Chapter 6. THE RECOMMENDED PLAN

The plan presented here is intended as a regional framework for management of drainage and drainage-related problems on the western side of the San Joaquin Valley. It consists of a set of actions that are quantified to the degree possible with information currently available. Actions are planned to continue over the 50-year period, from 1990, through a near-term planning horizon (2000), and on to a long-term planning horizon (2040). Actions are quantified and described for the two planning horizons.

Under the assumptions and conditions of the plan, no decision need be made now on exporting salt from the San Joaquin Valley. As explained in a later section of this chapter, "Rationale on Salt Balance," that decision can be deferred. Most, if not all, of the actions proposed in the recommended plan would be required as the first phase of any out-of-valley export system.

Uncertainties in the scientific information base, plus difficulties in forecasting human events, necessitate that the plan be updated from time to time as monitoring, additional studies, and local actions reveal new facts.

PLAN FORMULATION PROCEDURE

The recommended plan contains some aspects of both A and B performance levels from alternatives presented in Chapter 5. Performance standards used in formulating the recommended plan are shown in Table 23. The applicability of drainage management options in each water quality zone was assessed by using the performance standards (Table 24).

The sequence of plan formulation is illustrated in Figures 28, 29, and 30. The following discussions are provided as a guide to the decision points and places where judgment was applied. A detailed and comprehensive explanation of the technical processes and data used in formulating the plan is set forth in a report by the SJVDP (D.G. Swain, 1990).

Land Retirement Decisions

Land retirement was generally considered for inclusion as a plan component on lands that are saline and/or difficult to drain (class 4, USBR classification, for example) and where shallow ground water contains high selenium levels (50 ppm or more). Such decisions must, however, be based on all factors at the site and on the other alternatives available for managing the drainage problem. They do not preclude the future option of re-establishing irrigated agriculture if circumstances should change.

Source Control Decisions

Measures to control subsurface drainage at the source should generally be applied to all lands with drainage problems, except those that may be retired from irrigated agriculture. The specific

Table 23. PERFORMANCE STANDARDS USED TO FORMULATE RECOMMENDED PLAN

Category	Feature	Planning Criteria
WATER QUALITY (mean monthly)	SAN JOAQUIN RIVER near NEWMAN	BORON ≤0.7 ppm SELENIUM ≤5 ppb MOLYBDENUM ≤10 ppb
	SALT and MUD SLOUGHS	SALINITY ≤2,000 ppm TDS BORON ≤2 ppm SELENIUM ≤2 ppb MOLYBDENUM ≤10 ppb
	AGRICULTURAL WATER SUPPLY	SALINITY ≤1,250 ppm TDS BORON ≤1 ppm OR 1,250 ppm TDS ≤SALINITY ≤2,500 ppm TDS BORON ≤2 ppm (with dilution or restricted use)
	WETLAND WATER SUPPLY	SALINITY ≤1,250 ppm TDS BORON ≤1 ppm SELENIUM ≤2 ppb
	REUSE OF SUBSURFACE DRAINAGE ON SALT-TOLERANT PLANTS	EUCALYPTUS TREES ≤10,000 ppm TDS HALOPHYTES ≤25,000 ppm TDS
	EVAPORATION POND	INFLUENT QUALITY SELENIUM ≤2 ppb (No alternative habitat required) SELENIUM >2 and <50 ppb (Alternative habitat required) SELENIUM ≥50 ppb (No traditional evaporation ponds)
WATER QUANTITY	PUMPING SEMICONFINED AQUIFER	INITIAL AQUIFER THICKNESS ≥200 feet INITIAL SALINITY < 1,250 ppm TDS[a]
	GRASSLANDS WETLAND HABITAT SUBSTITUTE WATER SUPPLY	SUPPLY 129,000 acre-feet per year (74,000 acre-feet per year of fresh water plus facilities to provide at least 55,000 acre-feet of spills and tailwater)
	WATER SUPPLY FOR EVAPORATION POND ALTERNATIVE HABITAT	SUPPLY 10 acre-feet per acre per year
	SUPPLEMENTAL FISHERY FLOWS – MERCED RIVER near STEVINSON	SUPPLY 20,000 acre-feet per year (provided in October)
	DESIGN LIMIT TO REGIONAL DEEP PERCOLATION	LIMIT IS 0.4 acre-foot per acre per year[b]
LAND USE	WILDLIFE HABITAT	ALTERNATIVE HABITAT EQUAL IN SIZE TO EVAPORATION POND AREA WHERE Se INFLUENT >2 and <50 ppb
	RETIREMENT OF IRRIGATED AGRICULTURAL LANDS	LANDS WITH ≥50 ppb Se CONC. IN SHALLOW GROUND WATER AND RELATIVELY LOW PRODUCTIVITY (CLASS 4) DUE TO HIGH SALINITY AND POOR DRAINAGE CONDITIONS

[a] As salinity of pumped water exceeds 1,250 ppm TDS, its use as irrigation water becomes limited; however, it is considered usable for very salt-tolerant crops if salinity does not exceed 2,500 ppm TDS.

[b] That portion of applied irrigation water passing the root zone which requires drainage management. An additional 0.1 to 0.3 ac-ft/ac/yr of deep percolation is assumed to move downward through the Corcoran Clay layer.

Table 24. APPLICABILITY OF DRAINAGE MANAGEMENT OPTIONS
(Recommended Plan Performance Standards)

Subareas and Water Quality Zones	Drainage Source Control	San Joaquin River Discharge[1]	Salt-Tolerant Trees	Halophytes	Land Retirement[2]	Existing Evaporation Ponds	New Evaporation Ponds[3]	Ground Water Management
Grasslands								
A	X	Y(21k AF)	X	X	Y(3k Ac.)	Y(0.1k Ac.)	NA(>2 ppb Se)	Y(9k Ac.)
B	X	Y(15k AF)	X	X	NA(<50 ppb Se)	NA	X	NA(200 ft thick)
C	X	X	NR	NR	NR	NR	NR	NR
D[4]	X	NR-W	NR-W	NR-W	NR-W	NR-W	NR-W	NR-W
Westlands								
A	X	NA	X	X	Y(5K Ac.)	NA	NA(<2 ppb Se)	NA(>200 ft th ick)
B	X	NA	NA(>10k ppm TDS)	X	Y(15K Ac.)	Y(0.1k Ac.)	NA(>2 ppb Se)	NA(<200 ft thick)
C	X	NA	X	X	Y(13K Ac.)	NA	NA(>2 ppb Se)	Y(38k Ac.)
D	X	NA	X	X	NA(<50 ppb Se)	Y(0.4k Ac.)	NA(>2 ppb Se)	Y(24k Ac.)
Tulare								
A	X	NA	X	X	NA(<50 ppb Se)	Y(0.5k Ac.)	X	Y(916k Ac.)
B	X	NA	NA(>10k ppm TDS)	X	Y(7k Ac.)	Y(3.6k Ac.)	NA(>2 ppb Se)	NA(<200 ft thick)
C	X	NA	X	X	NA(<50 ppb Se)	Y(0.2k Ac.)	NA(>2 ppb Se)	NA(<200 ft thick)
D	X	NA	NA(>10k ppm TDS)	X	NA(<50 ppb Se)	Y(0.3k Ac.)	NA(>2 ppb Se)	Y(31k Ac.)
E	X	NA	X	X	NA(<50 ppb Se)	Y(0.3k Ac.)	X	Y(90k Ac.)
Kern								
A	X	NA	NA(>10k ppm TDS)	X	Y(24 Ac.)	Y(1.3k Ac.)	NA(>2 ppb Se)	NA(<200 ft thick)
B	X	NA	NA(>10K ppm TDS)	X	NA(<50 ppb Se)	NA	NA(.2 ppb Se)	NA(<200 ft thick)
C	X	NA	X	X	NA(<50 ppb Se)	Y(0.2k Ac.)	X	NA(<200 ft thick)
D	X	NA	NA(>10k ppm TDS)	X	Y(8k Ac.)	Y(0.2k Ac.)	NA(>2 ppb Se)	NA(<200 ft thick)

1 Applicability of option depends on selenium criterion (mean monthly concentration of 2 ppb) and critical year hydrology (1986-87) for San Joaquin River near Newman. Selenium load expected to drop up to 50 percent by 2040 as a result of removing salts from the shallow ground water and soils.

2 A combination of $\geq$50 ppb selenium concentration in the shallow ground water and relatively low land productivity due to high soil salinity and poor drainage conditions (USBR Class 4 or equivalent SCS soil classification) was used to select lands on which irrigated agriculture would be discontinued.

3 New evaporation ponds can be used when drainage water selenium concentration exceeds 2 ppb and is $\leq$50 ppb; however, mitigation measures including alternative habitat must be provided.

4 Manage wildlife wetland area.

X Option is applicable without any limitation in its application.

Y Option is applicable but limited to the quantities and units included in the parentheses.

NA Option not applicable because it failed to meet the performance standard in parentheses (see Table 7) or not physically available in the instances of discharge to the San Joaquin River.

NR Option not suggested because increased conservation with resulting increased salinity will lower the likelihood that drainage water can be used for wetland habitat.

NR-W Option is not applicable since shallow ground water within wetlands benefits waterfowl.

Figure 28
OVERALL PLAN FORMULATION SEQUENCE

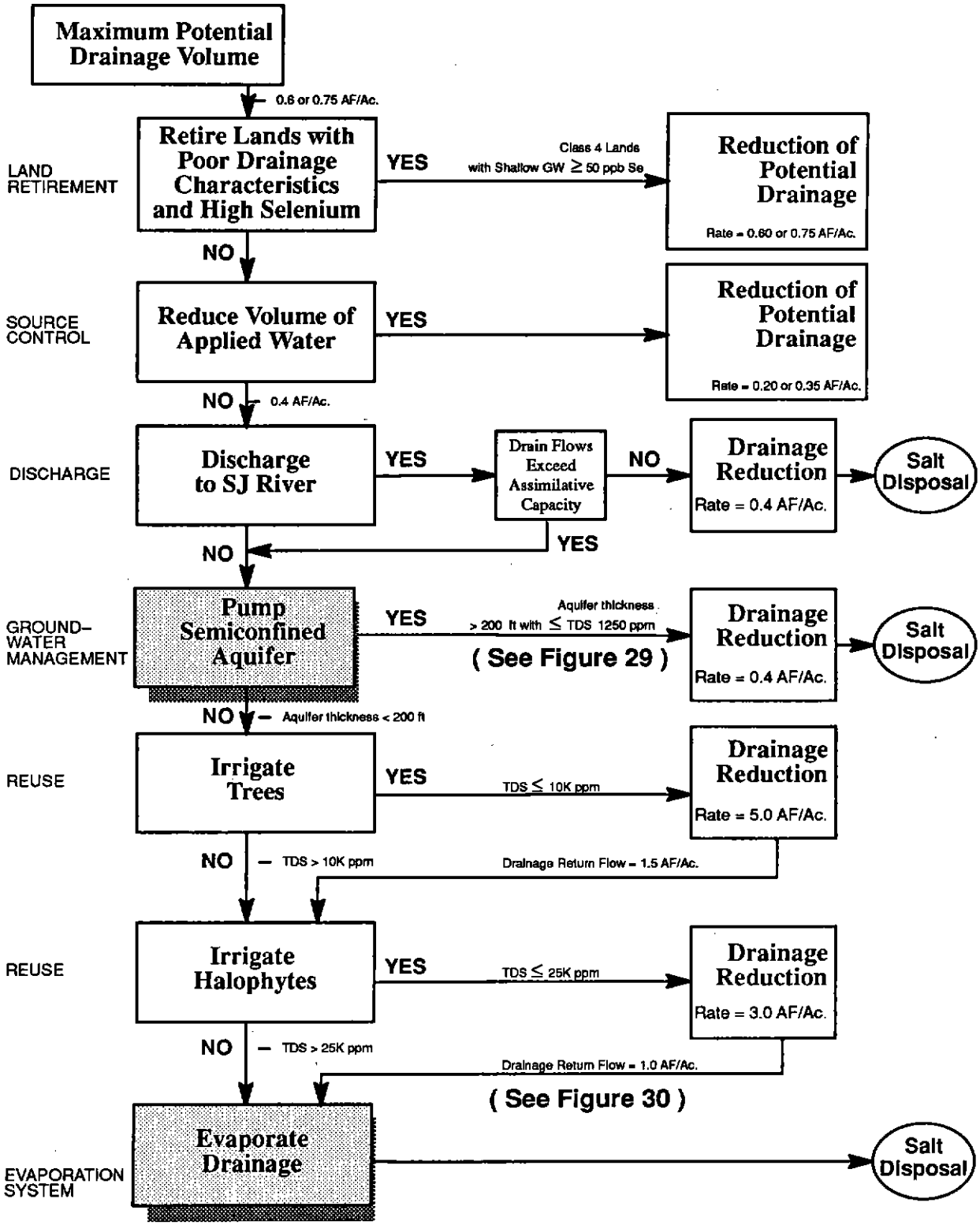


Figure 29
PLAN FORMULATION SEQUENCE
Pump Semiconfined Aquifer

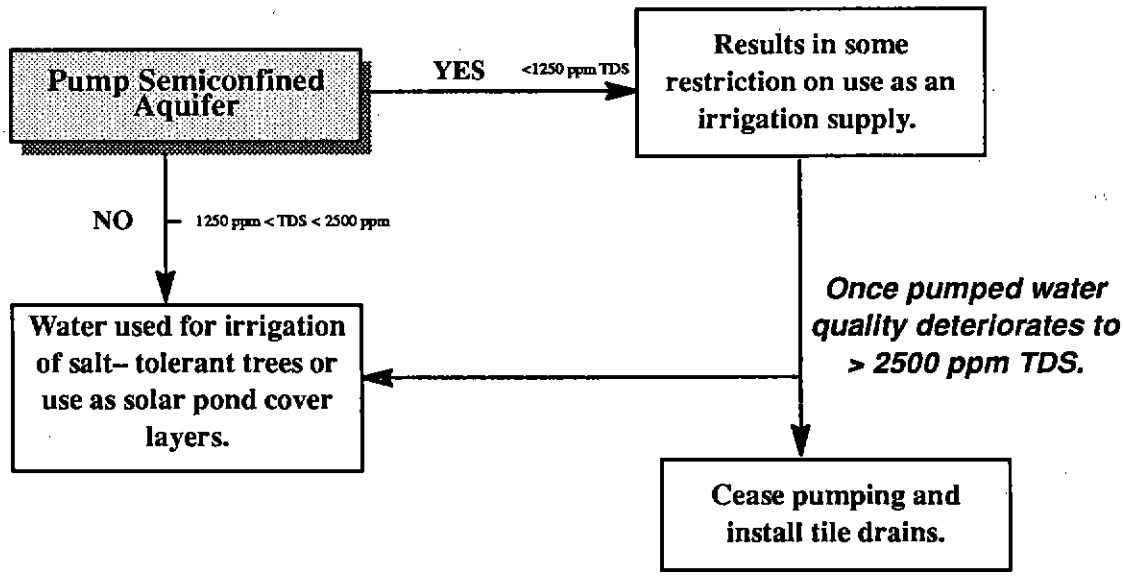
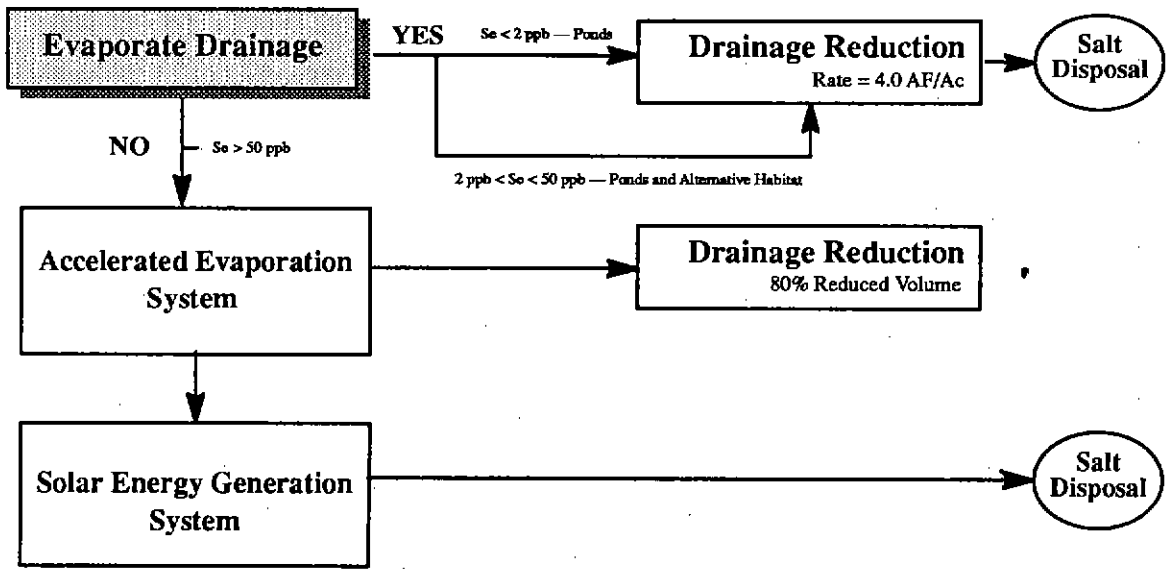


Figure 30
PLAN FORMULATION SEQUENCE
Evaporate Drainage



source control measures adopted will vary according to the types of crops grown and individual grower preference. Application of source control measures could eliminate an average of nearly 50 percent of the total problem water volume (pre-1985 conditions) by reducing deep percolation and, hence, potential drainage water. The rate at which source control can be implemented is generally controlled by the rate at which investments can be made to improve irrigation practices. The recommended plan takes this into account.

In the recommended plan, source control measures were not applied to water-quality Zone C and a portion of Zone B in the Grasslands Subarea. These zones contain low selenium and moderately saline water of a quality suitable for use in wetlands or for direct discharge to the San Joaquin River during much of the year.

The water collected in on-farm drains would have four possible fates: discharge to the San Joaquin River, water supply for wildlife areas (if selenium concentration is low), reuse on salt-tolerant plants, and/or discharge to evaporation ponds.

Decisions on Discharge to the San Joaquin River

The levels of performance required of the recommended plan in affecting the quality of water in the San Joaquin River were determined by State water-quality objectives and by scientific investigations of the U.S. Fish and Wildlife Service. It was determined that the selenium objectives of 5 ppb in the river and of 2 ppb in Mud and Salt sloughs were the most difficult objectives to be met. For planning, it was assumed that, if the selenium objective were met, then the boron and salt objectives could also be met.

Accordingly, the Drainage Program focused on the assimilative capacity of the San Joaquin River. The plan identifies means to collect and isolate (from wetlands) a comparatively small volume of high-selenium water in the Grasslands Subarea. That drainage volume would then be conveyed through a rehabilitated and extended San Luis Drain for discharge to the San Joaquin River below its confluence with the Merced River. It was also decided that the plan should include supplementing the Merced River with fresh water obtained from the eastern side of the San Joaquin Valley.

Replacement of the contaminated agricultural drainage water delivered and used in wetland areas before 1985 is a requirement of all plans. Mud and Salt Sloughs would not be used to convey water to wildlife habitat unless the selenium concentration of the supply is less than 2 ppb.

Reuse Decisions

It was assumed that, with some exceptions for the Grasslands Subarea, all water collected in tile drains would be reused on salt-tolerant trees and halophytes. This component is included in the plan under the conditional requirement that monitoring and analyses of the concentration of toxicants in biota (selenium, for example) would be necessary to give warning of any incipient problem and allow for remedial measures (keeping eucalyptus groves free of forest litter, for example). Reuse would eliminate a significant volume of problem water. The drainage water from trees and halophytes would be disposed of in evaporation ponds and solar ponds.

Evaporation Pond Decisions

The quality of drainage water (primarily selenium concentration) determines the selection, design, and operation of an evaporation system. It was assumed that all evaporation ponds would be designed and built according to criteria of the California Department of Fish and Game, which specify steep side slopes and minimum allowable pond depth (Bradford, et al., 1989). In addition, if influent selenium concentration is greater than 2 ppb, alternative, safe habitat equal to the pond area would be provided to facilitate hazing waterfowl from the pond area. If the influent concentration exceeds 50 ppb, an accelerated-rate evaporation pond would be used to reduce the required pond area because open ponds would not be considered feasible in the long run under these conditions. When possible, evaporation ponds would be located on the least productive agricultural land and at the lowest elevations of the drained areas.

Treatment for Selenium Removal

Although it is probable that an economical biological treatment process to remove selenium from drainage water will become available within the next 10 to 20 years, treatment is not included in the recommended plan. Instead, plan components are based on available technology. Treatment methods to remove selenium should be pursued and, when available, might replace or modify ground-water management or the evaporation processes. Treatment research should be continued not only on selenium removal but also on other toxic substances, such as arsenic, which are sometimes found in high concentrations in drainage water.

Ground-Water Pumping Decisions

Some growers now pump irrigation water from certain zones of the semiconfined aquifer. This pumping could be done in a more systematic and coordinated manner to focus specifically on lowering, and maintaining at lower levels, the shallow water table of drainage problem areas. Criteria for selecting potential pumping areas include adequate thicknesses of aquifers and water quality. Because pumping would eventually draw poor-quality water from higher in the aquifer into the producing wells, the length of time pumping could be continued was determined by the thickness of the aquifer zone and the rate of pumping. For an area to be included in the plan, the estimated life of the well field had to exceed 20 years. Application of planning criteria made a relatively minor amount of problem water area amenable to this component.

Rationale on Salt Balance

Implementation of the recommended plan would allow maintenance of a salt balance in the plant root zone. Primarily, this would be accomplished by source control and by drainage to remove shallow ground water and the salts it contains from crop root zones. This is in contrast to future-without conditions (described in Chapter 5), in which a salt balance could not be maintained and would lead to salinization and abandonment of lands within the next few decades because of problems associated with a persistently high water table.

The main value of actions proposed in the recommended plan would be to reduce or dampen the present effects of the dissolution-evaporation cycle in which salts are precipitated in soils through evaporation of water from a near-surface water table. The present principal source of salts is not imported water but the high concentrations of natural salts that have been leached from soils

(particularly during the last 30 to 40 years) and are now concentrated in shallow ground water (CH_2M Hill, 1988). These salts tend to recycle seasonally through the soil under high water table conditions.

Implementation of the recommended plan would maintain the water levels below the root zone. The problem water would be managed by tile drains, land retirement and ground-water pumping. The shallow water table would be lower and thus contribute less to evapotranspiration.

How long can such a strategy work, since about 3 million tons of salt per year are being added to the shallow ground-water system of the study area? The Drainage Program's answer is based on the assumption that the potential to continue to store salts in the subsurface (as now occurs) will be approaching exhaustion when subsurface water is saturated with salts in concentrations that exceed 2,500 ppm. When that water-quality condition is reached in the semiconfined aquifer, it is theorized, it will also have contributed to increased degradation of the confined aquifer (below the Corcoran Clay layer). Assuming that growers will not pump water of this salt content, most of the beneficial hydraulic stresses that moved drainage water downward will have ended. The water table will rise again, and it will become difficult to manage salt in crop root zones.

As a basis for estimating the useful life of the semiconfined aquifer, available ground-water data were analyzed for 1.7 million acres of land, including all waterlogged areas. Analyses showed that about one-third of these lands already overlie portions of the semiconfined aquifer where ground water generally exceeds 1,250 ppm TDS. Total dissolved solids of 1,250 ppm is considered the maximum allowable limit for most irrigation use. For the remaining two-thirds of these lands, estimates were made of the rate at which saline ground water (greater than 2,500 ppm TDS) would displace the usable ground water by downward movement beneath the problem water areas. It was assumed that the flow in the semiconfined aquifer was essentially vertical and was governed by the rate of movement through the Corcoran Clay.

The rate of downward movement of salts in the semiconfined aquifer was estimated at several locations in each of the subarea water-quality zones. The thickness of the usable aquifer and the rate of movement then determined the aquifer life. Aquifer life was considered to be exhausted when the quality of pumped ground water exceeded 2,500 ppm TDS. From the several locations analyzed in each subarea water-quality zone, the minimum and maximum aquifer thickness and life were based on one location each. The mean aquifer thickness and life were based on all locations analyzed. The number of locations varied from zone to zone. Table 25 shows the estimated useful aquifer life for water-quality zones in the Grasslands, Westlands, and Tulare subareas. The Northern Subarea is considered to be in salt balance, and insufficient information is available to estimate aquifer life in the Kern Subarea.

Under the assumptions and conditions stated above, the western valley has several decades remaining before salt removal and/or export will be required.

The process of salt contamination of ground water was set in motion decades ago with the onset of intense irrigation (Gilliom, et al., 1989a), and it will continue — to some extent — within the realm of probable use and management of water in the valley, regardless of the handling of the regional drainage problems. If it were possible to balance salt inflow and outflow in the valley, this would help slow the rate of salt contamination of ground water.

Table 25. ESTIMATED USEFUL LIFE OF THE SEMICONFINED AQUIFER

Subarea Water Quality Zone	Percent of Water Quality Zone Area with Usable Ground Water[a]	Present Thickness and Remaining Life of Semiconfined Aquifer					
		Mean Thickness[b] (feet)	Mean Life[c] (years)	Minimum Thickness[b] (feet)	Minimum Life[c] (years)	Maximum Thickness[b] (feet)	Maximum Life[c] (years)
Grasslands							
A	35	50	75	350	525	160	250
B	79	50	25	200	100	130	65
C	66	50	150	150	450	90	270
Westlands							
A	33	50	35	200	190	150	110
B	64	50	30	350	210	180	110
C	70	50	30	450	270	190	115
D	781	50	25	400	200	220	110
Tulare							
A	19	50	75	250	375	125	185
D	100	50	25	500	250	330	165
E	88	50	25	450	225	335	170

a Usable ground water contains less than 1250 ppm TDS.

b Thickness refers to that part of the semiconfined aquifer containing usable ground water.

c Life of the aquifer is the estimated time for saline ground water (greater than 2,500 ppm TDS) to completely displace presently usable ground water. in the semiconfined aquifer. It is calculated by dividing the aquifer thickness of usable ground water by the average rate of water movement across the Corcoran Clay. It was assumed that pumping from the confined aquifer beneath the Corcoran Clay will be maintained at current rates.

Management of drainage problems in the manner presented in the recommended plan tends to enhance near-term (up to 50 years) protection of soils and off-site impacts of drainage discharges, while continuing to diminish the life (for direct irrigation) of westside aquifers.

A functionally beneficial aspect of the recommended plan is that it includes the preliminary steps that would likely be needed when salt removal from the valley becomes necessary and feasible. These steps include integrated in-valley systems to collect and reduce the volume of drainage water, accompanied by containment and control of contaminants, such as selenium.

PLAN FEATURES COMMON TO ALL SUBAREAS

Several plan features are common to all subareas. The following discussion is intended to reduce the need for repetitive description of the recommended subarea plans.

The features that are an essential part of the plans for all subareas (exclusive of the Northern Subarea) are: drainage-water source control, reduction of drainage-water volume by reuse, disposal of concentrated drainage–water, changes in water institutions, and monitoring of the drainage-water environment.

Drainage-Water Source Control

Improvement in the application of irrigation water to reduce the source of deep percolation has been shown to be the most effective and least costly means of reducing the amount of potential

drainage problem water. Recognizing the necessity to leach salts past the root zone and the nonuniformity of soils, even in a single agricultural field, there is justifiable argument about the amount of improvement that can be achieved in irrigation water application to reduce deep percolation. Field demonstrations show, however, that irrigation water application can be improved (Boyle, 1990, 1989a, 1989b). Target reductions in deep percolation believed attainable through on-farm water conservation measures by 2000 and sustainable beyond that time are shown, by subarea, in Table 26. The comparatively low target for the Tulare Subarea reflects the average higher efficiencies in water application that prevail in that subarea now.

Table 26. RECOMMENDED TARGETS FOR REDUCTION IN DEEP PERCOLATION IN 2000

Subarea	Target Reduction (acre-feet/acre)
Northern	0.0[a]
Grasslands	0.35
Westlands	0.35
Tulare	0.20
Kern	0.35

[a] See discussion for Northern Subarea under "Description and Evaluation of Recommended Plan (by Subarea)" later in this chapter.

The target deep percolation reductions in Table 26 are included as part of the recommended plan for all irrigated lands in each subarea.

Reducing deep percolation on lands lying upslope (up the hydraulic gradient) from drainage problem areas would benefit downslope areas. The results of geologic investigations (Quinn, 1990) suggest that, over decades, the aquifers above the Corcoran Clay function as a set of regional aquifers. Therefore, water conservation on upslope areas is important, even though the impact on a downslope problem water area will probably not be nearly as immediate and direct as will water conservation practiced directly on downslope lands with drainage problems. Even on upslope lands, which are significantly larger in total area than downslope lands, a moderate level of water conservation could have a significant effect on the waterlogging problems — in the long run.

An exception to the universal inclusion of source control in the recommended plan is in the Northern Subarea and parts of the Grasslands Subarea lying in the basin trough. In these areas, source control is not included because of the relatively low levels of selenium occurring in the shallow ground water and the composition of the dissolved salts that are low in gypsum (W.C. Swain, 1990c). Program analyses (D.G. Swain, 1990) indicate that application of source control in these areas would not contribute to meeting present State water quality objectives nor appreciably reduce the salt load in the San Joaquin River — assuming that the present policy agreement requiring releases from New Melones Reservoir remains in effect to dilute the salt load in the San Joaquin River.

Reduction of Drainage-Water Volume by Reuse

The large volume of drainage water that is generated annually[1] (from 0.60 to 0.75 foot per acre in the water-quality zones) presents a difficult but not insurmountable problem for in-valley management. Assuming that source control measures would eliminate from 0.2 to 0.35 acre-foot per acre, the balance of 0.40 acre-foot per acre would have to be collected and reduced in the most economic means available, while meeting acceptable levels of environmental protection.

The first essential collection device in reuse is on-farm tile drains. Presently, there are only 133,000 acres of installed drains in all the westside area. The Drainage Program projects that the area drained by on-farm systems will increase to about 760,000 acres by 2040 (Table 27).

Table 27. PROJECTED ON-FARM TILE DRAINAGE ACREAGE
(Acres)

SUBAREA	1990	2000	2040
Northern	24,000	34,000	44,000
Grasslands	50,000	108,000	192,000
Westlands	5,000	69,000	140,000
Tulare	43,000	96,000	277,000
Kern	11,000	53,000	106,000
TOTAL	**133,000**	**360,000**	**759,000**

Subsurface water collected in the farm drains would be transported to the primary water reduction facility used in the recommended plan: salt-tolerant tree plantations and fields of halophytes. These plants would be irrigated with enough drainage water to leach salts from the root zone and meet the maximum capacity of the given species to transpire water. Transpiration is about 5 acre-feet per acre per year for eucalyptus trees and 3 acre-feet per acre per year for halophytes. Drainage from the trees and halophytes would average about 1.5 acre-feet per acre per year for a total application rate of 6.5 and 4.5 acre-feet per acre per year, respectively. An acre of trees would serve an average of about 16 acres of drained cropland. The trees would be located as close to the drained farmlands as possible.[2] The tree plantations would require subsurface drains, not only to remove salts from the root zone but also to provide feed water for the fields of halophytes, which would be located near the trees. In some parts of the Westlands, Tulare, and Kern subareas, drainage water would be too salty to use on trees and, therefore, halophytes would be the primary drainage reduction mechanism.

The acreages of trees and halophytes required for the recommended plan are given in Table 28. The atypical decline in acreages in the Grasslands Subarea is explained in the Grasslands plan later in this chapter.

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[1] If on-farm drains were available, the estimated volume in 1990 would be about 300,000 acre-feet per year. Based on analyses of water table measurements for 1977, 1983, and 1986-87, this volume is forecasted to more than double from 1990 to 2040.

[2] In addition to proximity to drained croplands, important land suitability criteria for the reduction facilities are: elevation, soils that can be drained, the absence of soil characteristics adverse to the species selected, and soils not suited for high-value crops.

Table 28. PRIMARY DRAINAGE-WATER REDUCTION FACILITIES
(Approximate acres)

Subarea	2000		2040	
	Trees	Halophytes	Trees	Halophytes
Grasslands	2,400	900	1,900	700
Westlands	3,900	2,100	8,000	4,100
Tulare	4,000	4,600	12,,300	12,300
Kern	1,600	3,300	3,600	6,000
TOTAL	**11,900**	**10,900**	**25,800**	**23,100**

Disposal of Concentrated Drainage Water

Other than in the Grasslands Subarea, the primary means of disposal of the residual drainage water and dissolved solids it contains would occur in evaporation and solar pond facilities. These pond systems would bear little resemblance, in structure or operation, to present evaporation ponds. A number of features would be changed to improve their safety and efficiency.

In the staged design of the recommended plan, ponds would follow drainage-water-volume reduction and, consequently, less pond area would be required than would be under current conditions. Compared to present pond acreages, the total acreage of ponds in 2040 would be about half the present, and each unit of pond area would serve about 8 to 10 times as much drained land as do ponds in 1990.

The estimated life of an evaporation pond is 30 years. Old ponds would be closed safely, and new ponds would replace them. The pond area in 2040, by type, in each subarea, is given in Table 43.

Institutional Components

The recommended plan contains several institutional components that are included in all subareas: tiered water pricing, improved scheduling of irrigation deliveries, water marketing, and formation of regional drainage management organizations. These are either new to the subarea or have never been applied at the scale that would be needed to implement this plan.

Tiered Water Pricing

Tiered water pricing means increasing irrigation water rates as more water is applied. This would provide incentives for water conservation. Although water districts are not allowed to make profits, water revenue surpluses could be used to help finance on-farm water conservation measures. Tiered water pricing is already being implemented by three water districts in the Grasslands Subarea.

Improved Scheduling of Water Deliveries

The aim of improved scheduling of water deliveries is to enable growers to obtain irrigation water deliveries when their land and crops need the water, not when the delivering entity can supply the water. In all the subarea plans, costs have been included, under the category of source control, to effect considerable improvements in scheduling water deliveries. These changes would build on the present programs of the California Department of Water Resources and several local water districts.

Water Transfers and Marketing

This would provide incentives for water conservation, wherein local water districts and/or irrigators would be permitted to retain some portion of the increase in the value of water sold for a profit. The portion of the increase in value retained by the suppliers in a transfer would also help fund water conservation measures. The Department of Water Resources and the Bureau of Reclamation are the principal agencies that could develop and implement policies and programs for water transfers and marketing.

Some transfers would require the approval of the State Water Resources Control Board. All transfers of State Water Project and Central Valley Project water would require, respectively, the authorization of the Department and the Bureau as project operator. Thomas and Leighton–Schwartz (1990) declare there are no serious legal impediments to the transfer of water made available by reclamation or conservation from drainage problem areas in the western San Joaquin Valley. Purpose and place of use restrictions in the CVP permits and contracts may be amended to facilitate transfers of project water to other uses or areas. The increases in repayment obligations in moving water from irrigation to municipal and industrial use do not appear to be substantial disincentives, according to Thomas.

Regional Drainage Management Organizations

Regional drainage management organizations are recommended for the Grasslands and Tulare subareas, with all upslope and downslope areas to be included within the boundaries of the organization. Such organizations would coordinate the drainage-related operations of existing local water entities, with respect to activities and issues that transcend local entity boundaries. Local water entities are in the best position to effectively manage the subsurface drainage problem because they deal with water throughout the hydrologic cycle in a given land area. Generally, they have the authority to manage drainage water; where they do not, the authority could be obtained through legislation. However, in recognition of hydrologic and economic linkages and relationships among local water entities, some drainage problems could probably be managed best at a regional level. For such needs, either regional entities or joint–power authorities could be formed.

A regional drainage management organization could reduce drainage management costs, bring about coordination among several local entities, and help internalize the costs of drainage management.

Westlands Water District could serve as the regional drainage management entity for the Westlands Subarea. In the Kern Subarea, Kern County Water Agency, through joint-powers agreement with the water districts or some other organizational arrangement, could serve as the regional drainage management entity.

Monitoring of the Drainage-Water Environment

The drainage problem that affects, or is related to, more than 1 million acres is not presently being monitored in a comprehensive, effective, and efficient manner. An extremely important premise underlying successful implementation of this plan is that the many facets and dimensions of the problem — ground-water levels, soil conditions, land uses, water quality, volume of drainage, conditions of evaporation ponds, impacts on biota, public health risks — must be monitored on a long-term, systematic basis. The objective of monitoring is to determine the effect

of actions and whether they should be changed. In 1990, no one can forecast with certainty what conditions will be in 2040. The strategy presented in this plan will, no doubt, have to be adjusted in response to unforeseen human events and responses of natural systems.

DESCRIPTION AND EVALUATION OF THE RECOMMENDED PLAN

Northern Subarea

No actions are recommended as part of a regional plan for the Northern Subarea (Figure 31). This is based on two assumptions: (1) State water-quality regulations for the San Joaquin River will continue to allow salt discharge to the river from ground-water seepage and from surface and subsurface drainage water originating from irrigation in the Northern Subarea, and (2) fresh water will continue to be released from New Melones Reservoir to help meet State water-quality objectives at the Vernalis gaging station.

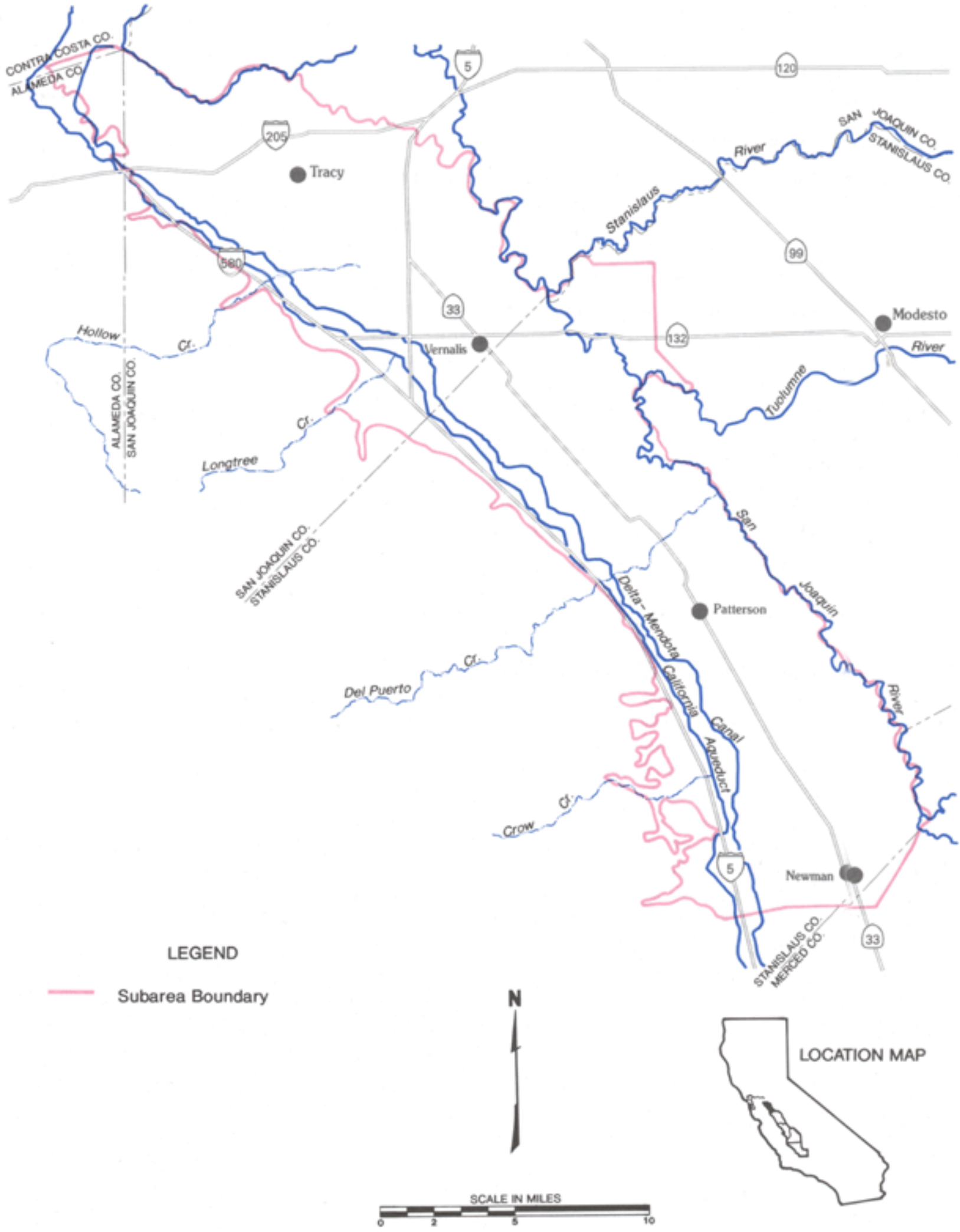
It was stated earlier in this report that both a water balance and a salt balance have nearly been achieved under existing hydrologic conditions in this subarea. As long as drainage water and seepage can be discharged to the San Joaquin River under the assumptions stated above, then no actions beyond those in place now would be required. However, if more restrictive objectives are adopted for either boron or salt in the river, this balance would have to be interrupted to reduce drainage water and salt and boron load.

In the event of possible new water-quality restrictions, the following two measures would aid in reducing drainage discharge to the river. Source control measures to reduce deep percolation on about 50,000 acres of irrigated land with water tables less than 5 feet from the surface would reduce drainage water inflow to the river; however, they would also increase concentrations of salt in the remaining subsurface drainage water. (For estimates and calculations, see AWMS, 1987, and D. G. Swain, 1990). Increased pumping of deep ground water to replace some of the surface water currently being used for irrigation would lower the high water table and reduce both drainage volume and seepage of salty ground water to the river.

A measure that should be studied further in relation to more restrictive water-quality objectives in the San Joaquin River is pumping shallow ground water into the river during high flows to create underground storage space for percolating agricultural drainage water. If feasible, this would improve river water quality by storing salty drainage water during low river flow. There are technical problems that may be insurmountable in terms of storage space and the short periods of time during which the flows could be accepted in the river (D.G. Swain, 1990). A variation of this option would be to intercept shallow, salty ground water moving to the river and pump it into surface-water storage ponds used as wildlife habitat. A possible drawback to this measure is that the average concentration of selenium in the intercepted moderately deep ground water may exceed the selenium water-quality objectives in the river (5 ppb). The ponds could be drained to the river during high flows and refilled during low-flow periods.

Figure 31

NORTHERN SUBAREA



Grasslands Subarea

Figure 32 shows the shallow ground-water quality zones. Agricultural components of the recommended plan for the subarea are listed in Table 29. Selected facilities and flows are shown on Figure 33.

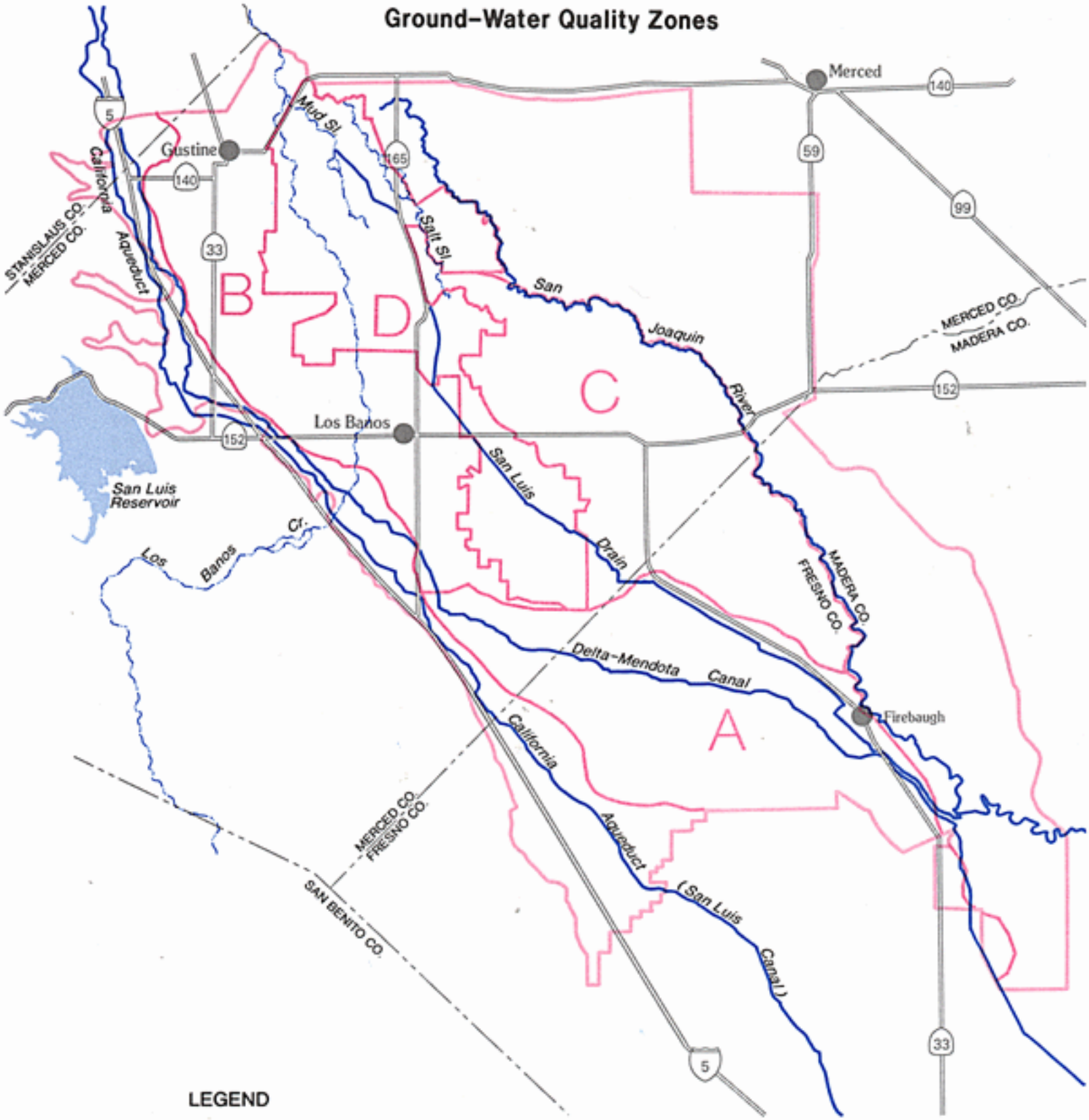
The agricultural components of the recommended plan for 2040 are:

- **Practicing source control on 93,600 acres of irrigated land.** The amount of water applied to irrigate drainage problem areas would be reduced, on the average, by 0.35 acre-foot per acre per year (a total of 32,700 acre-feet) by improving methods of irrigation water application, by improving scheduling of irrigation water application, and by tiered water pricing.
- **Reusing drainage water to irrigate 2,600 acres of salt-tolerant trees and halophytes.** Through installation of on-farm tile drains and conveyance facilities, drainage water would be collected and supplied to trees to reduce the total drainage volume by 10,900 acre-feet. Drains would be installed beneath the trees to collect the brackish water drained for subsequent use by halophytes. This would reduce the drainage volume by another 2,700 acre-feet, for a total reduction of 13,600 acre-feet. These reuse plantations could serve individual farms or an entire water or drainage district and would be located on the least productive soils. Most sites would be located on Storie Index class 4, 5, or 6 soils on the Panoche and Little Panoche Creek fan rim in the eastern part of water-quality Zone A.
- **Operating 120 acres of evaporation ponds and 130 acres of solar ponds.** Pond design and operation criteria would be consistent with State guidelines, and ponds would be located near tree and halophyte plantations. The volume of influent water evaporated annually would be about 700 acre-feet.
- **Pumping the semiconfined aquifer under about 10,000 acres of land.** Due to natural features, this option is most feasible in the southeastern and northwestern portions of the subarea. The design average annual yield would be 0.4 acre–foot per acre of land affected, for a total management of 4,000 acre-feet of problem water. To exert this effect at the land surface, 8,000 acre-feet would have to be pumped from the aquifer. These lands would also have received source control (0.35 acre-foot per acre), but they would not be artificially drained. Pumped ground water of initial good quality could be used for agriculture, or fish and wildlife, or a variety of other uses. If, in future years, influent water to a well should contain dissolved salt in excess of 2,500 ppm TDS, that water would be used for trees and halophytes, or as top water in solar ponds. This component would be applicable only in water-quality Zones A and B.
- **Retiring 3,000 acres of irrigated agricultural lands.** Lands having the combined characteristics of poor drainability, high salinity levels, and high levels of dissolved selenium (greater than 50 ppb) in shallow ground water would be retired. Only lands in water-quality Zone A met this criterion.

Figure 32

GRASSLANDS SUBAREA

Ground-Water Quality Zones



LEGEND

Subarea Boundary

A Ground Water Quality Zone

N

LOCATION MAP

Table 29. RECOMMENDED DRAINAGE MANAGEMENT PLAN GRASSLANDS SUBAREA (In 1000s)

PLAN COMPONENT	YEAR 2000			YEAR 2040		
	AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION		AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION	
	Acres	AF	%	Acres	AF	%
ZONE A						
SOURCE CONTROL	68.9	24.0	44.4	72.0	25.1	44.3
LAND RETIREMENT	0.0	0.0	0.0	3.0	2.3	4.0
GROUND-WATER MGM'T	5.0	2.0	3.7	10.0	4.0	7.1
DRAINAGE REUSE[a]	3.1	16.5	30.6	0.8	4.1	7.2
EVAPORATION SYSTEM	0.18	0.8	1.5	0.12	0.2	0.4
DISCHARGE TO SJ RIVER	26.8	10.7	19.8	52.5	21.0	37.0
Total		**54.0**	**100.0**		**56.7**	**100.0**
ZONE B						
SOURCE CONTROL	6.8	2.4	22.8	21.6	7.6	21.6
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	0.4	1.1	10.0	1.8	9.5	27.0
EVAPORATION SYSTEM	0.01	0.1	0.6	0.12	0.5	1.4
DISCHARGE TO SJ RIVER AND OR WETLANDS	9.3	7.0	66.6	23.5	17.6	50.0
Total		**10.6**	**100.0**		**35.2**	**100.0**
ZONE C						
SOURCE CONTROL	0.0	0.0	0.0	0.0	0.0	0.0
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE[a]	0.0	0.0	0.0	0.0	0.0	0.0
EVAPORATION SYSTEM	0.0	0.0	0.0	0.00	0.0	0.0
DISCHARGE TO SJ RIVER AND OR WETLANDS	29.3	22.0	100.0	84.7	63.5	100.0
Total		**22.0**	**100.0**		**63.5**	**100.0**
TOTAL						
SOURCE CONTROL	75.7	26.4	30.5	93.6	32.7	21.0
LAND RETIREMENT	0.0	0.0	0.0	3.0	2.3	1.4
GROUND-WATER MGM'T	5.0	2.0	2.3	10.0	4.0	2.6
DRAINAGE REUSE[a]	3.5	17.6	20.3	2.6	13.6	8.8
EVAPORATION SYSTEM	0.2	0.9	1.0	0.2	0.7	0.5
DISCHARGE TO SJ RIVER AND OR WETLANDS	65.4	39.7	45.9	160.6	102.1[b]	65.7
Total		**86.6**	**100.0**		**155.4**	**100.0**

[a] Includes potential drainage from irrigated agricultural land used to grow salt tolerant crops.

[b] Increases in volume from year 2000 to year 2040 are due largely to improvements forecasted to occur over time in the quality of shallow ground water drained from irrigated lands. For data and interpretation supporting this concept, see Gilliom, et al., (1989a) and Deverel and Gallathine (1988).

- **Discharging about 102,000 acre-feet of drainage water[3] to wetlands and/or the San Joaquin River (while meeting river water-quality standards).** About 63,500 acre-feet of subsurface drainage water of adequate quality[4] for fish and wildlife uses would be discharged from water-quality Zone C into Salt Slough, from which diversions could be made to adjacent public and private wetland management areas. About 17,500 acre-feet of subsurface drainage water from west of the wetland area (water-quality Zone B) would also be of adequate quality for use in wetland habitat areas. About 21,000 acre-feet of subsurface drainage water from irrigated land (water-quality Zone A) south of the Grasslands wetland area would be unsuitable for reuse in wetlands and, therefore, would be discharged into the San Luis Drain for delivery to the San Joaquin River below its confluence with the Merced River. The sediments removed from the drain would be placed within the Kesterson Reservoir disposal area and treated as the Kesterson sediments were managed in that cleanup effort. The amount of drainage water discharged is limited by the river criteria near Newman (Table 7). The San Luis Drain would be cleaned of sediments and modified structurally to receive drainage from water quality Zone A at a point near South Dos Palos, and the drain would be extended to the San Joaquin River, below the confluence of the Merced River. The Main, Panoche, Hamburg, and Charleston drains would be interconnected and routed to the San Luis Drain near South Dos Palos. The San Luis Drain thus would become the means by which a portion of the contaminated subsurface drainage now entering the South Grasslands area would be re-routed around the wetlands.

Management of agricultural drainage problems and protection, restoration, and substitute water supplies for fish and wildlife are planned as complementary activities. The interception of contaminated subsurface drainage water currently discharged into waterways of the Grasslands wetland area would make available nontoxic tailwater, operational spills, and nontoxic subsurface drainage for use in the wetlands.

Plan components for protection, restoration, and substitute water supplies for fish and wildlife in the Grasslands Subarea are shown on Figure 33 and discussed in the following subsections.

- Providing, on a firm basis, 129,000 acre-feet per year of adequate-quality water from existing sloughs, ditches, and canals that serve the Grasslands area. This volume is the average amount of surface and subsurface drainage water diverted to the wetlands before 1985, when use of the contaminated drainage water for wetland management was discontinued. It is assumed that the quantity and quality of tailwater, operational spills, and local runoff will continue to be suitable for fish and wildlife water supplies throughout the period of the plan. The 129,000 acre-feet of water could be obtained by:

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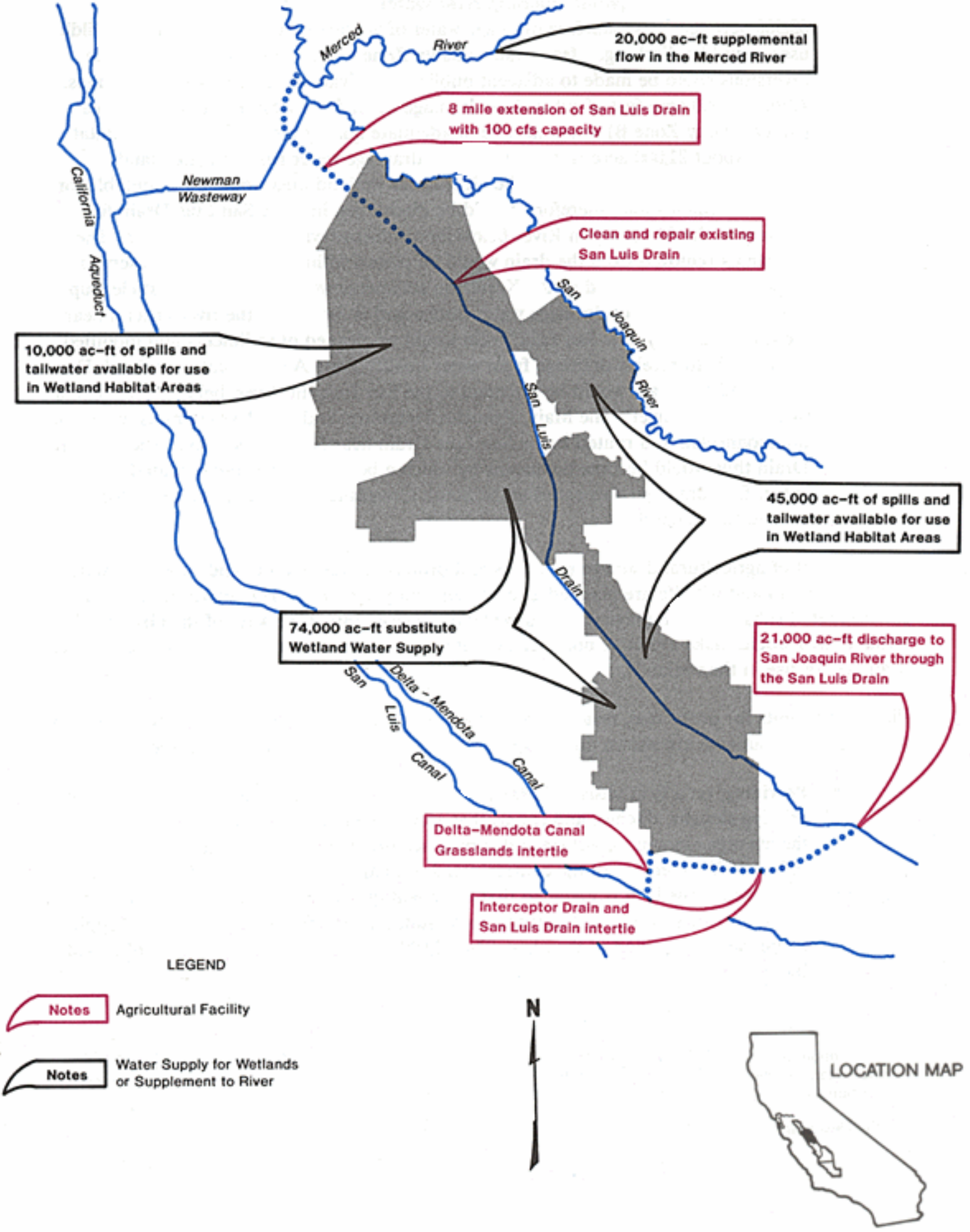
[3] Assumption used to calculate the volume of drainage water discharged: (a) Dry-year hydrology similar to the 1986-87 water year, (b) existing 150 ppb selenium in subsurface drainage water, decreased to 75 ppm by 2040, and (c) 5 ppb selenium criteria in the San Joaquin River near Newman.

[4] TDS less than 1,250 ppm, boron less than 1 ppm, and selenium less than 2 ppb.

Figure 33

FACILITIES AND FLOWS INCLUDED IN THE RECOMMENDED PLAN

Grasslands Subarea



SJVDP

— Providing up to about 74,000 acre-feet from the Central Valley Project through the Delta-Mendota Canal for diversion into wetland areas.

— Delivering an average of 45,000 acre-feet of tailwater, operational spills, and local runoff of adequate quality from water-quality Zone C to Salt Slough for use in wetlands.

— Delivering up to 10,000 acre-feet of tailwater, operational spills, and local runoff from water-quality Zone B to Los Banos Creek and vicinity.

- Providing the facilities necessary to deliver 74,000 acre-feet of substitute water, including a Delta-Mendota Canal Turnout with a capacity of 200 cubic feet per second and 1.75 miles of 200-cfs canal and siphons, to the wetlands of South Grasslands.
- Providing facilities to intercept all subsurface drainage water now being discharged from water-quality zone A into open channels in the Grasslands; facilities would also be provided to convey this water to the San Luis Drain near South Dos Palos.
- Using an estimated 63,500 acre-feet of subsurface drainage water from water-quality Zone C, and 17,500 acre-feet of subsurface drainage water from Zone B, by 2040, in wetlands. Most of this water would flow by gravity to Salt and Mud sloughs, where it would be conveyed to public and private wetlands.
- Providing, on a firm basis, an additional 20,000 acre-feet of fresh water to supplement October flows in the Merced River. This would minimize the straying of migrating adult salmon into the Grasslands instead of into the natural spawning grounds in the Merced River. This water must be obtained by purchasing surface or ground water from water-rights holders in the Merced River drainage or by extending the northern end of the Friant-Madera Canal into the Merced River watershed so that water stored behind Friant Dam could be delivered to the Merced River. Purchasing water in the Merced River drainage appears to be the most economical approach.
- Providing alternative wetland habitat near evaporation ponds. Because the selenium concentrations in the evaporation ponds would exceed 2 ppb, a hazing program would be required to discourage bird use. In addition, wetland habitat (one acre for each acre of evaporation ponds) would be developed close to the evaporation ponds to offer alternative clean habitat for hazed birds. Each acre of alternative habitat would require about 10 acre–feet of water per year.

Assessment of Plan Features and Their Effects

The plan for the Grasslands Subarea relies on the continued discharge of subsurface drainage water to the San Joaquin River, either directly to the river or through sloughs and wetlands. The opportunity for the discharge of contaminated subsurface drainage water depends on the flows in the San Joaquin River, the concentrations of contaminants in the subsurface drainage water, and the limiting water-quality objective at the point of discharge. Interception of contaminated subsurface drainage water south of the Grasslands Subarea and delivery to the San Luis Drain near South Dos Palos for conveyance to the San Joaquin River below the Merced River are key features of the plan. The removal and disposal of sediments within the San Luis Drain are necessary conditions for use of the drain as a plan component.

About half the subsurface drainage water would be suitable as a fish and wildlife water supply. Under conditions of the recommended plan, the quality of water delivered to the wetlands would be the best-quality water delivered since subsurface drainage was first introduced to the marsh area, and the volume (more than 129,000 acre-feet) would approximate the optimal water requirement for wildlife habitat in the subarea. Construction of the proposed wetland water-supply intertie facilities would provide the flexibility needed to ensure that the water would be delivered on an optimal schedule, assuming sufficient water is available in the Delta and sufficient capacity in the Delta-Mendota Canal to deliver the substitute water.

Table 30 compares the recommended plan features with those of the present and projected future-without conditions. The recommended plan would keep about 36,000 more acres of existing irrigated agricultural lands in production than under future-without conditions.

The annualized costs of the components of the recommended plan for the Grasslands Subarea are presented in Table 31. The category "Agricultural Drainage" comprises all drainage-related components of the recommended plan, except on-farm drainage systems. "On-Farm Drains"

Table 30. COMPARISON OF PLAN WITH PRESENT AND FUTURE-WITHOUT CONDITIONS, GRASSLANDS SUBAREA
In 1,000s

Item	Present (1990)	Future-Without (2040)	Recommended Plan (2040)
Agricultural Land Area (acres)			
Irrigable agricultural Land	365	303	339
Drainage reuse	0	2	3
Abandoned and/or retired agricultural land	0	40	3
Evaporation System			
Nontoxic evaporation pond	0.00	0.00	0.00
Toxic evaporation pond	0.10	0.20	0.12
Accelerated evaporation pond	0.00	0.00	0.02
Solar pond	0.00	0.00	0.13
Evaporation pond alternative habitat	0.00	0.00	0.12
Urban expansion	0	20	20
TOTAL [a]	**365**	**365**	**365**
Wildlife Areas (acres) [b]			
Wetlands	68.0	24.0	55.0
Other	29.0	72.4	41.4
Abandoned wildlife areas	0.0	0.6	0.6
TOTAL	**97.0**	**97.0**	**97.0**
Water Freed in Addressing Drainage Problems (acre-feet)	0	122[c]	55[d]
Firm Water Supply for Wildlife Areas (acre-feet)	97	97	226
Water Supply for Evaporation Pond Alternative Habitat (acre-feet)	0	0	1

[a] Evaporation systems are located on existing pond sites or on retired or nonirrigable lands, so are not included in "Total."
[b] Federal and State wildlife areas, private duck clubs, and other private wildlife areas.
[c] Includes increased conserved water through source control on problem water lands and firm water supply freed by land abandonment and conversion of crop land to salt-tolerant crops.
[d] Includes increased conserved water through source control on problem water lands; firm water supply freed by land retirement and conversion of cropland to salt-tolerant crops; and ground water pumped to control water levels within problem water areas.

includes the installation of new on-farm drainage systems from 1991 to 2040 and the annual operation from 1991 to 2040 of the newly installed drains and those already operating in 1990. "Fish and Wildlife" comprises the costs of constructing and operating facilities and purchasing water to deliver clean replacement water to waterfowl habitat formerly supplied with contaminated drainage water.

One-time costs include those for installation of facilities and purchase of land retired from irrigated agriculture. Costs were annualized, using an interest rate of 10 percent to reflect opportunities available to growers and a 50-year planning period. The grand total cost for the Grasslands Subarea would amount to about $107 per acre of problem farmland served by components of the recommended plan. This includes the cost of the fish and wildlife components. If these costs were separated, the per-acre cost to farmland served would be $81.

Included in the total cost is a provision necessary to minimize the risks to wildlife from evaporation ponds. The ponds in which the selenium level exceeded 2 ppb (the level assumed to be safe for wildlife) would include special features, such as steep side slopes, increased depth, hazing, and alternative habitat.

Table 31. ANNUALIZED COSTS OF THE RECOMMENDED PLAN FOR THE GRASSLANDS SUBAREA

AGRICULTURAL DRAINAGE		
One-time:		
Source control	$ 622,000	
Reuse	845,000	
Evaporation	224,000	
Ground-water management	193,000	
Land retirement	55,000	
San Luis Drain	2,300,000	
Subtotal	$4,239,000	
Operation, maintenance, and replacement:		
Source control	$1,232,000	
Reuse	145,000	
Evaporation	239,000	
Ground-water management	549,000	
Land retirement	6,000	
San Luis Drain	390,000	
Subtotal	$2,561,000	
Total		$ 6,800,000
ON-FARM DRAINS		
Installation	$2,653,000	
Operation, maintenance, and replacement	584,000	
Total		$ 3,237,000
FISH AND WILDLIFE		
Installation	$ 153,000	
Operation, maintenance, and replacement	18,000	
Water supply	2,548,000	
Total		$ 2,719,000
GRAND TOTAL		$12,756,000

Westlands Subarea

Figure 34 shows the location of the ground-water quality zones within the subarea. Agricultural components of the recommended plan for the subarea are shown on Table 32.

The agricultural components of the recommended plan for 2040 are:

- **Practicing source control on 159,300 acres of irrigated land.** The amount of applied irrigation water would be reduced by 0.35 acre-foot per acre per year (a total of 55,800 acre-feet) by improving methods of irrigation water application, improving scheduling of irrigation water application, and tiered water pricing.
- **Reusing drainage water to irrigate about 12,100 acres of salt-tolerant trees and halophytes.** Through installation of on-farm tile drains and conveyance facilities, drainage water would be collected and supplied to trees to reduce the total drainage volume by 45,700 acre-feet. Drains would be installed beneath the trees to collect the brackish water for direct use by halophytes. This would reduce the drainage volume by another 15,300 acre-feet, for a total reduction of about 61,000 acre-feet. These reuse plantations could serve individual farms or an entire water or drainage district. They would be located on the least productive soils, with most sites on class 4 soils on the alluvial fan rims. These soils occur in the eastern part of the subarea near the San Luis Drain. Existing collector drains and the San Luis Drain would be used to convey drainage water to reuse plantations.
- **Operating 400 acres of evaporation ponds and about 1,500 acres of solar ponds.** Pond design and operation criteria would be consistent with State guidelines, and the ponds would be located close to tree and halophyte plantations. About 200 acres of additional land would be used for accelerated-rate evaporation facilities.
- **Pumping the semiconfined aquifer under about 19,000 acres of land.** Due to natural features, this option is most feasible in the southeastern portion of the subarea. The design average annual yield would be 0.4 acre-foot per acre of land affected, for a total management of 7,600 acre-feet of problem water. To exert this effect at the land surface, 16,000 acre-feet would have to be pumped from the aquifer. These lands would also have received source control (0.35 acre-foot per acre), but they would not be artificially drained. Pumped ground water of initial good quality (some 16,000 acre-feet) could be used for agriculture, or fish and wildlife, or a variety of other uses. If, in future years, influent water to a well should contain dissolved salt in excess of 2,500 ppm, that water would be used as a supply for trees and halophytes, or as top water in solar ponds.
- **Retiring 33,000 acres of irrigated agricultural lands.** Lands having the combined characteristics of low productivity, poor drainability (USBR class 4 lands), and high levels of dissolved selenium (greater than 50 ppb) in shallow ground water would be retired. A part of water-quality Zones A, B, and C would be retired.

Figure 34

WESTLANDS SUBAREA

Ground-Water Quality Zones

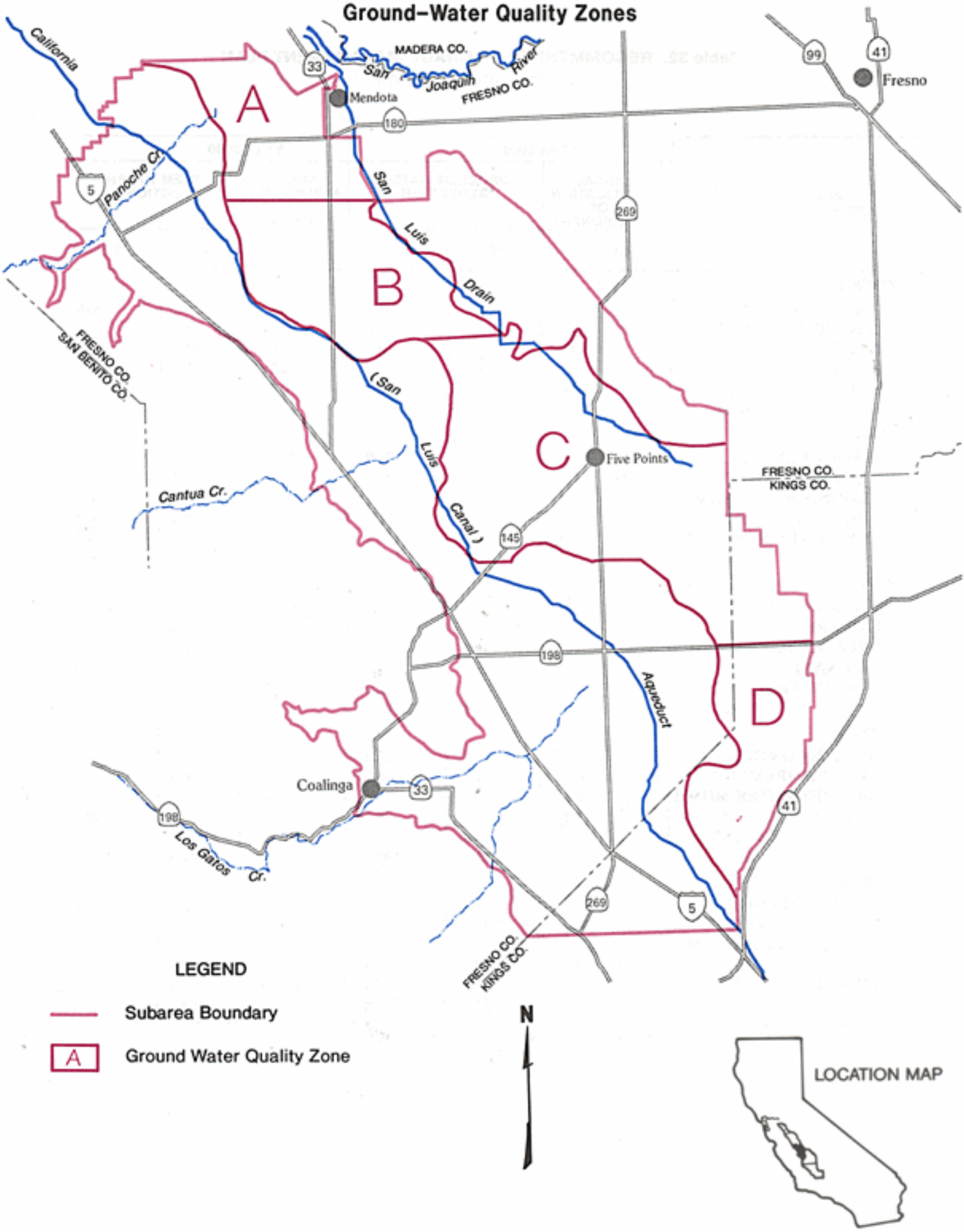


Table 32. RECOMMENDED DRAINAGE MANAGEMENT PLAN
WESTLANDS SUBAREA
(In 1000s)

PLAN COMPONENT	YEAR 2000			YEAR 2040		
	AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION		AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION	
	Acres	AF	%	Acres	AF	%
ZONE A						
SOURCE CONTROL	11.2	3.9	30.2	25.3	8.9	36.6
LAND RETIREMENT	5.0	3.8	29.4	5.0	3.8	15.4
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE[a]	1.0	4.9	38.1	2.2	11.1	45.5
EVAPORATION SYSTEM	0.06	0.3	2.3	0.27	0.6	2.5
Total		**12.9**	**100.0**		**24.4**	**100.0**
ZONE B						
SOURCE CONTROL	12.3	4.3	28.0	21.7	7.6	26.3
LAND RETIREMENT	7.0	5.3	34.1	15.0	11.2	38.8
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE[a]	1.2	5.0	32.7	2.0	8.8	30.4
EVAPORATION SYSTEM	0.07	0.8	5.2	0.94	1.3	4.5
Total		**15.4**	**100.0**		**28.89**	**100.0**
ZONE C						
SOURCE CONTROL	44.4	15.5	38.9	81.8	28.6	37.9
LAND RETIREMENT	6.0	4.5	11.3	13.0	9.8	12.9
GROUND-WATER MGM'T	10.0	4.0	10.0	11.0	4.4	5.8
DRAINAGE REUSE[a]	2.7	15.1	37.8	6.0	31.2	41.3
EVAPORATION SYSTEM	0.18	0.8	2.0	0.78	1.6	2.1
Total		**39.9**	**100.0**		**75.6**	**100.0**
ZONE D						
SOURCE CONTROL	16.2	5.7	44.0	30.5	10.7	44.0
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	5.0	2.0	15.4	8.0	3.2	13.2
DRAINAGE REUSE[a]	1.0	5.0	38.3	1.9	9.9	40.7
EVAPORATION SYSTEM	0.06	0.3	2.3	0.13	0.5	1.3
Total		**13.0**	**100.0**		**24.3**	**100.0**
TOTAL						
SOURCE CONTROL	84.1	29.4	36.3	159.3	55.8	36.4
LAND RETIREMENT	18.0	13.6	16.7	33.0	24.8	16.1
GROUND-WATER MGM'T	15.0	6.0	7.4	19.0	7.6	5.0
DRAINAGE REUSE[a]	5.9	30.0	36.9	12.1	61.0	39.9
EVAPORATION SYSTEM	0.4	2.2	2.7	1.0	4.0	2.6
Total		**81.2**	**100.0**		**153.2**	**100.0**

[a] Includes drainage from irrigated agricultural land used to grow salt tolerant crops.

Assessment of Plan Features and Their Effects

Table 33 compares the recommended plan features with those of present and projected future conditions without a plan. Compared to future-without conditions, the recommended plan would maintain about 100,000 more acres of existing irrigated agricultural lands in production. By 2040, the plan would result in the conservation or development of 181,000 acre-feet of water through implementation of plan components (such as source control, conversion of land to reuse drainage water, land retirement, and ground-water pumping) on drainage problem areas.

Table 33. COMPARISON OF PLAN WITH PRESENT AND FUTURE-WITHOUT CONDITIONS WESTLANDS SUBAREA
In 1,000s

Item	Present (1990)	Future-Without (2040)	Recommended Plan (2040)
Agricultural Land Area (acres)			
Irrigable agricultural land	640	489	590
Drainage reuse	0	6	12
Abandoned and/or retired agricultural land	0	140	33
Evaporation System			
Nontoxic evaporation pond	0.00	0.00	0.00
Toxic evaporation pond	0.50	0.20	0.40
Accelerated evaporation pond	0.00	0.00	0.20
Solar pond	0.00	0.00	1.52
Evaporation pond alternative habitat	0.00	0.00	0.40
Urban expansion	0	5	5
TOTAL [a]	**640**	**640**	**640**
Wildlife Areas (acres) [b]			
Wetlands	0.1	0.1	0.1
Other	0.4	0.4	0.4
Abandoned wildlife areas	0.0	0.0	0.0
TOTAL	**0.5**	**0.5**	**0.5**
Water Freed in Addressing Drainage Problems (acre-feet)	0	390[c]	189[d]
Firm Water Supply for Wildlife Areas (acre-feet)	0	0	0
Water Supply for Evaporation Pond Alternative Habitat (acre-feet)	0	0	4

[a] Evaporation systems are located on existing pond sites or on retired or nonirrigable lands, so are not included in "Total."
[b] Federal and State wildlife areas, private duck clubs, and other private wildlife areas.
[c] Includes increased conserved water through source control on problem water lands and firm water supply freed by land abandonment and conversion of crop land to salt-tolerant crops.
[d] Includes increased conserved water through source control on problem water lands; firm water supply freed by land retirement and conversion of cropland to salt-tolerant crops; and ground water pumped to control water levels within problem water areas.

The annualized costs of the components of the recommended plan for the Westlands Subarea are presented in Table 34. The category "Agricultural Drainage" comprises all drainage-related components of the recommended plan, except on-farm drainage systems. "On-Farm Drains" includes the installation of new on-farm drainage systems from 1991 to 2040 and the annual operation from 1991 to 2040 of the newly installed drains and those already operating in 1990.

One-time costs include those for installation of facilities and purchase of land retired from irrigated agriculture. Costs were annualized, using an interest rate of 10 percent to reflect opportunities available to growers and a 50-year planning period.

The grand total cost for the Westlands Subarea amounts to about $136 per acre of problem farmland served through the components stipulated in the recommended plan.

Included in the cost is a provision necessary to minimize the risk to wildlife from evaporation ponds. The ponds in which the influent selenium level exceeded 2 ppb (the level assumed to be safe for wildlife) would include special features, such as steep side slopes, increased depth, hazing, and alternative habitat.

Table 34. ANNUALIZED COSTS OF THE RECOMMENDED PLAN FOR THE WESTLANDS SUBAREA

AGRICULTURAL DRAINAGE		
One-time:		
Source control	$ 829,000	
Reuse	1,801,000	
Evaporation	702,000	
Ground-water management	319,000	
Land retirement	1,930,000	
Subtotal	$5,581,000	
Operation, maintenance, and replacement:		
Source control	$1,588,000	
Reuse	626,000	
Evaporation	596,000	
Ground-water management	903,000	
Land retirement	208,000	
Subtotal	$3,921,000	
Total		$ 9,502,000
ON-FARM DRAINS		
Installation	$3,008,000	
Operation, maintenance, and replacement	355,000	
Total		$ 3,363,000
GRAND TOTAL		$12,865,000

Tulare Subarea

Figure 35 shows the location of the ground-water quality zones within the subarea. Agricultural components of the recommended plan for the subarea are listed in Table 35.

The agricultural components of the recommended plan for 2040 are:

- **Practicing source control on 316,700 acres of irrigated land.** The amount of applied irrigation water will be reduced by 0.20 acre-foot per acre per year (a total of 63,200 acre-feet) by improving methods of irrigation water application, improving scheduling of irrigation water application, and tiered water pricing.

- **Reusing drainage water to irrigate 24,500 acres of salt-tolerant trees and halophytes.** Through installation of on-farm tile drains, drainage water would be collected and supplied to trees to reduce the total drainage volume by 68,900 acre-feet. Drains would be installed beneath the trees to collect the brackish water for direct use by halophytes. This would reduce the drainage volume by another 44,400 acre-feet, for a total reduction of 113,300 acre-feet. These reuse plantations could serve individual farms or an entire water or drainage district. They would be located on the least productive soils, with most sites on class 4, 5, and 6 soils (Storie Index) on the basin rim.

- **Operating 3,000 acres of evaporation ponds.**[5] Pond design and operation criteria would be consistent with State guidelines, and the ponds would be located close to tree and halophyte plantations.

- **Pumping the semiconfined aquifer under about 40,000 acres of land.** Due to natural features, this option is most feasible in the northern part of water-quality Zones D and E. The design average annual yield would be 0.4 acre-foot per acre of land affected, for a total management of 16,000 acre-feet of problem water. To exert this effect at the land surface, 32,000 acre-feet would have to be pumped from the aquifer. These lands would also have received source control (0.20 acre-foot per acre), but they would not be artificially drained. Pumped ground water of initial good quality could be used for agriculture, or fish and wildlife, or a variety of other uses. If, in future years, influent water to a well should contain dissolved salt in excess of 2,500 ppm, that water would be used for trees and halophytes.

- **Retiring 7,000 acres of irrigated agricultural lands.** Lands having the combined characteristics of low productivity, poor drainability (Storie Index 4, 5, and 6 lands), and overlying high selenium (greater than 50 ppb) in shallow ground water would be retired. All the lands lie within water-quality Zone B.

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[5] No solar ponds are included because salinity levels would probably be too low to support them.

Figure 35

TULARE SUBAREA

Ground-Water Quality Zones

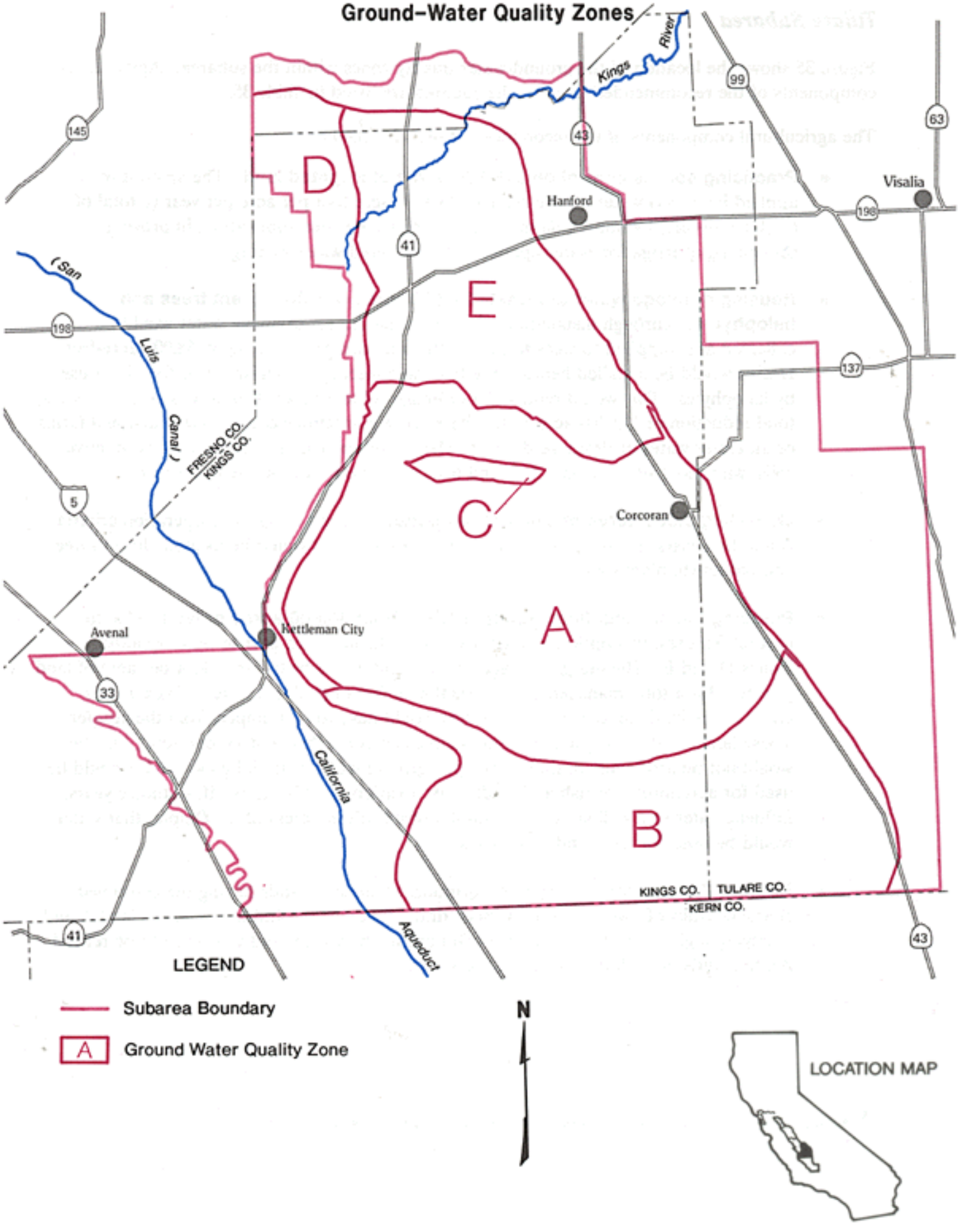

Table 35. RECOMMENDED DRAINAGE MANAGEMENT PLAN
TULARE SUBAREA
(in 1000s)

PLAN COMPONENT	YEAR 2000			YEAR 2040		
	AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION		AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION	
	Acres	AF	%	Acres	AF	%
ZONE A						
SOURCE CONTROL	60.9	12.2	30.8	169.5	33.9	30.8
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	2.0	0.8	2.0	3.0	1.2	1.1
DRAINAGE REUSE	5.0	25.2	63.7	14.0	71.3	64.7
EVAPORATION SYSTEM	0.34	1.4	3.5	0.96	3.8	3.4
Total		**39.6**	**100.0**		**110.2**	**100.0**
ZONE B						
SOURCE CONTROL	25.0	5.0	30.3	63.2	12.6	27.4
LAND RETIREMENT	0.0	0.0	0.0	7.0	4.2	9.2
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	2.5	9.0	54.5	6.3	22.8	49.7
EVAPORATION SYSTEM	0.62	2.5	15.2	1.58	6.3	13.7
Total		**16.5**	**100.0**		**45.9**	**100.0**
ZONE C						
SOURCE CONTROL	1.5	0.3	27.3	4.1	0.8	29.6
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	0.2	0.6	54.5	0.4	1.5	55.6
EVAPORATION SYSTEM	0.04	0.2	18.2	0.10	0.4	14.8
Total		**1.1**	**100.0**		**2.7**	**100.0**
ZONE D						
SOURCE CONTROL	6.9	1.4	31.1	19.7	3.9	31.4
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	2.0	0.8	17.8	10.0	4.0	32.3
DRAINAGE REUSE	0.5	1.8	40.0	1.0	3.5	28.2
EVAPORATION SYSTEM	0.12	0.5	11.1	0.24	1.0	8.1
Total		**4.5**	**100.0**		**12.4**	**100.0**
ZONE E						
SOURCE CONTROL	22.1	4.4	32.6	60.2	12.0	31.8
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	16.0	6.4	47.4	27.0	10.8	28.6
DRAINAGE REUSE	0.5	2.6	19.3	2.8	14.2	37.5
EVAPORATION SYSTEM	0.04	0.1	0.7	0.15	0.8	2.1
Total		**13.5**	**100.0**		**37.8**	**100.0**
TOTAL						
SOURCE CONTROL	116.4	23.3	31.0	316.7	63.2	30.2
LAND RETIREMENT	0.0	0.0	0.0	7.0	4.2	2.0
GROUND-WATER MGM'T	20.0	8.0	10.6	40.0	16.0	7.7
DRAINAGE REUSE	8.7	39.2	52.1	24.5	113.3	54.2
EVAPORATION SYSTEM	1.2	4.7	6.3	3.0	12.3	5.9
Total		**75.2**	**100.0**		**209.0**	**100.0**

Assessment of Plan Features and Their Effects

Table 36 compares the plan features with those of present and projected future conditions without the plan. Compared to future-without conditions, the recommended plan would maintain 166,000 more acres of existing irrigated agricultural lands in production. By 2040, the plan would result in the conservation or development of about 164,000 acre-feet of water through implementation of plan components (such as source control, conversion of land to reuse of drainage water, land retirement, and ground-water pumping) on drainage problem areas.

The annualized costs of the components of the recommended plan for the Tulare Subarea are presented in Table 37. The category "Agricultural Drainage" comprises all drainage–related components of the recommended plan, except on-farm drainage systems. "On-Farm Drains" includes the installation of new on-farm drainage systems from 1991 to 2040 and the annual operation from 1991 to 2040 of the newly installed drains and those already operating in 1990.

One-time costs include those for installation of facilities and purchase of land retired from irrigated agriculture. Costs were annualized, using an interest rate of 10 percent to reflect opportunities available to growers and a 50-year planning period.

Table 36. COMPARISON OF PLAN WITH PRESENT AND FUTURE-WITHOUT CONDITIONS TULARE SUBAREA In 1,000s

Item	Present (1990)	Future-Without (2040)	Recommended Plan (2040)
Agricultural Land Area (acres)			
Irrigable agricultural land	612	406	572
Drainage Reuse	0	11	25
Abandoned and/or retired agricultural land	0	190	7
Evaporation system			
Nontoxic evaporation pond	0.80	0.50	0.20
Toxic evaporation pond	4.10	0.90	2.90
Accelerated Evaporation pond	0.00	0.00	0.00
Solar pond	0.00	0.00	0.00
Evaporation pond alternative habitat	0.00	0.00	2.90
Urban expansion	0	5	5
TOTAL[a]	**612**	**612**	**612**
Wildlife Areas (acres)[b]			
Wetlands	1.7	0.0	0.0
Other	7.7	9.3	9.3
Abandoned wildlife areas	0.0	0.1	0.1
TOTAL	**9.4**	**9.4**	**9.4**
Water Freed In Addressing Drainage Problems (acre-feet)	0	454[c]	164[d]
Firm Water Supply for Wildlife Areas (acre-feet)	0	0	0
Water Supply for Evaporation Pond Alternative Habitat (acre-feet)	0	0	29

[a] Evaporation systems are located on existing pond sites or on retired or nonirrigable lands, so are not included in "Total."
[b] Federal and State wildlife areas, private duck clubs, and other private wildlife areas.
[c] Includes increased conserved water through source control on problem water lands and firm water supply freed by land abandonment and conversion of crop land to salt-tolerant crops.
[d] Includes increased conserved water through source control on problem water lands; firm water supply freed by land retirement and conversion of cropland to salt-tolerant crops; and ground water pumped to control water levels within problem water areas.

Table 37. ANNUALIZED COSTS OF THE RECOMMENDED PLAN FOR THE TULARE SUBAREA

AGRICULTURAL DRAINAGE		
One-time:		
Source control	$1,312,000	
Reuse	3,111,000	
Evaporation	396,000	
Ground-water management	513,000	
Land retirement	112,000	
Subtotal	$5,444,000	
Operation, maintenance, and replacement:		
Source control	$2,450,000	
Reuse	992,000	
Evaporation	241,000	
Ground-water management	1,441,000	
Land retirement	112,000	
Subtotal	$5,135,000	
Total		$10,579,000
ON-FARM DRAINS		
Installation	$3,144,000	
Operation, maintenance, and replacement	589,000	
Total		$ 3,733,000
GRAND TOTAL		$14,312,000

The grand total cost for the Tulare Subarea amounts to about $104 per acre of problem farmland served through components included in the recommended plan.

Included in the cost is a provision necessary to minimize the risk to wildlife from evaporation ponds. The ponds in which the influent selenium level exceeded 2 ppb (the level assumed to be safe for wildlife) would include special features, such as steep side slopes, increased depth, hazing, and alternative habitat.

Kern Subarea

Figure 36 shows the location of the ground-water quality zones within the subarea. Agricultural components of the recommended plan for the subarea are shown on Table 38.

The agricultural components of the recommended plan for 2040 are:

- **Practicing source control on 105,900 acres of irrigated land.** The amount of applied irrigation water will be reduced by 0.35 acre-foot per acre per year (a total of 37,100 acre-feet) by improving methods of irrigation water application, improving scheduling of irrigation water application, and tiered water pricing.

Figure 36

KERN SUBAREA

Ground-Water Quality Zones

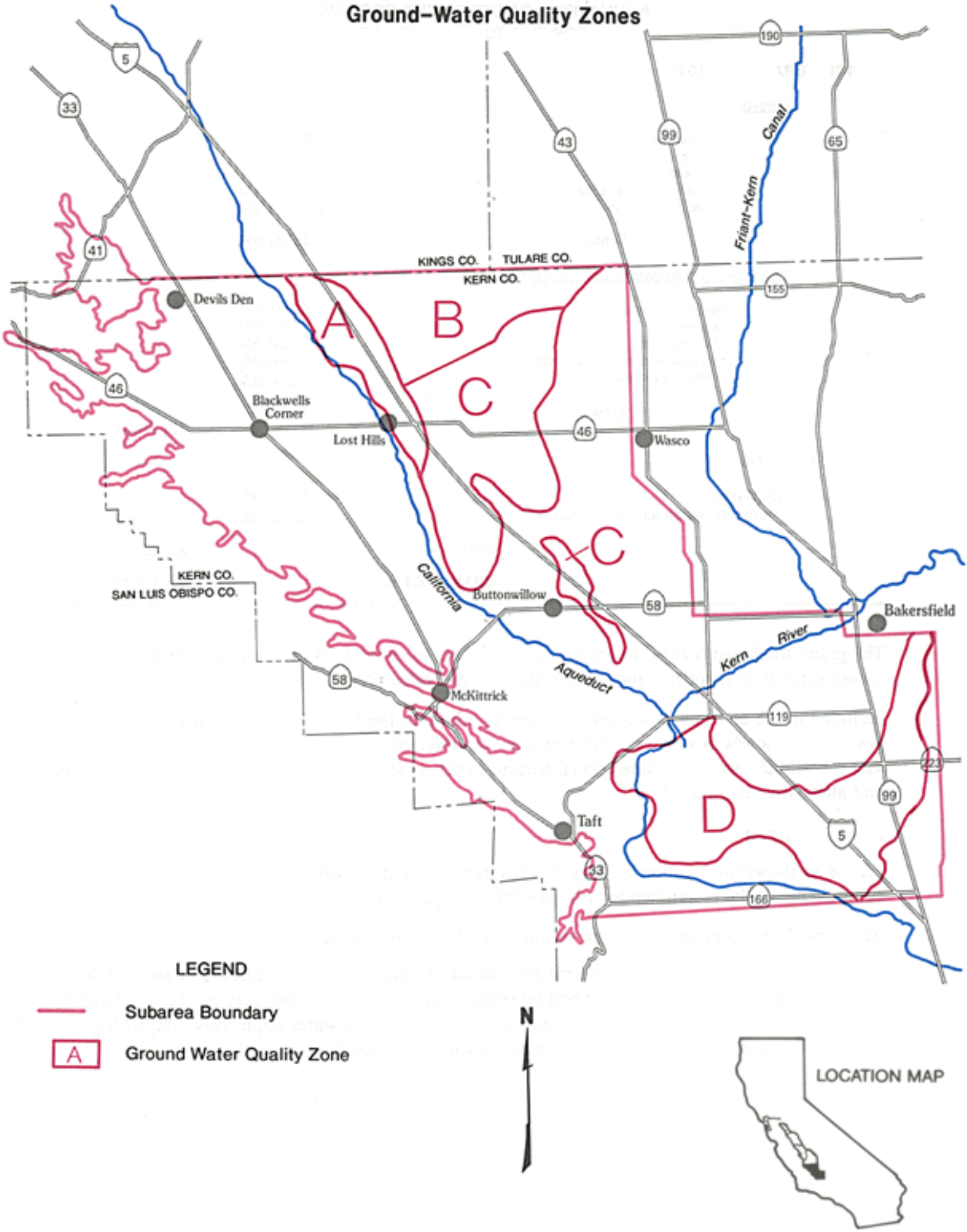

Table 38. RECOMMENDED DRAINAGE MANAGEMENT PLAN
KERN SUBAREA
(In 1000s)

PLAN COMPONENTS	YEAR 2000			YEAR 2040		
	AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION		AREAL APPLICATION OF COMPONENT	PROBLEM WATER REDUCTION	
	Acres	AF	%	Acres	AF	%
ZONE A						
SOURCE CONTROL	7.5	2.6	32.5	1.1	0.4	2.1
LAND RETIREMENT	2.2	1.7	21.2	24.0	18.0	95.4
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	0.8	2.9	36.3	0.1	0.4	2.0
EVAPORATION SYSTEM	0.15	0.8	10.0	0.08	0.1	0.5
Total		**8.0**	**100.0**		**18.9**	**100.0**
ZONE B						
SOURCE CONTROL	7.8	2.7	42.2	18.8	6.6	42.6
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	0.8	2.9	45.3	1.9	7.0	45.3
EVAPORATION SYSTEM	0.19	0.8	12.5	0.47	1.9	12.1
Total		**6.4**	**100.0**		**15.5**	**100.0**
ZONE C						
SOURCE CONTROL	13.4	4.7	43.1	32.4	11.3	43.1
LAND RETIREMENT	0.0	0.0	0.0	0.0	0.0	0.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	1.1	5.9	54.2	2.7	14.2	54.2
EVAPORATION SYSTEM	0.08	0.3	2.7	0.19	0.7	2.7
Total		**10.9**	**100.0**		**26.2**	**100.0**
ZONE D						
SOURCE CONTROL	24.4	8.5	41.0	53.6	18.8	37.5
LAND RETIREMENT	0.9	0.7	3.4	8.0	6.0	12.0
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	2.3	10.0	48.4	5.0	22.0	43.9
EVAPORATION SYSTEM	0.34	1.5	7.2	1.57	3.3	6.6
Total		**20.7**	**100.0**		**50.1**	**100.0**
TOTAL						
SOURCE CONTROL	53.1	18.5	40.2	105.9	37.1	33.5
LAND RETIREMENT	3.1	2.4	5.1	32.0	24.0	21.7
GROUND-WATER MGM'T	0.0	0.0	0.0	0.0	0.0	0.0
DRAINAGE REUSE	5.0	21.7	47.3	9.7	43.6	39.4
EVAPORATION SYSTEM	0.8	3.4	7.4	2.3	6.0	5.4
Total		**46.0**	**100.0**		**110.7**	**100.0**

- **Reusing drainage water to irrigate 9,700 acres of salt-tolerant trees and halophytes.** Through installation of on-farm tile drains, drainage water will be collected and supplied to trees to reduce the total drainage volume by 20,900 acre-feet. Drains would be installed beneath the trees to supply the water to halophytes. This would reduce the drainage volume by another 22,700 acre-feet, for a total reduction of 43,600 acre-feet. These reuse plantations could serve individual farms or an entire water or drainage district. They would be located on the least productive soils, with most sites on class 5 and 6 soils (Storie Index) on the alluvial fans in water-quality Zones A and D.
- **Operating 1,100 acres of evaporation ponds and 1,100 acres of solar ponds.** Pond design and operation criteria would be consistent with State guidelines, and the ponds would be located close to tree and halophyte plantations. An additional 100 acres of land would be required for accelerated-rate evaporation systems.
- **Retiring 32,000 acres of irrigated agricultural lands.** Lands having the combined characteristics of low productivity, poor drainability (Storie Index 4, 5, and 6 lands), and overlying high selenium (greater than 50 ppb) in shallow ground water would be retired. These lands lie within water-quality Zones A and D.

Assessment of Plan Features and Their Effects

Table 39 compares the plan features with those of present and projected future conditions without the plan. Compared to future-without conditions, the recommended plan would maintain about 52,000 more acres of existing irrigated agricultural lands in production. By 2040, the plan would create an opportunity to free at least 753,600 acre-feet of irrigation water for other uses.

The annualized costs of the components of the recommended plan for the Kern Subarea are presented in Table 40. The category "Agricultural Drainage" comprises all drainage-related components of the recommended plan, except on-farm drainage systems. "On-Farm Drains" includes the installation of new on-farm drainage systems from 1991 to 2040 and the annual operation from 1991 to 2040 of the newly installed drains and those already operating in 1990.

One-time costs include those for installation of facilities and purchase of land retired from irrigated agriculture. Costs were annualized, using an interest rate of 10 percent to reflect opportunities available to growers and a 50-year planning period.

The grand total cost for the Kern Subarea amounts to about $137 per acre of problem farmland served through the components stipulated in the recommended plan.

Included in the cost is a provision necessary to minimize the risk to wildlife from evaporation ponds. The ponds in which the influent selenium level exceeded 2 ppb (the level assumed to be safe for wildlife) would include special features, such as steep side slopes, increased depth, hazing, and alternative habitat.

Table 39. COMPARISON OF PLAN WITH PRESENT AND FUTURE-WITHOUT CONDITIONS KERN SUBAREA

In 1,000s

Item	Present (1990)	Future-Without (2040)	Recommended Plan (2040)
Agricultural Land Area (acres)			
Irrigable agricultural land	762	632	684
Drainage Reuse	0	5	10
Abandoned and/or retired agricultural land	0	90	32
Evaporation system			
Nontoxic evaporation pond	0.00	0.00	0.00
Toxic evaporation pond	1.70	0.70	1.07
Accelerated Evaporation pond	0.00	0.00	0.14
Solar pond	0.00	0.00	1.10
Evaporation pond alternative habitat	0.00	0.00	1.07
Urban expansion	0	35	35
TOTAL[a]	762	762	762
Wildlife Areas (acres)[b]			
Wetlands	6.1	0.0	0.0
Other	10.9	13.6	13.6
Abandoned wildlife areas	0.0	3.4	3.4
TOTAL	17.0	17.0	17.0
Water Freed In Addressing Drainage Problems (ac-ft)	0	268[c]	154[d]
Firm Water Supply for Wildlife Areas (acre-feet)	0	0	0
Water Supply for Evaporation Pond Alternative Habitat (acre-feet)	0	0	11

[a] Evaporation systems are located on existing pond sites or on retired or nonirrigable lands, so are not included in "Total."
[b] Federal and State wildlife areas, private duck clubs, and other private wildlife areas.
[c] Includes increased conserved water through source control on problem water lands and firm water supply freed by land abandonment and conversion of crop land to salt-tolerant crops.
[d] Includes increased conserved water through source control on problem water lands; firm water supply freed by land retirement and conversion of cropland to salt-tolerant crops; and ground water pumped to control water levels in problem water areas.

Table 40. ANNUALIZED COSTS OF THE RECOMMENDED PLAN FOR THE KERN SUBAREA

AGRICULTURAL DRAINAGE			
One-time:			
Source control		$ 551,000	
Reuse		1,391,000	
Evaporation		542,000	
Land retirement		652,000	
Subtotal		$3,136,000	
Operation, maintenance, and replacement:			
Source control		$1,051,000	
Reuse		637,000	
Evaporation		489,000	
Land retirement		68,000	
Subtotal		$2,245,000	
	Total		$5,381,000
ON-FARM DRAINS			
Installation		$2,051,000	
Operation, maintenance, and replacement		288,000	
	Total		$2,339,000
	GRAND TOTAL		$7,720,000

Evaluation of Plan and Comparison to Future-Without

The actions included in the recommended plan for each subarea would reduce the amount of irrigation water used on the lands overlying problem water. The volume would be reduced through: (1) Water conserved through source control measures, (2) water not applied to retired land, and (3) water not applied to lands being supplied through reuse of drainage water (for example, eucalyptus trees replacing a cotton field). In addition, a relatively small volume of water, some 56,000 acre-feet per year, would be pumped from the semiconfined aquifer.

The estimated water potentially available through recommended plan actions to reduce irrigation water application is given in Table 41. Although the water is potentially available with the plan, the water may not be physically available for any given use. That is because of restrictions due to water law (including contracts), economics, or private property rights (for example, pumped ground water). In the Westlands Subarea, for instance, 189,000 acre-feet annually would be conserved or developed in implementing the recommended plan. However, there is currently a shortage of irrigation water for some lands in the Westlands Water District. Consequently, water made available by reduced demand in the drainage problem area would probably be transferred to the area of shortage. Considerations of service area boundaries, priority of rights, availability of funds, and the full array of alternative uses for such water should be examined in more detail.

The water needs for fish and wildlife are shown in Table 42. Comparison of Tables 41 and 42 shows that a possible source of the water needed for fish and wildlife to offset the effects of drainage could be found in the water made available under the plan. It is assumed that 189,000 acre-feet of water freed in the Grasslands Subarea may be used to satisfy the 158,000-acre-foot shortage in the current firm water supply of the Grassland Water District. Additional investigation is required to determine the means of making the needed water available. The investigation should include consideration of marketing part of the available water to help pay for costs of solving drainage problems, including protecting fish and wildlife.

Table 41. WATER POTENTIALLY AVAILABLE THROUGH RECOMMENDED PLAN ACTIONS
In 1,000 acre-feet annually

	Source Control and Reuse		Ground-Water Management		Land Retirement		Total Water Available	
Subarea	2000	2040	2000	2040	2000	2040	2000	2040
Northern	0	0	0	0	0	0	0	0
Grasslands	35	39	4	8	0	8	39	55
Westlands	45	87	12	16	47	86	104	189
Tulare	42	117	16	32	0	15	58	164
Kern	32	64	0	0	9	90	41	154
TOTAL	154	307	32	56	56	199	242	562

Table 43 shows the area of wetlands, evaporation ponds, and solar ponds included in the recommended plan. The new year-round wetlands have been created to provide alternative habitat to unsafe evaporation ponds, and they are necessary for successful hazing. The wetlands would require fresh water at the rate of about 10 acre-feet per acre per year.

Comparison of the recommended plan to the future-without conditions provides a scale for further evaluation of the recommended plan. Selected features of the two courses of action are

displayed in Tables 44 and 45. Table 44 shows that the recommended plan, which emphasizes more planned regional control of drainage water (beginning with intensive drainage water source control measures), provides water that could be made available for other uses, including fish and wildlife. However, by far the largest volume of water would be made available under future-without conditions, in which 1,140,000 acre-feet of water annually would not be used on 460,000 acres of presently irrigated lands because of salinization and abandonment of those lands.

Table 42. SUMMARY OF ANNUAL WATER NEEDS FOR FISH PROTECTION, SUBSTITUTE WATER SUPPLY FOR WILDLIFE AREAS, AND ALTERNATIVE HABITAT FOR EVAPORATION PONDS (As Related to Drainage Problem)

In acre-feet

Subarea	2000	2040
Grasslands[a]	149,300	150,200
Westlands[b]	2,300	4,000
Tulare[b]	11,200	29,000
Kern[b]	4,600	10,700
TOTAL	167,400	193,900

[a] Includes 20,000 acre-feet per year for Merced River fisheries, 129,000 acre-feet per year for substitute water supply, and 300 acre-feet per year (2000) / 1,200 acre-feet per year (2040) for alternative habitat for evaporation ponds. Some substitute water supply needs can be met with existing water-district spills and tailwater of adequate quality (about 55,000 acre-feet per year is estimated under the recommended plan on a firm basis).

[b] All needs are for alternative habitat to evaporation ponds.

Table 43. AREA OF EVAPORATION AND SOLAR PONDS AND WETLANDS IN THE RECOMMENDED PLAN

In acres

	Evaporation Ponds						Solar Ponds[a]		New Year-Round Wetlands[b]	
	Nontoxic Ponds (≤2 ppb selenium)		Standard Ponds (2–50 ppb selenium)		Accelerated Rate Ponds[a]					
Subarea	2000	2040	2000	2040	2000	2040	2000	2040	2000	2040
Northern	0	0	0	0	0	0	0	0	0	0
Grasslands	0	0	10	120	0	70	0	110	10	120
Westlands	0	0	230	410	20	200	140	1,520	230	410
Tulare	40	200	1,120	2,900	0	0	0	0	1,120	2,900
Kern	0	0	460	1,070	120	140	190	1,100	460	1,070
TOTAL	40	200	1,820	4,500	140	410	330	2,730	1,820	4,500

[a] These ponds must be evaluated to determine their effect on wildlife and shallow ground water.

[b] Provided as alternative habitat to standard evaporation ponds (new wetlands require 10 acre-feet per acre per year).

Table 44. COMPARISON OF SELECTED WATER FEATURES AND EFFECTS OF THE RECOMMENDED PLAN AND FUTURE-WITHOUT CONDITIONS, 2040

In acre-feet

	Future-Without Conditions	Recommended Plan
Water supplied to wetland areas	97,000	271,000[a]
Supplementation of Merced River	0	20,000
Water made available by land abandonment	1,140,000	0
Water made available through land retirement	0	195,000
Water pumped from the semiconfined aquifer	0	56,000
Water conserved through source control and reuse of drainage water	54,000[b]	308,000[c]

a Includes, approximately: 97,000 acre-feet per year of existing firm supply; 129,000 acre-feet per year of substitute water supply; and 45,000 acre-feet of water to create a wetland habitat that is an alternative to toxic evaporation ponds.
b Conservation rate of 0.2 acre-foot per acre of drained land.
c Conservation rate of 0.35 acre-foot per acre of drained land (except Tulare, which is 0.20 acre-foot); includes freeing of irrigation water supply supplanted by using drainage water on salt-tolerant plants.

Table 45. COMPARISON OF SELECTED LAND FEATURES AND EFFECTS OF THE RECOMMENDED PLAN AND FUTURE-WITHOUT CONDITIONS, 2040

In acres

	Future-Without Conditions	Recommended Plan
Seasonal and permanent wetlands	24,000	55,000[a]
Reuse areas (salt-tolerant plants)	28,000	49,000
Irrigated land area	1,965,000	2,325,000
Crop land drained [b]	345,000	783,000
Land abandoned [c]	460,000	0
Land retired from irrigation	0	75,000

a Does not include new wetlands created as alternative habitat for evaporation ponds because such lands are an adjunct of the drainage management system, not lands dedicated to wetlands.
b Does not include tile drains that would be installed under salt-tolerant plants.
c Salinization of formerly irrigated lands.

Estimates of the economic benefits of fish and wildlife resources in the San Joaquin Valley have been based on both market (user) and nonmarket (nonuser) values (Loomis et al., 1990). The combined annual market and nonmarket values of fish and wildlife for the recommended plan exceed those values associated with the future-without alternative by a ratio of almost 2 to 1.

Conditions that are expected to prevail with the recommended plan have been analyzed for 2040, and the agriculturally related economic impacts of plan conditions and future-without conditions for 2040 are compared in Table 46. The recommended plan would maintain more land in agricultural production and higher levels of retail sales, employment, and income. About 360,000 more acres would be kept in irrigated agriculture, with an associated crop value of $285 million. The positive impact on retail sales in neighboring communities would be nearly $41 million, and personal income would be about $78 million higher than in the future-without.

Total direct agricultural employment in the four subareas would be about 2,500 jobs higher with the recommended plan than without it. Additional employment of more than 3,200 person-years would occur both in industries that serve agriculture and in the general economies of nearby communities. The overall improvement in employment would exceed 5,700 jobs.

Table 46. INCREASE IN RETAIL SALES, INCOME, AND EMPLOYMENT FROM FUTURE-WITHOUT CONDITIONS TO THE RECOMMENDED PLAN FOR SELECTED SUBAREAS, 2040

Item	Grasslands	Westlands	Tulare	Kern	Total
Increase in irrigated crop area (1,000 acres)	36	101	170	53	360
Crop value maintained	23,788	85,862	139,332	35,877	284,859
Direct retail sales	865	3,125	5,071	1,305	10,366
Indirect and induced retail sales	2,529	9,158	14,932	3,836	30,455
TOTAL RETAIL SALES	**3,394**	**12,283**	**20,003**	**5,141**	**40,821**
Direct personal income	2,984	10,888	17,975	4,590	36,437
Indirect and induced personal income	4,054	19,635	11,417	5,975	10,565
TOTAL PERSONAL INCOME	**7,038**	**30,523**	**29,392**	**10,565**	**77,518**
Direct employment	223	780	1,206	319	2,528
Indirect and induced employment	568	1,423	812	414	3,217
TOTAL EMPLOYMENT	**791**	**2,203**	**2,018**	**733**	**5,745**

Note: Crop value, retail sales, and income are in 1,000s (1990) of dollars per year, and employment is in person-years per year.