream of the lift.

The design flow rate for the entire project area is 350 cfs and the capacity at the field headgates is 7.8 cfs or 3,520 gpm. These capacities are conservative and include an allowance for transportation losses, flexibility for varying crop mixes, irrigation efficiencies, reliability for pump outages, and the capability of meeting peak demand while irrigating in 12 hour per day increments.



State of California
The Resources Agency
Department of Water Resources

COLUSA BASIN
CONJUNCTIVE USE PROJECT

Figure

YOLO ZAMORA WATER DISTRICT
PROPOSED SURFACE WATER DELIVERY FACILITIES

Alternative I

Conveyance Facilities. The proposed conveyance facilities would consist of a pumping plant at the Knights Landing Outfall Gates to divert water from the Sacramento River to the Colusa Basin Drain. The proposed facilities are designed to divert water into the Drain at a rate of 200 cfs. The water is then ponded in the Drain as far north as College City. In addition, tailwater from RD-108 is recaptured and delivered to the drain. The Sycamore Slough Pumping Plant has a capacity of 155 cfs and discharges tailwater into Lateral 14A from which a pipeline through the Drain levee would permit gravity flow into the Drain. This option assumes that tailwater will be available on a schedule suitable for delivery to YZWD and that no discharge restrictions will be in place. As an alternative the pumping plant at the Knights Landing outfall gates could be sized to divert all required flows.

From the Drain the water is lifted through Pumplift #1 and discharged into the proposed Main Canal of the distribution system. The water is again lifted through Pumplift #2 which is located one and one-quarter mile south of the Drain. This is the last lift on the proposed Main Canal which continues for 10 miles and terminates at the northwest corner of the Yolo-Zamora Water District. This channel also has five laterals which deliver water north (down slope) of the channel. This portion of the system delivers water to 6,200 acres (one-half of the entire recharge area).

The south branch ties in to the Main Canal 1,000 feet north of Pumplift #3. This branch serves 4,100 acres of the recharge area. The Western Lateral turnout is located approximately 1.5 miles south of Pumplift #3 and which serves an area of 2,000 acres. The remainder of the deliveries are lifted through Pumplift #4 and conveyed to the southern portion of the district via the South Branch and Lateral 8.

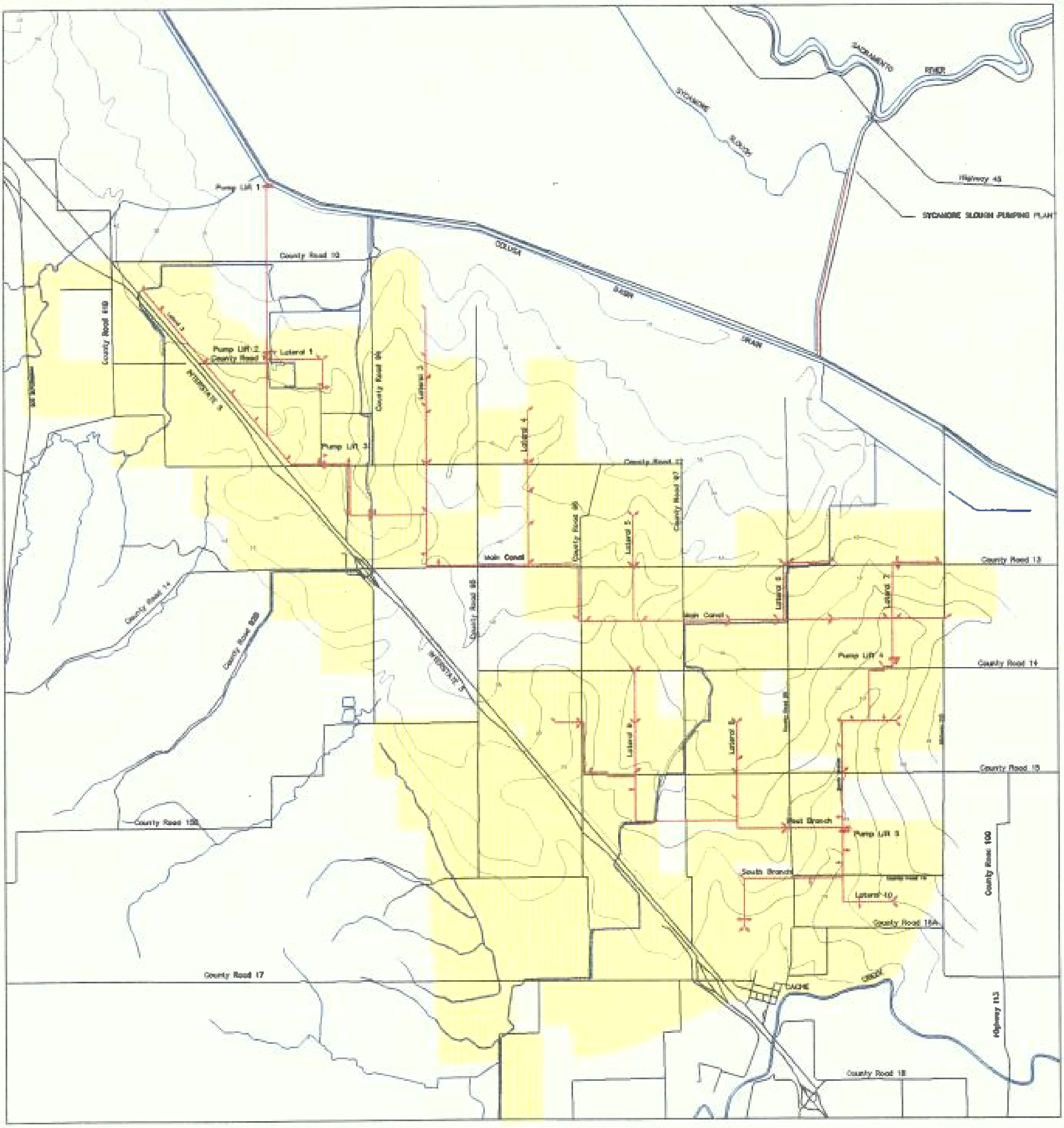
This distribution system has delivery cost/quantity of area served ratios that vary based on the elevation of the area served and the distance from the Colusa Basin Drain. The most efficient portion of this system is the Main Canal and its five gravity laterals. Once the water is lifted through Pumplift #2 it will gravity flow to 50% of the project recharge area. Conversely, the South Branch conveys water normal to the natural contours, up slope from the water source. After being lifted through the first two pumplifts the water must then be lifted again by Pumplift #3 to be distributed through the Western Lateral. The least efficient portion of the system is the remainder of the South Branch which is lifted a fourth time by Pumplift #4 to serve 1,375 acres where the average required head is 50 feet higher the water surface elevation at the drain.

Several assumptions were made regarding the design of the conveyance facilities. The invert dimensions were sized to accommodate common sized excavation equipment, the maximum velocity in an unlined open channel is 1.0 foot-per-second. The water surface elevation within the delivery channels was kept a minimum of 1.0-foot above the high point of the field. The canal alignments were selected to minimize the number of lifts as well as the static lift at any given location, avoid existing infrastructure, and utilize existing road and power transmission line corridors.

The control structures (check/drop structures and turnouts) were designed based on the alternatives detailed in Design of Small Canal Structures; U.S.B.R., 1974. The concrete box culverts were designed based on the guidelines detailed in Standard Plans; California Department of Transportation, July 1992. Other assumptions are as follows: the maximum velocity in a CMP culvert is 5 feet per second; road crossings were provided for existing traffic corridors only; and field headgates are provided for 160 acre areas or less (depending on property ownership boundaries).

Assumptions regarding the earthwork and associated costs are as follows: hydraulic excavation will be required for depths greater than 10 feet below the ground surface; spoil material will be spread over adjacent fields for an additional cost; and an attempt was made (given the pumplift locations, canal alignments and required head at field headgates) to balance the cut and fill material for each reach of the open channels. An attempt was made to develop the capability to deliver water to the entire district however, (given the high project yield that will be realized with the proposed 12,300 acres, the physical barrier that the Interstate creates, and the high elevations west of the Interstate) it was decided that the initial study will be focused on the east side of Interstate 5.

A design and cost estimate were developed for the alternative system configuration (based on the northern Drain diversion). Although this is a viable configuration, the capital cost is 10% greater than the system proposed in this report. This is due to an increase in earthwork required for open channel construction and the construction of an additional pumplift. These additional earthwork and pumplift requirements are both due to the existing topography relative to the diversion from the Drain. Although an estimate of the operation and maintenance costs was not developed, it is assumed that these costs would be similar to that of the proposed system since the water surface elevations at the diversions and field headgates and the canal alignments are the same for both configurations. A detailed cost estimate of the alternative configuration is shown in the Economic Analysis, Project Capital Costs section of this report. Figure 61 shows the configuration of this system.



Figure

State of California
The Resources Agency
Department of Water Resources

COLUSA BASIN
CONJUNCTIVE USE PROJECT

YOLO ZAMORA WATER DISTRICT
PROPOSED SURFACE WATER DELIVERY FACILITIES

Alternative I — Northern Turnout

LEGEND

- YOLO ZAMORA WATER DISTRICT
- EXISTING FACILITIES
- PROPOSED CONVEYANCE
- PROPOSED LIFT STATION
- PROPOSED TURNOUT

SCALE
0 1 2
MILES

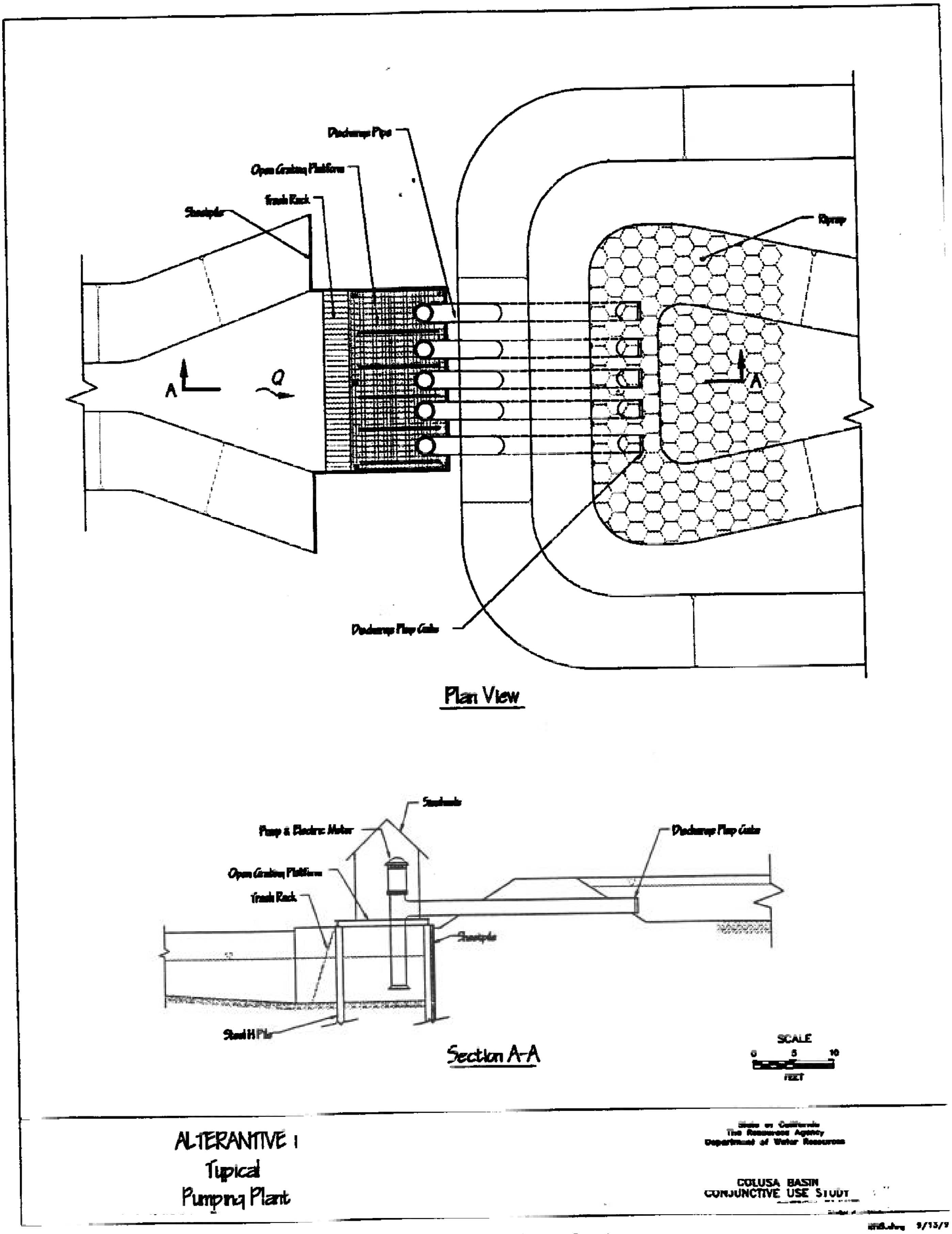


Figure 62. Alternative I Typical Pumping Plant

Pumping Plants. Several assumptions and criteria were considered in siting and sizing the four pumping plants for Alternative I. A typical pumplift configuration is shown in figure 62. The sites were chosen to minimize conflict with existing utilities, ease of access, proximity to power supply, and the distance between lifts was maximized to simplify operation of the system. The construction of the structural components (sumps, structural members, and platforms) are consistent with all the lifts for ease of construction, operation, and maintenance. Other assumptions include: sump dimensions were determined using Floway Pumps Handbook, canal inverts downstream of lifts were placed at or below stripped ground level, vertical propeller pump efficiency is 75%, and a reliability factor of 1.15 was applied to the braking horsepower to size each electric motor. Table 18 presents the pumplift parameters for each of the four proposed stations.

Table 18. Summary of Alternative I Pumplift Parameters

Pumplift	Unit	Motor Size (HP)	static Lift (feet)	Capacity (cfs)
Turnout	1,2	200	10	100 (EA)
1	1,2,3	300	15	88 (EA)
1	4	200	15	58
1	5	100	15	29
2	1,2,3	300	15	88 (EA)
2	4	200	15	58
2	5	100	15	29
3	1	300	15	84
3	2	200	15	56
4	1	75	7	28
4	2	50	7	42

Pumplift #1 is located in the Colusa Basin Drain and serves the entire project area. It lifts the water out of the drain and discharges into the Main Canal at station 0+00. The static lift is 15 feet, the design flow rate is 350 cfs, the total plant horsepower is 1,200 hp, and the total plant demand is 900 kilowatts. The mechanical component are listed in Table 1. Pumplift #2, which is located one and one quarter miles south of the drain, also serves the entire project area and has identical structural/mechanical components and capacities as Pumplift #1.

Pumplift #3 is located at station 10+00 of the South Branch and serves 4,700 acres. The static lift is 15 feet, the design flow rate is 140 cfs, the total plant horsepower is 500 hp, and the total plant demand is 375 kilowatts.

Pumplift #4 is located at station 150+00 of the South Branch and serves 1,375 acres. The static lift is 7 feet, the design flow rate is 70 cfs, the total plant horsepower is 125 hp, and the total plant demand is 95 kilowatts.

Alternative II - Colusa County Water District

An existing surface water delivery system exists within the CCWD. The system receives water from the Tehema-Colusa Canal and distributes it through 105 miles of underground pipeline. Essentially the entire district is served by the existing distribution system. The design objective in Alternative II is, therefore, to convey additional surface water supply from the Colusa Basin Drain to the Tehama-Colusa Canal for distribution throughout the district.

An existing pipeline that can convey water from the Colusa Basin Drain to the T-C Canal would be utilized in this alternative. The quantity of project recharge was based on the capacity of this pipeline instead of the estimated groundwater demand within the District. The proposed project recharge, based on this assumption, is 15,600 af.

The District's CVP contractual supply is 68,200 af while the current demand ranges from 125,000 af to 166,000 af (depending on the quantity of fallowed area). Therefore, the potential for project recharge is 57,000 af to 98,000 af. However, it should be noted that CCWD has requested that its contract with the USBR be increased by 55,000 acre-feet per year. The proposed surface water conveyance facilities for Alternative II are shown in figure 63.

Design Flow rate. The design flow rate for Alternative II was dictated by the capacity of the existing pipeline (Lateral 2A) that originates near the Colusa Basin Drain and discharges into the Tehama-Colusa Canal. It is assumed that this pipeline will be the sole source of delivery into the District. The pipeline diameter increases in a westerly direction from 48 inches to 60 inches. A maximum velocity of 5 feet per second was assumed in order to define the design flow rate for project recharge. The resulting discharge rate is 65 cfs.

Conveyance Facilities. Surface water diversions from the Sacramento River to the Colusa Basin Drain will occur as described in Alternative I Conveyance Facilities. Construction of new recharge conveyance facilities within the District would not be required for Alternative II. Lateral 2A will be used to convey water from the Drain to the Tehama-Colusa Canal. Since the District has an existing delivery system with additional capacity, project water would be conveyed and distributed through these facilities. The District Manager indicated that the system can serve the entire district and was sized to meet 100 percent

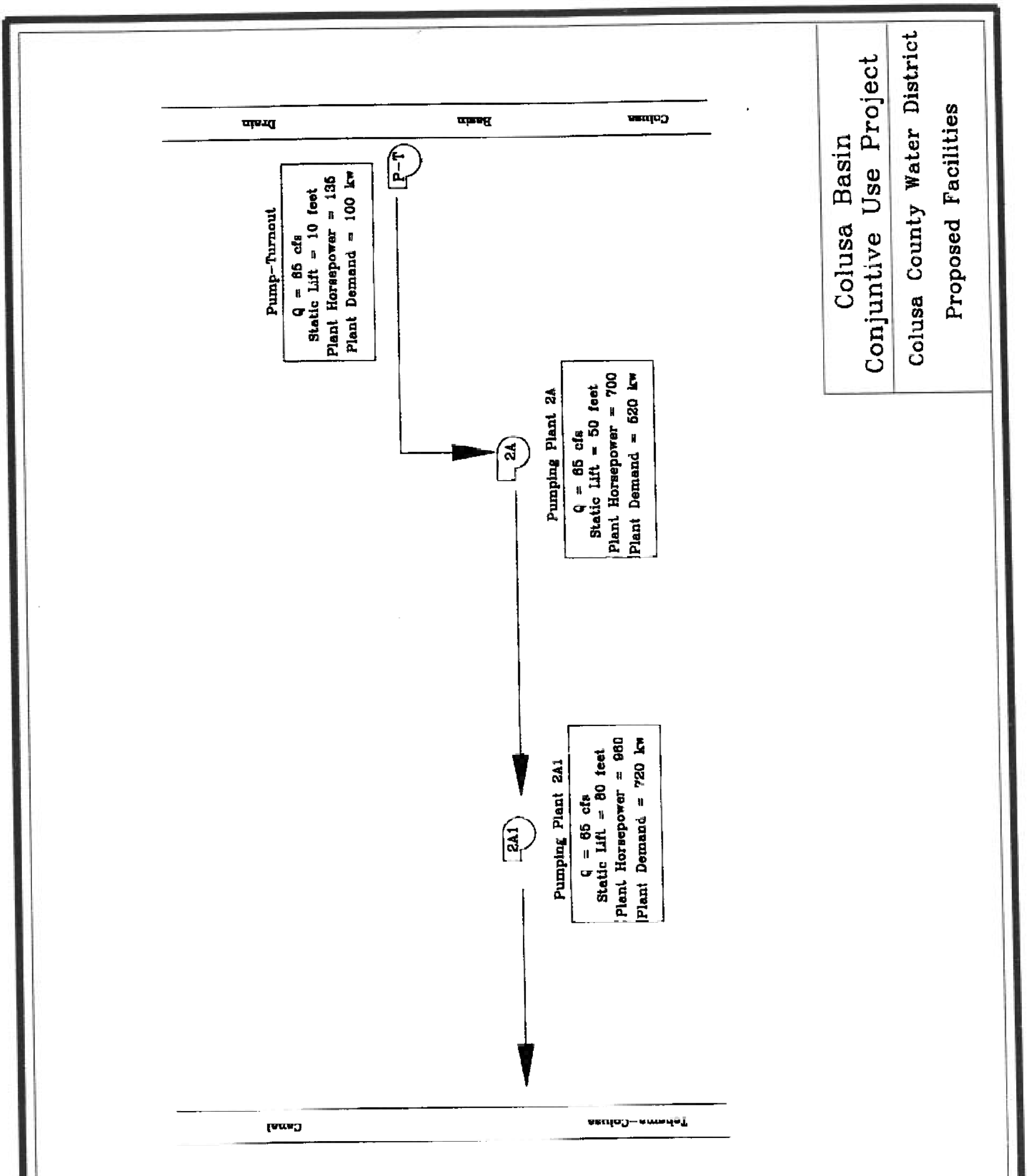


Figure 63. Alternative II Facilities

of its demands.

Pumping Plants. A pumping plant will need to be constructed at the Knights Landing Outfall Gates that will lift water out the Sacramento River and discharge into the Colusa Basin Drain. The static head is 10 feet, the capacity is 65 cfs, the total horsepower is 135 hp, and the plant demand is 100 kilowatts.

Two pumping plants were constructed along Lateral 2A; they are Pumping Plants 2A and 2A1. Pumping Plant 2A is located approximately 1.5 miles west of the Colusa Basin Drain and north of White Road. The design capacity at Pumping Plant 2A is 65 cfs with a static head of 50 feet, a total horsepower requirement of 700 hp, and a plant demand of 522 kilowatts. Pumping Plant 2A1 is located approximately 1.5 miles east of Highway 99 and north of White Road. The design capacity of Pumping Plant 2A1 is also 65 cfs with a static head of 80 feet, a total horsepower requirement of 960 hp, and a plant demand of 716 kilowatts. The Pumping Plant configuration is similar to that of Pumping Plant 2A.

Although the some of the structural components of the pumping plants are still intact, the mechanical components have been removed. The costs estimates presented in this report reflect construction and installation of new structural and mechanical components at both locations. Gated by-pass lines are provided to allow deliveries to continue to be made from the Tehama-Colusa Canal to the portion of District east of Highway 99. Table 19 presents the pumplift parameters for the two proposed stations. A plan and Profile of Pumping Plant 2A is shown in figure 64.

Table 19. Summary of Alternative II Pumplift Parameters

Pump Lift	Unit	Motor Size (HP)	Static Lift (FT)	Capacity (CFS)
Turnout	1	135	10	65
2A	1	250	50	24
2A	2	450	50	42
2A1	1	350	80	24
2A2	2	610	80	42

Project Recovery Facilities

Alternative I - Yolo-Zamora Water District

The annual project recovery associated with Alternative I is based on an estimated annual recharge of 38,300 acre-feet with occurs during wet and above normal years (20 out of 40 years). It was assumed that the total project recharge would be 10% less

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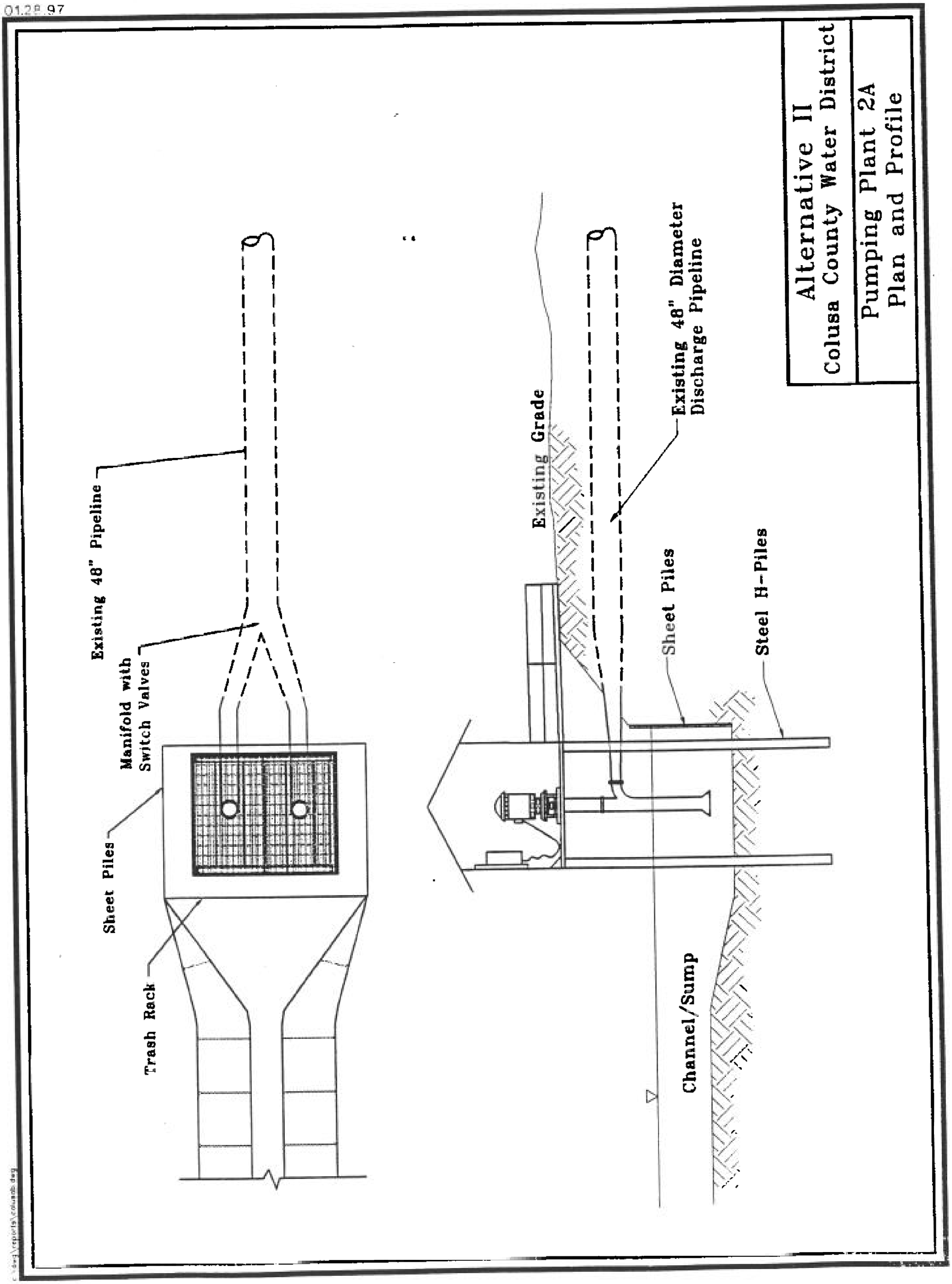

Figure 64. Alternative II Colusa County Water District Pumping Plant 2A Plan and Profile

than the volume of water delivered to account for losses due to deep percolation, aquifer losses, and a net increase in aquifer storage at the end of the project life. The total project recharge is 696,400 af. Based on the assumptions that extraction also occurs twenty times during the forty years of operation (below normal, dry, and critical years) and total project recovery equals total project recharge, an extraction occurrence would result in a project recovery of 34,800 acre-feet.

A groundwater extraction and delivery system will be developed in Reclamation District 108 to provide the capability to substitute groundwater for the reduction in surface water diversions. The design of the system is based on the following criteria and assumptions: The proposed production wells will be capable of supplementing the total groundwater substitution demand independent of all existing wells; the total design capacity is 145 cfs based on a delivery of 34,800 acre-feet over a 120 day period and 29 wells each with a flow capacity of 5 cfs; since an extraction occurrence of 34,800 acre-feet is less than 20% of RD 108's annual demand, no peaking or reliability factor was applied to the well field design capacity; the proposed production wells will be located so that they discharge directly into the existing conveyance facilities, therefore no new conveyance facilities are proposed within RD-108; the proposed pump motors will be electric and are sized to produce 5 cfs with a static head of 100 feet plus 15 feet of dynamic head (column losses); each well is designed to be 900 feet deep with a 16 inch diameter, 1/4 inch casing; and, well drilling/construction, and pump and motor costs were obtained from Eaton Drilling Co. of Woodland.

Alternative II - Colusa County Water District

The annual project recovery associated with Alternative II in Colusa County Water District is based on an estimated annual recharge of 15,600 af which would also occur 20 out of 40 years. Assuming the same losses occur for both alternatives, the total project recharge is 283,600 af. Based on the assumptions that extraction also occurs twenty times during the forty years of operation and total project recovery equals total project recharge, an extraction occurrence would result in a project recovery of 14,200 af.

The groundwater extraction and delivery system proposed for Alternative II in Reclamation District 108 is based on the criteria and assumptions detailed for Alternative I extraction facilities with a modification to the capacity. The total design capacity is 60 cfs based on a delivery of 14,200 af in a 120 day period. This is achieved with 12 wells each with a flow capacity of 5 cfs.

Economic Analysis

The capital, operation, and maintenance unit costs were obtained from Means Heavy Construction Cost Data; 1995, American Basin Conjunctive Use Pre-feasibility Study, Los Rios Farms Conjunctive Use Study, manufacturer price quotes, and service price quotes.

Project Capital Costs

The cost of constructing the proposed surface water delivery and groundwater extraction systems is $18 million for Alternative I and $4.4 million for Alternative II. The cost of the proposed Alternative I and Alternative II recharge systems are $12.4 million and $2.1 million, respectively. Construction of the alternative recharge system configuration in YZWD is $14.2 million. The costs of the proposed extraction well fields in RD 108 are $5.6 million for Alternative I and $2.3 million for Alternative II. A summary of the capital costs required to construct the proposed recharge and recovery facilities is shown in tables 20 through 23. A construction cost summary for Alternative I - alternate recharge facilities configuration is shown in table 24. Pump lift costs are itemized in table 25.

Table 20. Yolo-Zamora Conveyance System Summary of Construction Costs

Item	Quantity	Unit	Unit Cost	Item Cost
Main Channel				
Excavation	438,600	CY	$1.50	$657,900
Placement/Compaction	381,400	CY	$2.00	$762,800
Lateral Turnouts	5	LS	$10,000	$50,000
Road Crossings	6	EA	$41,000	$246,000
Main Channel Laterals				
Excavation	26,100	CY	$1.50	$39,150
Placement/Compaction	22,700	CY	$2.00	$45,400
Check/Drop Structures	6	EA	$3,000	$18,000
Field Headgates	25	EA	$4,000	$100,000
South Branch Channel				
Excavation	157,400	CY	$1,50	$236,100
Placement/Compaction	136,900	CY	$2.00	$273,800
Lateral Turnouts	5	EA	$10,000	$50,000
Road Crossings	2	EA	$41,000	$82,000
South Branch Laterals				

Excavation	18,500	CY	$1.50	$27,750
Placement/Compaction	16,100	CY	$2.00	$32,200
Check/Drop Structures	7	EA	$3,000	$21,000
Field Headgates	38	EA	$4,000	$152,000
Open Channels Subtotal				**2,794,100**
Road Crossings				
4 - 24" CMP	160	LF	$70	$11,200
5 - 30" CMP	200	LF	$90	$18,000
20 - 48" CMP	800	LF	$110	$88,000
Subtotal				**$117,200**
Pumplifts				
Sacto. River Diversion	1	EA	$2,395,300	$2,395,000
Pumplift No. 1	1	EA	$807,400	$807,400
Pumplift No. 2	1	EA	$807,400	$807,400
Pumplift No. 3	1	EA	$377,400	$377,400
Pumplift No. 4	1	EA	$233,200	$233,200
Subtotal				**4,620,700**
Facilities Subtotal				$7,532,000
Contingencies (25%)				$1,883,000
Subtotal				$9,415,000
Eng. & Admin. (25%)				$2,353,750
Compensation for Crops				$600,000
GRAND TOTAL				**$12,369,000**

Table 21. Alternative I - YZWD Facilities Summary of Construction Costs

Item	Quantity	Unit	Unit Cost	Item Cost
Groundwater Wells				
Test Hole $ E-log	29	EA	$7,000	$203,000
Well Construction	29	EA	$69,500	$2,015,500
Development & Testing	29	EA	$3,500	$101,500
Subtotal				**$2,320,000**
Mechanical Equipment				

Turbine Pump	29	EA	$15,000	$435,000
159 HP Electric Motor	29	EA	$29,000	$841,000
Subtotal				**$1,276,000**
Facilities Subtotal				$3,596,000
Contingencies (25%)				$899,000
Subtotal				$4,495,000
Eng. & Admin. (25%)				$1,123,750
Extraction Facility Cost				**$5,619,000**
Conveyance System Cost				**$12,369,000**
GRAND TOTAL				**$17,988,000**

Table 22. Alternative I - Yolo-Zamora Conveyance System Summary of Construction Costs

Item	Quantity	Unit	Unit Cost	Item Cost
Open channel Improvements				
Excavation	43,200	CY	$1.50	$64,800
Placement & Compaction	49,700	CY	$2.75	$136,675
Open Channel Subtotal				**$201,475**
Pumplifts				
Sacto. River Turnout	1	EA	$490,400	$490,400
Pumping Plant 2A	1	EA	$317,200	$317,200
Pumping Plant 2A1	1	EA	$342,200	$342,200
Pumplift Subtotal				**$1,149,800**
Facilities Subtotal				$1,351,275
Contingencies (25%)				$337,819
Subtotal				$1,689.094
Engineering & Administration (25%)				$422,273
TOTAL				**$2,111,000**

Table 23. Alternative II - CCWD Project Facilities Summary of Construction Costs

Item	Quantity	Unit	Unit Cost	Item Cost

Groundwater Wells				
Well Construction	12	EA	$69,500	$834,000
Test Hole & E-log	12	EA	$7,000	$84,000
Development & Testing	12	EA	$3,500	$42,000
Subtotal				**$528,000**
Mechanical Equipment				
Turbine Pump	12	EA	$15,000	$180,000
150 HP Electric Motor	12	EA	$229,00	$348,000
Subtotal				**$528,000**
Facilities Subtotal				$1,488,000
Contingencies (25%)				$372,000
Subtotal				$1,860,000
Eng. & Admin. (25%)				$465,000
TOTAL				**$2,235,000**
CONVEYANCE TOTAL				**$2,111,000**
GRAND TOTAL				$4,436,000

Table 24. **Alternative I - Yolo-Zamora Conveyance system (Northern Diversion) Summary of Construction Costs**

Item	Quantity	Unit	Unit Cost	Item Cost
Main Channel				
Excavation	526,500	CY	$1.50	$789,750
Placement/Compaction	457,800	CY	$2.00	$915,600
Lateral Turnouts	5	EA	$10,000	$50,000
Road Crossings	6	EA	$41,000	$246,000
Main Channel Laterals				
Excavation	26,100	CY	$1.50	$39,150
Placement/Compaction	22,700	CY	$2.00	$45,400
Check/Drop Structures	6	EA	$3,000	$18,000
Field Headgates	25	EA	$4,000	$100,000
South Branch Channel				

Excavation	157,400	CY	$1.50	$236,100
Placement/Compaction	136,900	CY	$2.00	$273,800
Lateral Turnouts	5	EA	$10,000	$50,000
Road Crossings	2	EA	$41,000	$82,000
South Branch Laterals				
Excavation	18,500	CY	$1.50	$27,750
Placement/Compaction	16,100	CY	$2.00	$32,200
Check/Drop Structures	7	EA	$3,000	$21,000
Field Headgates	38	EA	$4,000	$152,000
Subtotal				**$3,078,750**
Road Crossings				
4 - 24" CMP	200	LF	$70	$14,000
5 - 30" CMP	180	LF	$90	$16,200
20 - 48" CMP	900	LF	$110	$99,000
Subtotal				**$129,200**
Pumplift				
River Pump/Diversion	1	LS	$2,395,200	$2,395,200
Pumplift No. 1	1	LS	$807,400	$807,400
Pumplift No. 2	1	LS	$846,200	$846,200
Pumplift No. 3	1	LS	$807,400	$807,400
Pumplift No. 4	1	LS	$377,400	$377,400
Pumplift No. 5	1	LS	$233,200	$233,200
Subtotal				**$5,466,900**
Facilities Subtotal				$8,674,850
Contingencies (25%)				$2,168,713
Subtotal				$10,843,563
Eng. & Admin. (25%)				2,710,891
Crop Loss Compensation				$600,000
GRAND TOTAL				**$14,154,000**

Table 25. Pumplift Cost Summaries

Item	Quantity	Unit	Unit Cost	Item Cost
Sacramento River Pump-Turnout, Alternative I, 350 cfs				

H-Piles	840	LF	$35	$29,400
100 cfs Pump	3	EA	$74,000	$222,000
50 cfs Pump	1	EA	$45,000	$45,000
200 HP Motor/Controls	3	EA	$38,000	$114,000
100 HP Motor/Controls	1	EA	$27,000	$27,000
Misc. Equip.	1	LS	$6,000	$6,000
54" Welded Steel Dis. Pipe	160	LF	$220	$35,200
54" Steel Flap Gate	3	EA	$5,200	$15,600
42" Welded Steel Dis. Pipe	55	LF	$160	$8,800
42" Steel Flap Gate	1	EA	$3,400	$3,400
18" Stone Protection	150	CY	$43	$6,400
Sump, Platform, Trashrack	1	LS	$132,400	$132,400
Fish Screening Provisions	350	CFS	$5,000	$1,750,000
TOTAL				**$2,395,300**

YZWD Alternative 1, Pumplifts No. 1 and 2

Excavation	350	CY	$20	$7,000
Sheet Piling	4,000	SF	$25	$100,000
H-Piles	600	LF	$35	$21,000
88 cfs Pump	3	EA	$60,000	$180,000
58 cfs Pump	1	EA	$48,000	$48,000
29 cfs Pump	1	EA	$37,000	$37,000
300 HP Motor/Controls	3	EA	$50,000	$150,000
200 HP Motor/Controls	1	EA	$38,000	$38,000
100 HP Motor/Controls	1	EA	$27,000	$27,000
Misc. Equip.	1	LS	$10,000	$10,000
48" Welded Steel Dis. Pipe	150	LF	$180	$27,000
48" Steel Flap Gate	3	EA	$3,700	$11,100
42" Welded Steel Dis. Pipe	50	LF	$160	$8,000
42" Steel Flap Gate	1	EA	$3,400	$3,400
36" Welded Steel Dis. Pipe	50	LF	$135	$6,750
36" Steel Flap Gate	1	EA	$3,100	$3,100
18" Stone Protection	230	CY	$43	$10,000
Sump, Platform, Trashrack	1	LS	$120,000	$120,000
TOTAL				**$807,400**

YZWD Alternative 1, Pumplift No. 3

Excavation	150	CY	$20	$3,000
Sheet Piles	2,580	SF	$25	$64,500
H-Piles	300	LF	$35	$10,500
88 cfs Pump	1	EA	$60,000	$60,000
300 HP Motor/Controls	1	EA	$50,000	$50,000
58 cfs Pump	1	EA	$48,000	$48,000
200 HP Motor/Controls	1	EA	$38,000	$38,000
Misc. Equip.	1	LS	$5,000	$5,000
48" Welded Steel Dis. Pipe	50	LF	$180	$9,000
48" Steel Flap Gate	1	EA	$3,700	$3,700

42" Welded Steel Dis. Pipe	50	LF	$160	$8,000
42" Steel Flap Gate	1	EA	$3,400	$3,400
18" Stone Protection	100	CY	$43	$4,300
Sump. Platform, Trashrack	1	LS	$70,000	$70,000
TOTAL				**$377,400**
YZWD Alternative 1, Pumplift No. 4				
Excavation	200	CY	$20	$4,000
Sheet Piles	1,500	SF	$25	$37,500
H-Piles	200	LF	$35	$7,000
42 cfs Pump	1	EA	$43,000	$43,000
75 HP Motor/controls	1	EA	$22,000	$22,000
25 cfs Pump	1	EA	$37,000	$37,000
50 HP Motor/controls	1	EA	$18,000	$18,000
Misc. Equip.	1	LS	$5,000	$5,000
42" Welded Steel Dis. Pipe	30	LF	$160	$4,800
42" Steel Flap Gate	1	EA	$3,400	$3,400
36" Welded Steel Dis. Pipe	30	LF	$135	$4,050
36" Steel Flap Gate	1	EA	$3,100	$3,100
18" Stone Protection	100	CY	$43	$4,300
Sump, Platform, Trashrack	1	LS	$40,000	$40,000
TOTAL				**$233,200**
Sacramento River Pump-Turnout, Alternative II - 65 cfs				
H-Piles	200	LF	$35	$7,000
65 cfs Pump	1	EA	$54,000	$54,000
135 HP Motor/controls	1	EA	$34,000	$34,000
Misc. Equip.	1	LS	$5,000	$5,000
48" Welded Steel Dis. Pipe	200	LF	$180	$5,400
48" Steel Flap Gate	1	EA	$3,700	$3,700
18" Stone Protection	100	CY	$43	$4,300
Sump, Platform, Trashrack	1	LS	$52,000	$52,000
Fish Screening Provisions	65	CFS	$5,000	$325,000
TOTAL				**$490,400**
CCWD Alternative II, Pumping Plant 2A				
Excavation	250	CY	$20	$5,000
Sheet Piling	1,350	SF	$25	$33,750
42 cfs Pump	1	EA	$43,000	$43,000
450 HP Motor/Controls	1	EA	$68,000	$68,000
24 cfs Pump	1	EA	$37,000	$37,000
250 HP Motor/Controls	1	EA	$46,000	$46,000
Misc. Equip.	1	LS	$5,000	$5,000
42" Welded Steel Dis. Pipe	15	LF	$160	$2,400
36" Welded Steel Dis. Pipe	15	LF	$135	$2,025
Manifold w/Check Valves	1	EA	$35,000	$35,000

Sump, Platform, Trashrack	1	LS	$40,000	$40,000
TOTAL				**$317,200**
CCWD Alternative II, Pumping Plant 2A1				
Excavation	250	CY	$20	$5,000
Sheet Piling	1,350	SF	$25	$33,750
42 cfs Pump	1	EA	$43,000	$43,000
610 HP Motor/Controls	1	EA	$82,000	$82,000
24 cfs Pump	1	EA	$37,000	$37,000
350 HP Motor/Controls	1	EA	$57,000	$57,000
Misc. Equip.	1	LS	$5,000	$5,000
42" Welded Steel Dis. Pipe	15	LF	$160	$2,400
36" Welded Steel Dis. Pipe	15	LF	$135	$2,025
Manifold W/Check Valves	1	EA	$35,000	$35,000
Sump, Platform, Trashrack	1	LS	$40,000	$40,000
TOTAL				**$342,200**

The construction estimates include a right-of-way acquisition fee of $2,000 per acre for land that is permanently disturbed by the construction of open channels and pumplifts. The capital cost is increased by 25% for contingencies and 25% for project engineering and administration during planning, design, and construction activities.

Project Operation and Maintenance Costs

Average annual costs were developed by obtaining an annual cost for each occurrence and then applying 50% for a recharge occurrence and 50% for an extraction occurrence to each year of the project life. The operation and maintenance costs associated with project recharge included power costs, canal maintenance, pump refurbishing, and motor overhaul. Administration costs were not considered in this analysis.

The operation and maintenance costs associated with project recharge and recovery were determined using the following criteria and assumptions: Pump and motor maintenance (pump refurbish and motor overhaul) occurs after 20,000 hours of operation; the unit power cost is $.09 per kilowatt-hour which considers operation rate schedules and stand-by charges; extraction power costs were determined based on an average total head of 115 feet; the unit energy requirement for extraction is 171 kilowatt-hours per acre-foot which, under these project assumptions, results in a unit energy cost of $15 per acre foot; and, maintenance costs associated with conveyance facilities within RD-108 were not considered in this analysis.

Unit Cost

Based on the design, operation, and maintenance parameters for Alternative I detailed in this report the unit cost required to recharge and recover water is approximately $87 per acre-foot developed by the project. Similarly, based on the considerations detailed for Alternative II, the unit cost is about $61 per acre-foot. This unit cost represents the cost of project build-out, operation, and maintenance. However, it does not include possible costs incurred during project negotiations (to assure local participation), costs associated with further investigations prior to implementation, administrative costs or potential reduction in yield at the Delta Pumping Plant. The project unit costs are shown in tables 26 and 27.

Table 26. Alternative I - Economic Analysis

ANNUAL CAPITAL COST	$1,195,510
ANNUAL O&M COST	$325,800
TOTAL EQUIVALENT ANNUAL COST	$1,521,310
AVERAGE ANNUAL YIELD (af)	17,400
UNIT COST (Dollars/af)	**$87**

Table 27. Alternative II - Economic Analysis

ANNUAL CAPITAL COST	$294,823
ANNUAL O&M COST	$135,100
TOTAL EQUIVALENT ANNUAL COST	$429,923
AVERAGE ANNUAL YIELD (af)	7,100
UNIT COST (Dollars/af)	**$61**

The unit cost was developed using the following assumptions and criteria: A discount rate of 6 per cent was used; total project recharge equals total project recovery; and, a forty-year project life and amortization period was used with the capital costs were discounted accordingly.

Chapter 7

Environmental, Legal, and Institutional Considerations

The proposed conjunctive use project will construct new conveyance facilities to convey water from the Sacramento River to the Colusa Basin Drain and to the Yolo-Zamora Water District. A well field, with up to 29 wells, within RD-108 would be constructed to facilitate project recovery. The Department is in the process of installing a monitoring well network within RD-108 to facilitate collection of well defined groundwater level and quality data. If the proposed project advances to the feasibility study level additional exploration and testing will be needed to evaluate potential land subsidence. The potential environmental impacts associated with the proposed project and potential regulatory complications are discussed in this chapter.

Environmental Setting and Potential Impacts

The project area is shown in figure 1. Proposed project facilities and operations are discussed in earlier chapters.

Land Use

The project area is primarily used for irrigated agriculture of various orchard crops, row crops, and rice. As discussed earlier the source of irrigation supply within YZWD is groundwater, surface water within RD-108 and both within CCWD.

Most project facilities will be constructed along the margins of agricultural fields of along road easements. The proposed conveyance along agricultural fields will generally include turnouts that will deliver water to the adjacent fields. During recharge years, the project would provide surface water from the Sacramento River to reduce groundwater pumping for irrigation.

Surface water and/or groundwater is readily available throughout the area, and water supply is not a limiting factor that would force the fallowing of tillable land. Therefore, the additional surface water deliveries will not provide a new source of water that alleviates existing shortages and results in increased land being brought into production.

Water Resources

Surface Water. Proposed project facilities would pump water into the Colusa Basin Drain from the Sacramento River at the Knights Landing Outfall Gates. Provisions will be made for development of fish screens at the proposed pumping plant if needed to alleviate potential fishery impacts. The volume and timing of diversions from the river will be insignificant compared to the volume of water in the Sacramento River during the diversion period in wet and above normal years.

The project may include facilities to capture return flows that would otherwise be released to the Sacramento River from RD-108's Rough and Ready Pumping Plant. This water would move through RD-108's lateral 14A and then be released to the Colusa Basin Drain. This may result in a slight improvement to water quality in both the Sacramento River and the Colusa Basin Drain although existing data are insufficient to fully determine potential impacts.

The Colusa Basin Drain receives water from streams draining the Coast Range foothills, precipitation runoff from the western Sacramento Valley and agricultural return flows derived from water supplied from the Sacramento River and from groundwater. The amount of water delivered to the drain by the proposed project will generally be a small proportion of the water that has historically been present in the drain from other sources. In the future, as reductions in irrigation return flows increase the proportion will increase. It is expected that project water pumped into the drain will be offset by diversions to YZWD or CCWD and will not significantly affect the water levels normally maintained during the irrigation season by controlling outflow at the outfall gates. The quality of water supplied to the drain by the proposed project is expected to be better quality than that in the drain itself.

Construction of the pumping plants on the Sacramento River and the drain will disturb the channel and possibly limited associated riparian habitat. These impacts will be temporary, affect a limited area, and will probably not be significant.

__Groundwater Elevation Changes__. Expected deliveries for inlieu recharge will reduce groundwater pumping within YZWD and/or CCWD and will reduce seasonal groundwater level declines. Potential groundwater elevation changes and available groundwater quality data are discussed elsewhere in Chapters 3 and 4. If the proposed project is implemented a network of monitoring wells will be needed to assess groundwater level and quality changes and allow modification of pumping and recharge activities to be modified to minimize any significant adverse impacts detected. The development of the monitoring well network is not expected to disturb significant amounts of natural habitat.

__Vegetation__

Most of the project area has been developed for irrigated agriculture with only remnants of native habitat remaining. The California Department of Fish and Game's Natural Diversity Database did not contain any reports of sensitive plant species in the project area. Plant surveys will be needed to confirm the absence of sensitive species during the environmental assessment phase of project development.

Disturbed areas along road easements and farm margins in the project area have herbaceous vegetation. Some area along road and field margins have mature walnut and/or oak trees. Construction of conveyance canals will eliminate vegetation along road and field margins, but these areas are unlikely to have native plant species.

Construction of conveyance canals may eliminate some trees along road and field margins, but it may be feasible to modify the alignments to reduce or eliminate losses. Trees that are removed during construction will need to be replaced to mitigate for construction impacts.

Extensive stands of willows, tules and other riparian plants are present along Lateral 14A and the Colusa Basin Drain. Project impacts to this vegetation will be insignificant as long as water levels are not significant changed. If significant changes occur additional evaluation of potential impacts will be needed. Construction of the diversion from the drain to YZWD may adversely impact riparian vegetation at the diversion site. The diversion to CCWD will rehabilitate an existing diversion.

Wildlife

Wildlife Species. Since most of the project area is used for irrigated agriculture, most of the terrestrial wildlife is concentrated in the riparian, marsh and aquatic habitats created by the conveyance systems in the study area. The flooded rice fields also attract aquatic birds, wading birds, and amphibians. Several species protected by the State and,or Federal Endangered Species Acts were listed in the California Natural Diversity Database as occurring in the study area. These species are listed in table 28.

Wildlife surveys will be needed to determine which species are present in the project area. There were no reported sightings, in the project area, for the Valley elderberry longhorn beetle (Desmocerus califrornicus dimorphus), a federally listed threatened species in the database, and preliminary surveys of the area did not find any elderberry (Sambucus spp.) plants.

The Colusa Basin Drain traverses the project area and the Sacramento River borders the area approximately 4 miles east of the drain. Along with Lateral 14A these water bodies contain populations of resident fish. The river and drain have populations of anadramous fish.

Table 28. Special Status Species Found in the Project Area

Species	Status U.S.	Status CA	Notes
Winter-run chinook salmon (*Oncorhynchus tshawytscha*)	E	E	Winter-run salmon enter the Sacramento River from mid-December through early August. Fry and smolts begin their outmigration from the Sacramento River in late July.
Spring-run chinook salmon	May be C2 soon	SC	Spring-run chinook enter the Sacramento River from late March through September, and spawn from mid-August through early October. Spring-run and fall-run salmon spawning overlap during early October in the Sacramento River.
Steelhead trout (*Oncorhynchus mykiss*)		SC	Steelhead migrate in the Sacramento River from early August through November, and spawn from January through March. Fish which survive the spawning run return to the sea between April and June.
Sacramento splittail (*Pogonichthys macrolepidotus*)	T	T	Sacramento splittail are found in the Sacramento River upstream from Knights Landing and may be present in Lateral 14A and the Colusa Drain.
Swainson's hawk (*Buteo swainsoni*)	T	T	Frequently sighted in mature riparian woodland along Sacramento and Feather Rivers. Roost and nest in tall trees, forage in grassland and other open areas.
Bank swallow (*Riparia riparia*)		T	Migratory a summer resident, nesting in colonies in banks or on cliffs near water. Feeds primarily over open riparian areas.
Yellow-billed cuckoo (*Coccyzus americanus occidentalis*)		E	Inhabits deciduous riparian thickets (primarily willows) adjacent to slow-moving watercourses and orchards.
Tricolored blackbird (*Agelaius tricolor*)	C2	SC	Usually nests in dense cattails or tules. Forages in croplands, grassy fields, flooded land, and along edges of ponds.
Giant garter snake (*Thamnophis gigas*)	E	E	Forages in and along streams. Basks on streamside rocks or stream banks. May seek refuge in burrows, rock piles, or rotting logs.

E= listed as endangered; C2= candidate for listing as endangered; T= listed as threatened; SC= California Species of Special Concern

Sensitive Species. The species found in the project area and protected by the State and/or Federal Endangered Species Act, the Migratory Bird Treaty Act, or other measures are listed in table 28. The main sensitive species concerns will be:

- Potential pumping plant impacted to Sacramento Splitail and anadromous fish species such as winter run salmon. As the pumping plants will operate only in wet and above normal and the pumping plants will be screened the impacts should not be significant.

- Construction impacts to giant garter snake at the pumping plant sites. Construction will need to be scheduled during April through September to minimize impacts, and monitoring of construction activities and snake surveys will be needed. Construction of conveyance canals may increase habitat for this species.

- Construction impacts to potential tricolored blackbird nesting areas in marshes along existing canals.

- Potential construction impacts to nesting Swainson's hawks. Surveys for nesting hawks will need to be conducted in the spring before construction activities are undertaken. If nesting hawks are found within one-half mile of proposed construction areas, activities will have to be delayed until early September.

Environmental Documentation

Implementation of the project will require compliance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA) as well as the State and Federal Endangered Species Acts.

NEPA and CEQA Compliance

The proposed project may have a significant effect on the environment, and does not quality for a statutory exemption from CEQA. As DWR has no means of directly delivering water from its facilities on the Feather River to the project area, it will need to negotiate an exchange agreement with the USBR. The Bureau is required by the NEPA to analyze the environmental impacts of its actions. DWR will need to request that Bureau act as lead agency under NEPA. It the project proceeded to implementation an Environmental Assessment/Initial Study of the project will be needed. The key areas for the assessments will be:

- Will the project change the amount of surface water in any water body?

- Will the project alter the course or flow of flood waters?

- Will the project change the diversity of species or number of any species of plant or animal?

- Will the project reduce the numbers of any unique, rare, or endangered species of plant or animal?

- Will the project alter the present or planned land use of the area?

If there is substantial evidence that the proposed project will cause a significant effect on the environment the preparation of and Environmental Impact Statement/Environmental Impact Report will be required. If there is no such evidence, the project is modified to avoid the effects, or mitigation measures are added that eliminate the significant effects than a Finding of no Significant Impact/Negative Declaration will be appropriate.

Endangered Species Acts

The presence of several special status species in the project area will involve both the U. S. Fish and Wildlife Service and the California Department of Fish and Game in the project approval process. These agencies will be concerned with construction impacts to giant garter snakes and bird species and potential diversion impacts to fish.

Permitting and Institutional Considerations

The proposed project will require construction of facilities within the Colusa Basin Drain, and possible the Sacramento River; cross flood control levees; and potentially affect habitat of rare, threatened, or endangered species. As such, it will be necessary to comply with the requirements of various regulatory agencies and to obtain various permits.

Section 404 and Section 10 Permits

As the project would place fill in water bodies, the project's activities will be regulated under Section 404 of the Clean Water Act by the U. S. Army Corps of Engineers.

Construction of irrigation ditches is statutorily exempt from Section 404 regulations. Construction of pumping plants and placement of associated fill materials can be included in Nationwide Permits 18 (Minor Discharges) and 19 (Minor Dredging) providing no more than 25 cubic yards are discharged or dredged and that the discharge does not cause the loss of more than 0.1 acre of a special aquatic site (eg, wetlands). If these limits are exceeded, the agency constructing the facilities would need to apply for an individual 404 permit for the project.

The agency constructing the proposed project must inform the Corps of Engineers if any threatened or endangered species or critical habitat might be affected or is in the vicinity of the project. The Corps will prepare a Biological Assessment to determine whether the project may affect the species listed as threatened or endangered under the Federal Endangered Species Act. It may be necessary to obtain permits from the U. S. Fish and Wildlife Service and the National Marine Fishery Service allowing the incidental take of species that are adversely affected by the project. It may also be necessary to obtain a permit from the Department of Fish and Game pursuant to the California Endangered Species Act.

The presence of jurisdictional wetlands under Section 404 along the alignment of proposed facilities has not been determined since wetland delineation is beyond the scope of this investigation. However, background on wetlands and potential relations to a conjunctive use project are discussed below.

Much of the project area is located in the Colusa Basin, and area that historically received relatively frequent flood inundation and, therefore, contained extensive wetlands. The area has been largely reclaimed for agricultural use and only remnants of the historic wetland and riparian habitat remain.

It is expected that the proposed conjunctive use project will maintain existing agricultural practices with the exception of a periodic interchange of surface and groundwater as a source of irrigation supply. This is not expected to have any significant adverse impact on remnant wetlands or riparian vegetation. However, it is possible that localized drawdown of groundwater levels might affect wetlands that are maintained through groundwater discharge or by areas of shallow groundwater. If such wetlands are identified, extraction wells could be located in areas that would not affect them, or monitoring water levels could be used to control well operations to minimize impacts. Similar controls can be used to protect riparian vegetation from excessive water level declines.

If facilities are constructed in a navigable waterway, a Section 10 permit will probably be required from the Corps of Engineers.

Water Quality Permits

As project facilities will be placing fill material into State waters, the constructing agency will need to obtain a Clean Water Act Section 401 Water Quality certification or waiver from the State Water Resources Control Board. The application for the certification or waiver must include a copy of the 1601 agreement from the Department of Fish and Game for the project.

Construction activities will involve ground clearing for pumping plants and conveyance facilities. If the clearing covers 5 acres or more, the National Storm Water Program will require that the project proponent obtain an National Discharge Elimination Permit.

Streambed Alteration Agreements

The California Fish and Game Code, Section 1601, requires public agencies to notify the Department of Fish and Game of work to be done in a river, lake, of stream. Fish and Game requires project proponents to submit a "Notification of Removal of Material and/or Alteration of Lake, River, or Streambed Bottom or Margin" and Environmental Impact Report, Negative Declaration, or comparable environmental review documents.

A stream is defined as a body of water that flows at least periodically or intermittently through a bed or channel and supports or has supported fish and other aquatic life, including a watercourses that supports or has supported riparian vegetation (14 CCR Sec. 1.72). Ditches can be subject to Section 1600 jurisdiction.

Flood Control Regulations Governing Land Use

The State Reclamation Board has designated a floodway associated with the Colusa Basin Drain. It is anticipated that project facilities will be constructed within the floodway and that they may cross flood control levees associated with the drain. If the proposed facilities are constructed by the local participants they must submit an application for consideration and approval by the Reclamation Board of any construction, improvement, or alteration of any flood control structure or facility. Facilities constructed as part of the State Water Project are exempt from this requirement. Flow restrictions are the primary concern. The Board's Standards for Encroachment state:

"no embankment, waste or spoil materials may be placed within the limits of a stream channel, a project floodway, or a bypass without a determination by the Reclamation Board as to its effect on:

(1) The flood carrying capacity of the stream or floodway;
(2) Recreation and environmental factors;
(3) Fish and Wildlife."

If facilities are constructed on state land under the jurisdiction of the State Lands Commission the constructing entity would need to obtain a Land Use Lease from the Commission. Facilities constructed as part of the State Water Project are exempt from this requirement.

Water Transfer Considerations

Water Code Section 1220 prohibits export of groundwater from the Sacramento and Delta-Central Sierra hydrologic regions unless such export is in compliance with a county adopted groundwater management plan. The project area includes portions of Colusa and Yolo Counties, neither of which have adopted a groundwater management plan that covers this area. This section of the Water Code does not impact the use of groundwater by this project within the service area of the participating agencies as presently contemplated. However, it may be an impediment to the pumping and export of groundwater should that be needed. Furthermore, Yolo County has adopted a water transfer ordinance that would regulate the direct export of groundwater.

Water Code Section 10750 et. seq. allows specified local agencies to adopt groundwater management programs. The Water Code authorizes inclusions of components facilitating conjunctive use projects and local agency extraction programs in the adopted management plan. To date, the local participating agencies have not adopted groundwater management plans. However, it is anticipated that they will in the future. Therefore, the Department should work closely with these agencies to assure that thoughtful management through conjunctive use is not prohibited or unreasonable restricted while addressing export and extraction issues. Whether the adoption of a groundwater management program would satisfy or supplant the requirements of Water Code Section 1220 requires further legal evaluation.

In the case of Baldwin v. County of Tehama the California Supreme Court determined that Counties have some authority to regulate groundwater use. The decision left the extent of this authority undefined. Both Colusa and Yolo Counties are considering development of local ordinances to manage groundwater. Operation of the proposed conjunctive use project would require compliance with the adopted ordinances and their provisions could affect the feasibility of the proposed project or its continued viability.

In 1995 the Yolo County Board of Supervisors adopted "Water Transfer Guidelines for Evaluating Impacts from Out-of-County Water Transfers". These guidelines will provide a basis for evaluating the impacts of proposed water transfers.

USBR Coordination

The groundwater substitution portion of the proposed conjunctive use project will result in the transfer of a portion of RD-108's base supply to the Department. Under the water rights settlement agreement between RD-108 and the USBR, the Bureau may have the right to approve this transfer.

As the Department lacks the facilities to deliver water directly from the State Water Project to the local participants, and exchange with the Bureau will be required to effect delivery. Additional releases would be made from USBR facilities on the Sacramento River for diversion to the project participants. The State Water Project would release an equivalent amount of water down the Feather River to compensate the Bureau.

In addition, informal consultation with the Bureau will be needed to provide assurance that any expected depletion of the Sacramento River system will be accounted for and to effect proper allocation of water developed in accordance with provisions of the Coordinated Operation Agreement for the Central Valley Project and the State Water Project.

Compatibility with Other Potential Projects

Many agencies have come to view conjunctive use as a means of improving the efficiency of the existing water resources system and are contemplating developing projects to increase useable water supplies.

Calfed

Calfed is investigating a wide range of alternatives that may be available for addressing future water supply needs including water needed to provide for environmental protection. Among the alternatives being considered would be a conjunctive use program for the Sacramento Valley that would develop up to 500,000 acre-feet of useable groundwater storage capacity. Calfed is not expected to develop projects to accomplish this but would instead facilitate the development of conjunctive use projects by other entities. While no specific projects have been identified, it is possible that the proposed conjunctive use project could partially meet Calfed's goal.

California Urban Water Agencies - Agriculture (CUWA-Ag)

CUWA-Ag is a coalition of urban and agricultural water agencies that receive water exported from the Sacramento-San Joaquin Delta. They have undertaken a series of negotiations with upstream water right holders in an attempt to arrange a settlement concerning responsibility to meet anticipated increased inflow requirements expected to result from the SWRCB's adoption of new Delta water quality standards. These negotiations are looking at three tiers of projects. The first would involve credit for existing water conservation activities that have increased inflow to the Delta. The second would involve additional conservation activities. The third tier would involve the potential for developing "new" water through conjunctive use projects. RD-108 has been a participant in these negotiations. It is expected that the proposed project could provide the basis for any conjunctive use in the project area.

Yolo County FCWCD

The Yolo County Flood Control and Water Conservation District (YCFCWCD) derives its water supply from Cache Creek. It occasionally provides surplus water to a portion of Yolo Zamora and is in the process of developing increased yield through a conjunctive use project. It may have additional water that could be made available to YZWD in the future. This water could be made available to the part of YZWD that is not expected to be served by the proposed project. To assure compatibility between the potential projects coordination should be implemented with YCFCWCD. The draft report on the Yolo-Solano Supplemental Water Supply program (Borcalli & Associates, 1992) indicated that the demand for supplemental water within YZWD was 10,000 af/year.

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Appendix A

Water Rights Along the Colusa Basin Drain

Appendix A
Water Rights along Colusa Basin Drain

Appl. No.	Lic/Per	Date	Owner	Source	diversion	season
462	L7205	9/15/16	Provident ID	Sac. R, Colusa Basin Dr., Drain #13, Unnamed Drain, Drain #55, Willow Cr.	250	4/1 to 10/1
640	L7206	4/9/17	Provident ID	same as A462	100	4/1 to 10/1
735	L535	7/14/17	Schaad	RD 108 Back Levee Dr.	2	5/15 to 10/1
892	L7207	1/18/18	Provident ID	same as A462	110	4/1 to 10/1
1422	L1109	9/2/19	Perez	Colusa Basin Main Dr.	10	4/15 to 10/1
1725	L1538	3/15/20	Knaggs	RD 108 Back Levee Borrow Pit	27.42	5/1 to 9/30
3423	L9994	5/17/23	Mormon church,Rich	Sac R., Colusa Basin Dr.	7.25	4/1 to 10/1
4901	L9995	1/28/26	Mormon Church	Sac R., Ridge Cut	22	4/1 to 10/31
4902	L9996	1/28/26	Mormon Church	Sac R., Ridge Cut	8.12	4/1 to 10/31
5359	L9997	2/17/27	Mormon Church et al	Sac R., Ridge Cut	4.26	4/1 to 10/31
8570	L1963	3/4/36	Montz Ranches	Willow Creek	1.82	4/1 to 10/1
8970	L2487	5/10/37	Pollock	Knights Landing Ridge cut	2	4/1 to 10/1
9554	L2766	4/10/39	Youngmark	RD 108 Drain	12.95	4/1 to 10/1
10417	L2851	3/25/42	Wallace Constr	Ridge Cut	11	4/15 to 10/1
10595	L4331	1/27/43	Garner et al	Colusa Basin Dr.	10	4/15 to 10/1
11011	L4131	3/20/45	Balsdon Ranch	RD 2047 Main Drain	28	3/15 to 10/15
11028	L4355	4/12/45	Zumwalt MWC	Colusa Trough	96	4/1 to 10/15
11242	L5493	12/26/45	Holzapfel	B1 Drain, trib to Willow Creek	22	3/15 to 11/1
11314	L4226	3/12/46	Zumwalt MWC	Salt/Freshwater Cr.	11.7	4/1 to 10/15
11460	L4227	7/5/46	Kalfsbeek	Salt/Freshwater Cr.	8	4/1 to 10/15
11819	L4231	4/9/47	Calvert	Colusa Basin Main Dr.	7	4/1 to 10/15
11854	L4061	5/5/47	Ridge Cut Farms	RD108 Back Levee Borrow Pit	13.7	4/15 to 9/15
11855	L4062	5/5/47	Ridge Cut Farms	RD108 Back Levee Borrow Pit	13.7	4/15 to 9/15
11863	L4329	5/8/47	Kalfsbeek et al	RD 108 Drain	8	4/15 to 9/15
11864	L4330	5/8/47	Kalfsbeek et al	RD 108 Drain	8	4/15 to 9/15
11865	L5428	5/8/47	Mafrici et al	RD 108 Drain	6.4	4/1 to 11/1
11875 A	L4339A	5/12/47	Kalfsbeek et al	RD 108 Drain	3.5	4/15 to 9/15
11875 B	L4339B	5/12/47	Kalfsbeek et al	RD 108 Drain	4.5	4/15 to 9/15
11878	L5499	5/13/47	Wallace Estate	Knights Landing Ridge Cut	34	4/15 to 10/15
11881	L4334	5/15/47	Wallace	RD 2047 Main Drain	13	4/15 to 10/1
11885	L3654	5/22/47	Cooling	RD 108 Back Borrow Pit	7.5	4/1 to 10/1
11886	L4645	5/22/47	Ash et al	RD 2047 Main Drain	15	4/15 to 10/1
11888 A	L4365A	5/22/47	Ottenwaller	RD 2047 Main Drain	6.7	4/1 to 10/1
11888 B	L4365B	5/22/47	Seaver	RD 2047 Main Drain	2.6	4/1 to 10/1
11889	L3810	5/22/47	Paulo	RD 2047 Main Drain	8.25	4/1 to 10/1
11899	L7060	5/26/47	RD 108	RD 108 Back Levee Borrow Pit	75	4/1 to 10/1
11900	L4367	5/26/47	Campbell	RD 2047 Main Drain	16.4	4/1 to 10/1
11901	L4970	5/26/47	Goette Farms	RD 2047 Main Drain	8	4/1 to 9/15
11902	L6553	5/26/47	Goette	RD 2047 Main Drain	9	4/1 to 10/1
11903	L4366	5/26/47	Ottenwalter	RD 2047 Main Drain	8.1	4/1 to 10/1
11909	L4200	5/29/47	Campbell	Powell Slough	4.5	4/1 to 10/1
11910	L4636	5/29/47	River Garden Farms	Knights Landing Ridge Cut	19	4/1 to 9/15
11925	L4632	6/9/47	Strain	RD 2047 Main Drain	8	4/15 to 9/15
11926	L4633	6/9/47	Strain	RD 2047 Main Drain	22	4/15 to 9/15

Appendix A (continued)

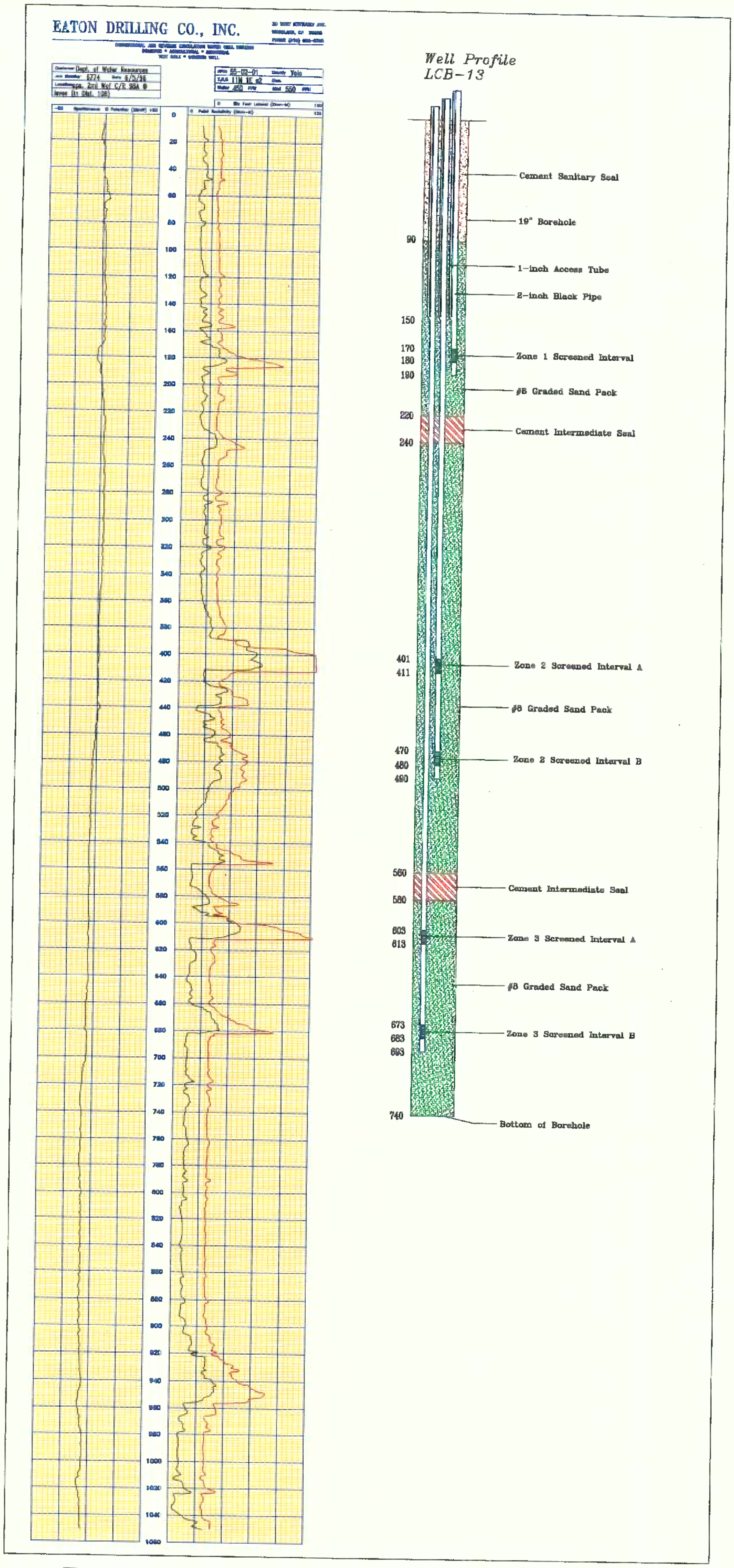
Appl. No.	Lic/Per	Date	Owner	Source	diversion	season
11931	L4306	6/10/47	Beauchamp&Bulrush Farms	RD 2047 Main Drain	12	4/1 to 10/1
11954	L3804	6/24/47	Sarti	RD 2047 Main Drain	8	4/1 to 9/15
11955	L4643	6/24/47	Maxwell ID	RD 2047 Main Drain	14	4/15 to 10/1
11956	L4586	6/24/47	Maxwell ID	RD 2047 Main Drain	8.5	4/1 to 10/1
11957	L4644	6/24/47	Maxwell ID	(1) Logan & Hunter Creeks, (2) RD 2047 Main Drain	(1) 15 (2) 50.5	4/15 to 10/1
11958	L4694	6/24/47	Maxwell ID	Stone Corral Cr.	13.5	4/15 to 10/1
11959	L3849	6/24/47	Zumwalt MWC	RD 2047 Main Drain	15	4/1 to 9/15
12087	L6558	9/16/47	Baber	RD 2047 Main Drain	2	5/1 to 9/15
12115	L4197	9/30/47	USFWS	RD 2047 Main Drain	8	4/15 to 11/1
12256	L4303	1/23/48	Knaggs	Colusa Basin Drain	9	4/1 to 10/1
12363	L4307	2/27/48	Hahn	Colusa Basin Drain	11.5	4/1 to 10/1
12411	L4868	3/17/48	Moore	RD 2047 Main Drain	7	4/15 ro 10/1
12412	L4056	3/17/48	Davis Trust et al	RD 2047 Main Drain	6	4/1 to 10/1
12429	L4690	3/23/48	Gunnersfield Ent.	RD 2047 Main Drain, Lateral C	13	4/15 to 10/1
12459	L4433	4/1/48	King Estate	Colusa Basin Drain	3	5/1 to 9/15
12889	L7061	1/4/49	Doherty	RD 2047 Main Drain	3	3/15 to 10/1
12946	L4240	2/23/49	Perez	RD 2047 Main Drain	7	4/1 to 9/15
12995	L3688	3/23/49	Knaggs	RD 108 West Levee Borrow Pit	1.72	4/1 to 10/1
12996	L4304	3/23/49	Knaggs	RD 108 West Levee Borrow Pit	2.11	4/1 to 10/1
12997	L4305	3/23/49	Knaggs	RD 108 West Levee Borrow Pit	2.98	4/1 to 10/1
13000	L5796	3/25/49	Davis Trust et al	Unnamed Trib to Colusa Trough	5	4/1 to 10/1
13001	L7062	3/25/49	Davis Trust et al	RD 2047 Main Drain	0.27	4/1 to 10/1
13002	L4057	3/25/49	Davis Trust et al	RD 2047 Main Drain	1	4/1 to 10/1
13003	L4208	3/28/49	Smith Co., D.C. Farms	RD 108 canal	5	4/15 to 10/15
13006	L5436	3/28/49	Anderson	RD 787 back levee borrow pit	6.5	4/15 to 9/15
13452	L4364	11/9/49	Provident ID	Colusa Basin Main Drain	3.25	4/1 to 10/1
13734	L4473	5/12/50	Silver Bullet Farms	RD 2047 Main Drain	3	4/1 to 10/1
14131	L4372	1/18/51	Massa	Drain Trib to Colusa Trough	3	5/1 to 10/31
14297	L4521	5/9/51	Capital Outing Club	Lateral F drain of RD 2047 (Lurline Cr.)	3	5/1 to 11/1
14649	L4252	1/21/52	Cave et al	(1) Lateral F (Lurline Cr. or RD 2047 (2) RD 2047 Main Drain	20.1	4/1 to 10/1
14661	L9585	1/29/52	Santa Rosa Tule Duck Club	Colusa Basin Main Drain	1.1	1/1 to 12/31; 4/15 to 11/15
15392	L5391	6/29/53	Tuttle et al	Knights Landing Ridge Cut	21.2	4/1 to 9/30
16185	L8151	12/21/54	Whitmire	Colusa Basin Dr Back Borrow Pit	9.3	4/1 to 6/30; 9/1 to 10/31
16305	L12087	4/7/55	Colusa Drain MWC	Sacramento R.	36	4/1 to 6/30
16361	P13861	5/5/55	Knaggs	Sac R., Colusa Basin Drain at Knights Landing	65.36	4/1 to 6/30;
16362	P13862	5/5/55	Ridge Cut Farms	Sycamore Slough	14.52	4/1 to 6/30; 9/1 to 9/30
16442	L8527	6/27/55	Mafrici et al	Colusa Basin Main Drain	3.24	4/1 to 6/30; 9/1 to 10/31
16515	L8209	8/11/55	Daniels	Colusa Basin Drain	1.1	4/15 to 6/30; 9/1 to 10/31

Appendix A (continued)

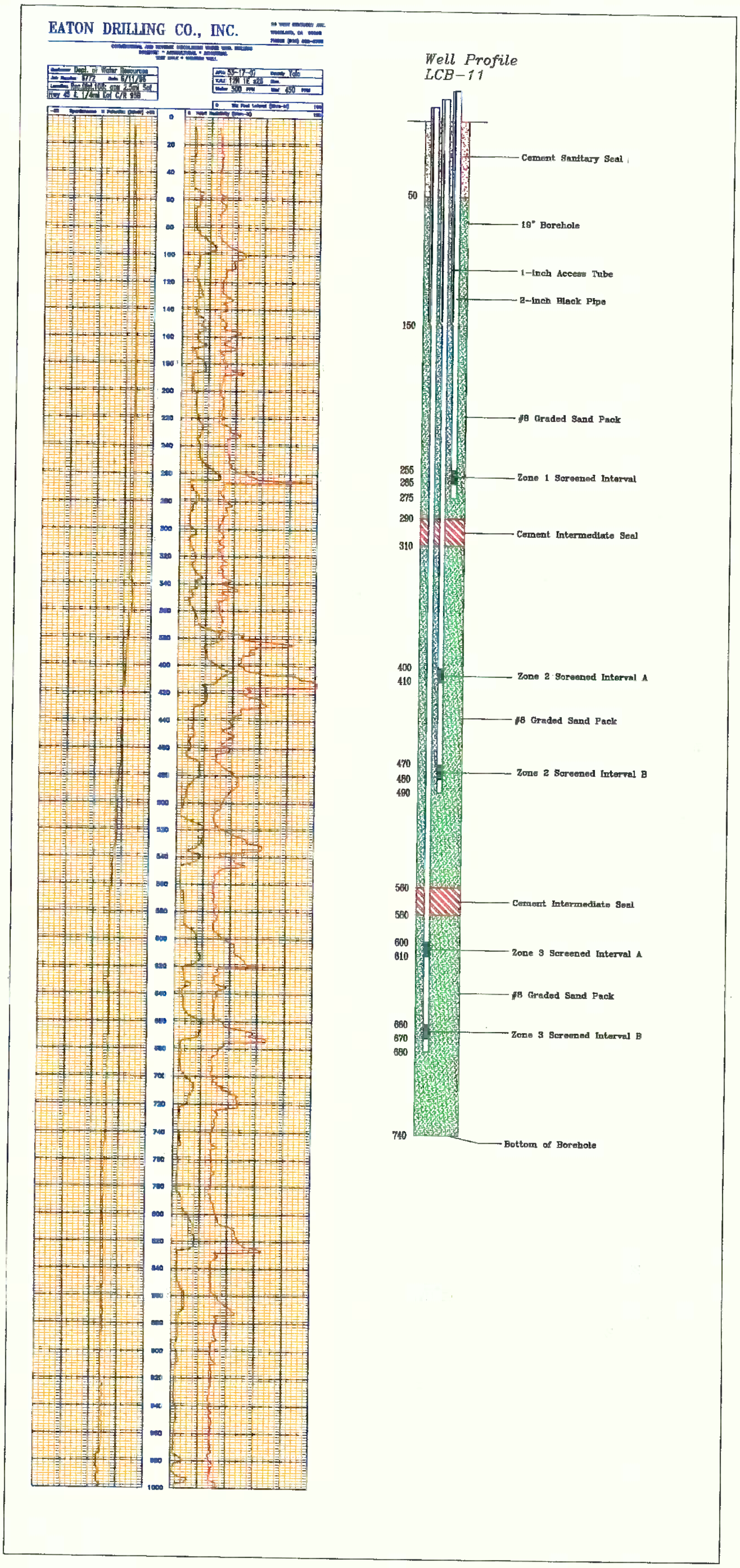
Appl. No.	Lic/Per	Date	Owner	Source	diversion	season
16516	L8210	8/11/55	Tolson	Colusa Basin Drain	2.1	4/1 to 6/30; 9/1 to 10/15
17066	L8989	5/2/56	Princeton-Cordura-Glenn ID	Colusa Basin Drain		4/1 to 6/30; 9/1 to 10/31
17853	L7126	10/17/57	Schaad	Colusa Basin Drain	50	4/15 to 9/15
18469	L9912	1/12/59	Jensen et al	RD 2047 Main Drain	6.25	3/15 to 6/30; 9/1 to 9/30
20809	L9691	6/8/62	Gordon	Central Drain	2.4 (1) 1.2 (2)	4/1 to 6/30 (1) 9/1 to 1/31 (2)
20915	L9690	8/27/62	Gordon	Central Drain	2.25 (1) 1.12 (2)	4/1 to 6/30 (1) 9/1 to 1/31 (2)
21088 A	L9046A	12/21/62	Perez	Colusa Basin Drain, Shepart Slough	3.05	4/1 to 6/30; 9/1 to 9/30
21088 B	L9046B	12/21/62	Perez Trust	Colusa Basin Drain	3.05	4/1 to 6/30; 9/1 to 9/30
22696	L11028	2/3/67	Baber	Colusa Basin Drain	1.3	4/1 to 6/30; 9/1 to 10/1
22946	L11955	11/9/67	Kalfsbeek	Colusa Basin Drain	16.25 max	3/15 to 6/30; 9/1 to 1/15
23945	P18965	12/9/71	Wallace Brothers	Colusa Basin Drain	17	4/1 to 6/30; 9/1 to 9/30
23946	P18966	12/9/71	Wallace	RD 2047 Main Drain	17	4/1 to 6/30
24806	L11942	5/6/75	Santa Rosa Tule Duck Club	Colusa Basin Main Drain	3	4/15 to 6/30
25792	P19419	7/20/78	Wallace	RD 2047 Main Drain	17	7/1 to 8/31
25793	P19420	7/20/78	Wallace	RD 2047 Main Drain	17	7/1 to 8/31
26141	P19426	11/29/79	Buck Horn Ranch	Colusa Basin Drain	11	3/1 to 6/30; 9/1 to 9/30
26164	P19931	1/8/80	King Trust	Colusa Basin Drain	6.25	3/1 to 6/30;
26604	P19117	11/5/80	Mumma Brothers	Colusa Basin Drain	2.5	4/20 to 6/15
26941	P19207	8/5/81	Hahn	Colusa Basin Drain	5	4/1 to 6/30
27183	P19932	1/20/82	King Trust	Colusa Basin Main Drain	2.75	3/1 to 6/30; 9/1 to 10/31
27184	P19933	1/20/82	King Trust	Colusa Basin Drain	3	3/1 to 6/30; 9/1 to 10/31
28985	P20401	3/12/87	Schaad	Colusa Basin Main Drain	2.7	11/1 to 1/15
29471	P20615	4/20/89	Knaggs	Knights Landing Ridge Cut	5.5	4/15 to 6/30
30169	P20721	8/4/92	Silver Bullet Farms	RD 2047 Drain	3	10/1 to 3/30
S365			McCullough	Colusa Basin Drain		Apr-Nov
S2050				Provident Main Drain		
S2051			Willow Creek MWC	Central Drain		
S4612			Bacchini	Knights Landing Ridge Cut		
S7368			Glenn-Colusa ID	Colusa Basin Drain		
S8442			Anderson Farms	Colusa Basin Drain		
S8443			Anderson Farms	Colusa Basin Drain		
S8444			Anderson Farms	Colusa Basin Drain		

Appendix B

Monitoring Well Logs



Electric log and completion diagram
for monitoring well LCB-13



Electric log and completion diagram for monitoring well LCB-11