Partial Draft for Sub-team

Water Quality Criteria for Agricultural Supply

Figure 1 is a map of the Delta.

Agricultural Water Quality Linkages

Water quality requirements for agriculture are simple in the sense that quality for crops being grown needs to be achieved at every headgate, and these levels of water quality can be established from available data. Also, water from the federal and state water projects is of generally good quality for agriculture. Complexity arises from the need to consider the following:

- The full extent of delivery system
- Variations in cropping patterns
- Variations in water supply levels
- Recycling of tailwater and subsurface drainage water
- Environmental and regulatory standards for drainage water quality
- Regulatory and contractual standards for water supply quality
- Water quality influences sustainability as well as current economic product of agriculture
- Future changes in water management (50-year planning horizon)

Linkage To Water Supply

Water quality requirements depend on the crop being grown. However, it can equally be said that farmers will grow crops requiring higher quality water (since they are often of higher value) when such water is available. Therefore, farmers want the best possible water quality. In a year with full water deliveries, this is much less of a problem than in dry years when deliveries are curtailed.

In dry years, surface water supply shortfall is replaced by groundwater that is often of lower quality (higher salinity). Surface water is then blended with groundwater to achieve acceptable salinity levels. The relationship between surface water quality, groundwater quality, and required blend ratios are illustrated in Figure 2. For a given groundwater quality, higher quality surface water results in a greater percentage groundwater in the blend. Likewise, higher quality groundwater allows for a greater percentage of groundwater in the blend. Of course, when surface water is plentiful, little blending occurs, and more water is irrigated "as is".

Furthermore, as more saline water is used for irrigation, a larger quantity of leaching water is required (Figure 3), subsurface drainage volume increases (Figure 4), and so does salt loading (Figure 5) Alternatively, if adequate leaching is not provided, soil salinity increases (Figure 6) and drainage water quality declines (Figure 7 -- pending). As irrigation water quality declines, opportunities for tailwater and drainage recycling are reduced. Therefore, water quantity and quality are inextricably linked for agriculture.

Another example of this fact is in the Sacramento Valley, where increasing measures for water conservation, such as reduced through-flow and tailwater recycling in rice fields, has led to increases in salinity and reduced water quality in fields and agricultural water delivery systems. Therefore, the water quality requirement at the last, downstream headgate may be the key to establishing water quality criteria at the initial diversion. These and other facts of agricultural water use should be taken into account as actions are prioritized for inclusion in the CALFED programs.

Linkage to Ongoing Programs and Existing Standards

Some water quality programs in place, such as efforts to reduce rice herbicides in the Sacramento Valley river systems, are not on CALFED's list. They need to be included so that ongoing efforts are fairly recognized and so that those implementing them are not inadvertently harmed by CALFED.
Regulatory and contractual criteria already exist for many locations, and CALFED should not specify criteria that are less stringent. For example, there are contractual (USBR) criteria for Mendota Pool. Many factors influence this water quality, including upstream drainage inflows to DMC (some undocumented), and the extent of groundwater integration along the DMC.

Linkage to Irrigation and Drainage Management

Guidelines for acceptable ranges of various parameters (including salinity) depend on a number of irrigation and drainage management assumptions. The pertinent assumptions are catalogued in Ayers and Westcot (1989). Some examples include:

- A **15 percent leaching fraction** is included in applied water. If this is not the case, then more water or water of better quality is required.
- **Surface or sprinkler irrigation with adequate drainage** are assumed. Guidelines must therefore be modified for subsurface irrigation (common within the legal Delta), for drip (increasingly common in the San Joaquin Valley), and for situations in which subsurface drainage is inadequate (drainage affected areas in the San Joaquin and Sacramento valleys and Delta).
- A particular, **vertical distribution of water uptake** from the root zone: 40 percent from the top 25 percent of the depth; 30 percent from the next 25 percent of the depth; 20 percent from the next 25 percent of the depth; and 10 percent from the bottom 25 percent of the root zone.

- **Good irrigation and drainage uniformity**. Within-field variability of irrigation application and drainage was not considered as part of the development of these criteria. Figure 7.5 illustrates the relationship between irrigation distribution uniformity (DU), water requirements, and irrigation scheduling. When irrigations are scheduled to meet crop and leaching needs, better DU results in lower subsurface drainage volumes while more fully meeting crop needs throughout the field.

To the extent that these and other conditions are not met, the criteria must be modified.

Linkage to Conveyance System Extent and Operation

The geographic scope of agricultural water use related to the Delta includes all agriculture in tributary regions, and all agriculture in areas whose water supply passes through the Delta. This would include, for example, the Sacramento Valley and Southern California areas receiving State Water Project water for irrigation.

Ayers and Westcot criteria are given according to the level of crop sensitivity. For a given parameter, more sensitive crops require higher quality water. Since conveyance systems mix water delivered to the full range of crops grown in the region, agricultural water quality standards should be based on the most sensitive crops grown in the region. For example, strawberry, carrot, and beans require an $EC_w < 0.7$, or TDS < 450 mg/L.

Parameters of Concern

Both the quantity and quality of water supply are important for irrigation. A water supply must be adequate to fulfill anticipated irrigation needs. If poor quality water is applied, however, special management practices may be required to maintain full crop productivity. The problems that result from using poor quality waters will vary in type degree and severity. Some impacts are osmotic effects on crop yield, effects on soil permeability, and specific ion toxicities. Other problems which can arise, such as excessive vegetative growth, lodging, or delayed crop maturity resulting from excessive nutrients (usually nitrogen) in the water supply; white deposits on fruit or leaves due to sprinkling with waters high in bicarbonate, and others are discussed in the context of this report. The primary factor in evaluating water quality for irrigation however, is the quantity and kind of salt present in the water supply.

A summary of water quality parameters of concern for agriculture and their effects is presented in Table 1. Each of the parameters will be described in more detail, including the rationale for inclusion, potential level of impact to crop yield, and associated agricultural management techniques are presented in individual sections following this general discussion.

Guidelines for evaluating water quality based on the parameters of concern for irrigation are summarized in Table 2. Information contained in Table 2 relative to the degree of restriction in use is drawn mainly from Table 1 in Ayers and Westcot, 1989. A number of critical assumptions are associated with these guidelines, and a summary of some of these assumptions provided in this section has been extracted from the same document.

These guidelines are limited to the aspects of irrigation water quality that are normally encountered and that materially affect crop production. Emphasis is on long-term, dominating influences of water quality on soil-plant-water systems as it relates to crop production. The guidelines are intended as a management tool only, and the user should guard against drawing unwarranted conclusions based strictly on generalizations.

The water quality guidelines in Table 2 are intended to cover the wide range of conditions encountered in irrigated agriculture. They incorporate some of the newer concepts in soil-water-plant relationships. Several basic assumptions have been used to define their range of usability. If the water is used under very different conditions, the guidelines may be adjusted. Wide deviations from the assumptions might result in wrong judgments on the usability of a particular water supply, especially if it is a borderline case. Where sufficient experience, field trials, research or observations are available, the guidelines may be modified to fit local conditions more closely.

The basic assumptions in the guidelines are:

1. Yield Potential: Full crop production, including necessary management inputs, is assumed when the guidelines indicate that water quality does not constitute a problem. The existence of a potential problem indicates that certain tolerant crops may have to be grown to maintain full productivity. It does not indicate that the water is unsuitable for use on any crop.
2. Site Conditions (Soil & Climate): Soil texture ranges from sandy-loam to clay-loam with good internal drainage. The climate is semi-arid to arid with low effective rainfall. Drainage is assumed to be good, with no uncontrolled shallow water table present.
3. Methods and Timing of Irrigation: Normal surface or sprinkler irrigation methods are assumed including flood, basin, strip-check, furrow, corrugation, and sprinkle. It is assumed the crop utilizes a considerable portion of the stored soil plant available water between irrigations (50-percent or more). With these irrigation methods, about 15-percent of the applied water is assumed to percolate below the rooting depth, this translates into an approximate leaching fraction of 15-percent. The guidelines are too restrictive for specialized irrigation methods, such as localized drip irrigation, which results in near daily or frequent irrigation, but are applicable for subsurface irrigation if surface applied leaching satisfies the leaching requirement.
4. Water Uptake by Crops: Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth. On average about 40-percent is assumed to be taken from the upper quarter of the rooting depth, 30-percent from the second quarter, 20-percent from the third quarter, and 10-percent form the lowest quarter. Each irrigation is assumed to leach the upper root zone

and maintain it at a relatively low salinity. Salinity is assumed to increase with depth to the lower part of the root zone. The average salinity of the soil-water is assumed to be three times that of the applied water and is representative of the average root zone salinity to which the crop responds. These conditions result from a leaching fraction of 15-20-percent and irrigations that are timed to keep the crop adequately watered at all times.

Salts leached from the upper root zone accumulate to some extent in the lower part, but a salt balance is achieved as salts are moved below the root zone by sufficient leaching. The higher salinity in the lower root zone becomes less important if adequate moisture is maintained in the upper, "more active" part of the root zone and long-term leaching is accomplished.

The following sections discuss individual parameters of concern.

Salinity

All irrigation water is a mixture of pure water and some salts. When water is applied as irrigation, crop uptake and evaporation remove pure water with some dissolved salts, particularly nutrient salts. However, most of the water's salt load remains in the crop's root zone after uptake of water by roots. When water does not flush from the soil, but is only added to meet crop needs, the soil accumulates residual salt over time. If the frequency of flushing, or leaching, is too low, then salts concentrations may reach levels that cause stress to growing plants.

In general, salt influences plant growth by depriving the roots of water. Water uptake by plants is driven by differences in water content and salt concentration between the root interior and the soil. When the salt concentration of the soil increases, plants must accumulate salt themselves, or must become drier to continue to extract water from the soil.

Plants vary in their ability to adapt to saline conditions by these and other mechanisms, and therefore vary in their ability to tolerate saline conditions. Even tolerant plants, though they survive, may not produce as much when grown under saline conditions. This is because extraction of water from saline soil requires more plant energy, which might otherwise be allocated for increasing the plant's size or improving its quality.

Criteria Development

The crops grown in areas served from the Delta, therefore, dictate agricultural salinity criteria for agriculture. A map of DWR hydrologic regions is shown on Figure 8. Acreage of crops grown within these regions are shown in Table 3, where crops are grouped within each region as being of major, intermediate, or minor importance (based on their percentage of total acreage). For each crop group in each of the four regions shown in Table 3, the effect of increasing irrigation water salinity has been illustrated. Figures 9, 10, 11, and 12 show these relationships. If the most sensitive crops are considered, irrigation water salinity levels at or below the criterion of 450 mg/L total dissolved solids (TDS) are required to avoid yield reductions due to salinity.

Management Options

The major objective in selecting management practices to control salinity is to maintain adequate soil water availability to the crop. Procedures that require relatively minor changes in management are more frequent irrigations, selection of more salt-tolerant crops, additional leaching, pre-plant irrigations, and altered seed placement. Alternatives that may require significant changes in management are changing the irrigation method, altering the water supply, land-grading, modifying the soil profile, and installing artificial drainage. Management must fit the method of irrigation, and a summary of the factors affecting the selection of an irrigation method under saline conditions is presented in Table 4. Although some of these management options are relatively easy to implement, the economic impact may make them impractical depending on the agronomic system in place. Detailed discussions of various management practices follow:

- Additional Leaching -- Salts leached from the upper root zone accumulate to some extent in the lower part, but a salt balance is achieved as salts are moved below the root zone by sufficient leaching. The higher salinity in the lower root zone becomes less important if adequate moisture is maintained in the upper, "more active" part of the root zone and long-term leaching is accomplished.

- More Frequent Irrigations - Salts concentrate in the soil profile as water is extracted for consumptive use by the crop. Hence, concentrations are lowest following an irrigation and typically highest before the next irrigation. Increasing irrigation frequency has historically been considered favorable under saline conditions, however recent research at the University of California, Davis (Hanson, 1993), suggest the benefits of this management option may be overrated. The studies suggest that, just as under low-salinity conditions, scheduling should be based solely on soil moisture depletion. But because high salinity levels reduce yield, crop evapotranspiration will also be reduced. Therefore, over a given time period, soil moisture depletion will be lower under saline conditions than under non-saline conditions. The value of this management practice will need to be considered in relation to the economic impact of probable yield reduction.

- Crop Selection - When using saline irrigation water, selection of a salt-tolerant crop may be required to avoid potential reductions in crop yield. There is an approximate tenfold range in salt tolerance of agricultural crops as illustrated in part in Figures 9 through 12, for crops in the hydrologic regions of interest in California. The selection of a more salt-tolerant crop, however, will not eliminate the need for leaching and for increased management. It makes economic sense that agronomic areas will be dominated by the highest value crops that can be grown with the available water quality, and existing conditions.

Specific Ions

Unlike general salinity, which influences crops by reducing water availability, specific ions become problems when present at relative or absolute levels that are toxic to crops or that impact soil physical properties. Toxicity normally results when ions concentrate in the soil, are taken up with the soil-water, and accumulate in plant tissues. Crop sensitivity depends on the nature of the crop (species/cultivar, growth stage), ionic concentrations, and soil and weather conditions. Effects on soils occur when soil chemical conditions become imbalanced, favoring unfavorable changes in soil physical properties. Soil properties such as texture and existing chemistry strongly influence the effect specific ions may have. Specific ions that commonly cause plant growth or soil problems are chloride, sodium (sodium adsorption ratio, or SAR), and boron.

The effects and rationale for the inclusion of each specific ion is presented below.

Chloride

The most common toxic ion encountered in irrigation water supplies is chloride. Chloride is not adsorbed (or retained) on soil particles. It therefore moves readily with the soil water and is taken up by the crop, accumulating in the leaves during transpiration. At toxic levels injury symptoms develop such as leaf burning and desiccation. Continued uptake can lead to necrosis (dead tissue) and is often accompanied by early leaf drop or defoliation. Plant tissue analysis is typically used to confirm chloride toxicity.

Uptake of chloride depends on the ability of the crop to exclude chloride and concentrations in irrigation in the soil water. Soil water concentrations are controlled by concentrations in irrigation water and the amount of leaching that occurs. Crop tolerance of chloride is not as well documented as crop tolerance of salinity, and quantitative yield reduction relationships have not been defined. However, in general, woody plants, such as California's fruit and nut crops, tend to be more sensitive to chloride.

Crops grown under overhead sprinkler irrigation can take up chloride by absorption irrigation water into leaves during and after irrigation. Management practices to avoid this kind of uptake are discussed later in this report.

Boron

Surface waters usually do not contain boron at toxic levels. Groundwater from wells or springs can contain toxic levels, especially near geothermal areas and earthquake faults. Some areas near the Delta are underlain by groundwater with high levels of boron. The average concentration in seawater is reported as 4.5 mg/l in the form of borate (US-EPA, 1976). Historic concentrations of boron at monitored sites of the Delta are presented later in this report.

Boron is essential in relatively small quantities for optimum plant growth however, minimal exceedence of the desirable limit can lead to toxicity related problems. Boron toxicity can affect almost all agronomic crops, and like salinity, there is a wide range of tolerance among crops. Climatic and soil conditions also influence boron toxicity, with boron uptake being generally higher at low soil pH . The first symptoms are normally yellowing or spotting of older leaves, , and/or drying of the leaf tips and edges (leaf burn). Drying and chlorosis can progress from the edges towards the center of the leaf, and become more severe with prolonged exposure. Seriously affected tree crops may not show typical leaf symptoms, but may exhibit twig die-back and develop a gum layer on limbs and trunks.

Criteria

The limits presented in the water quality guidelines are not based on plant symptoms, but upon an expected significant loss in yield if the boron value is exceeded. Sensitive crops have shown toxic effects at and below 1 mg/L (Ayers and Westcot, 1985). Table 4 presents the allowable maximum boron concentrations in irrigation water for some crops grown in the area of study in California.

Table 4

Tolerable Concentrations of Boron in Irrigation Water

Crop	Boron (mg/L)
Barley	2.0 - 4.0
Beans	0.7 - 1.0
Corn	2.0 - 4.0
Cotton	6.0 - 15.0
Alfalfa	4.0 - 6.0
Sugar Beets	4.0 - 6.0
Wheat	0.75 - 1.0
Cantaloupe	2.0 - 4.0
Tomatoes	4.0 - 6.0
Lemons	<0.5
Orange	0.5 - 0.75
Grapes	0.5 - 0.75
Peaches	0.5 - 0.75
Plums	0.5 - 0.75

Management
Reclaiming boron-affected soils requires leaching the boron from the root zone. Because boron mobility is reduced by adsorption on soil particles, removing it from the soil profile requires approximately two to three times more leaching water than is typically required for reclaiming saline soils (Hanson, 1993).

SAR (Sodium)

Sodium hazards in irrigation and soil waters can negatively affect crop production. Unlike the salinity hazard, excessive sodium does not impair the uptake of water by plants, but rather impairs soil structure and reduces the infiltration of water into the soil. Thus, the plant growth can be affected by drought stress or lack of aeration. When calcium and magnesium are the predominant cations adsorbed on soil particles, the soil tends to have a granular structure that is easily tilled and readily permeable. Unbalanced, large amounts of sodium can disperse soil particles, so that soil structure breaks down and hydraulic conductivity decreases. However, good soil structure and adequate drainage are essential for soil reclamation and salinity management , and must therefore be maintained. Additional agronomic issues arising or magnified from excess sodium include crusting of soil, especially seed beds, temporary saturation of the soil surface layer, and/or related disease, weed, respiratory, and nutritional problems. In extreme cases and for sensitive plants, sodium ions can be phytotoxic, much in the same manner as chloride.

The exchangeable sodium percentage (ESP) of soil extracts is generally a good indicator of the exchangeable sodium status within the soil. The sodium adsorption ratio (SAR) relates sodium, calcium, and magnesium concentrations in water. In combination with the EC of the water, SAR indicates the water's tendency to disperse soil.

Criteria
Criteria for SAR and depend on EC of irrigation water, and are shown in Table 2. In effect, a given, relative concentration of sodium has less impact in saltier water. These criteria are for soil dispersion.

Management
Sodium is generally managed by replacement with calcium through addition of gypsum, or addition of sulfuric acid, which reacts with soil carbonates to liberate calcium. These treatments must be followed by leaching with water of acceptable quality.

pH

This parameter is related to plugging of irrigation equipment, such as drip emitters, and precipitation of residues on plants, such as cut flowers, in greenhouses. (to be completed at a later date).

Turbidity

Turbidity is a measure of "suspended and settle-able solids" and is descriptive of the organic and inorganic particulate matter in water. Effects of turbidity on plants and soils include the formation of crusts on the soil surface (which can inhibit water infiltration and aeration, and can impede seedling emergence), and the formation of films on plant leaves (blocking sunlight and reducing photosynthesis and marketability).

Another impact of turbid water on irrigation practices is on the conveyance and delivery of water for crop production. Settle-able matter in the water can prematurely decrease reservoir capacity, and increase maintenance requirements on delivery canals due to siltation.

Criteria

Management

As agricultural lands in the Sacramento and San Joaquin Valley continue to be irrigated with low-volume irrigation systems like drip and micro-sprinkle, discharge clogging, maintenance, and on-farm water management (filtration) requirements will need to be considered when selecting a new system or evaluating water supply. Filtration and maintenance impacts of turbid waters on low volume irrigation can be costly and may make them unfeasible to use.

Nutrients

Nutrients in irrigation water supplies can provide fertilizer benefits for crop or landscape production, but in certain instances (when they exceed plant needs or are applied in irrigation water at a time when the plants development is disturbed by them.) they can cause agronomic problems. Excessive vegetative growth, delayed or uneven maturity, or reduced quality are some of the impacts. Nutrients occurring in such quantities include nitrogen as nitrate and ammonia.

Criteria

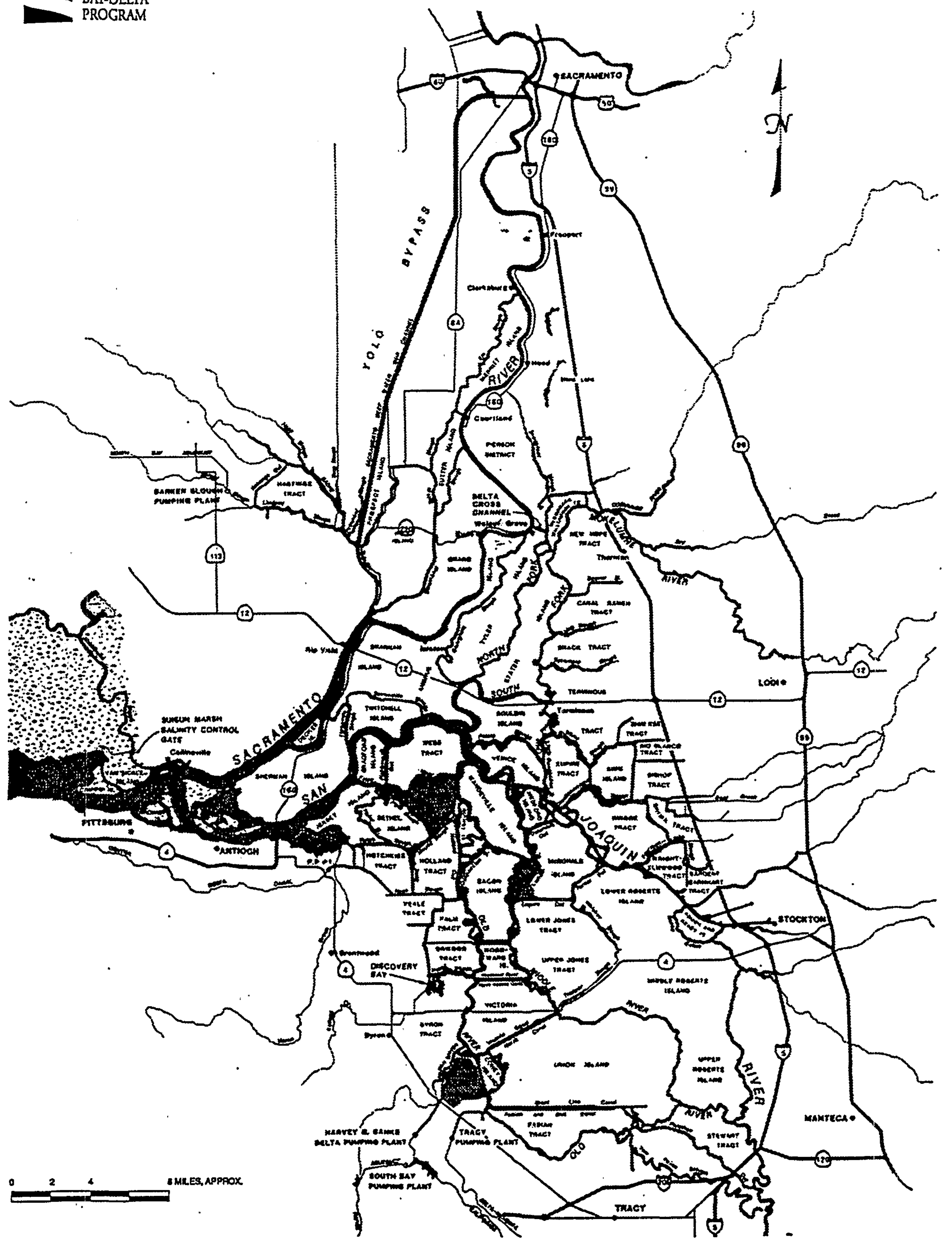
Criteria for nitrate are shown in Table 2. [Criteria for ammonium may not be needed, and can be added later. Further discussion of criteria to be added later].]

Management

Sensitive crops may require an alternative water supply, or may not be grown. Additional plant and soil monitoring provides valuable management information if nutrient levels in the irrigation water do not exceed plant needs.

Temperature

Primarily related to seedling emergence and crop development in rice production. Details to be added later.



SOURCE:
SACRAMENTO-SAN JOAQUIN
DELTA ATLAS
DWR, 1995

FIGURE 1
DELTA LOCATION MAP
INCLUDING WATERWAYS AND ROADS
CALFED BAY-DELTA PROGRAM
AGRICULTURAL WATER QUALITY SUBSTEAM REPORT

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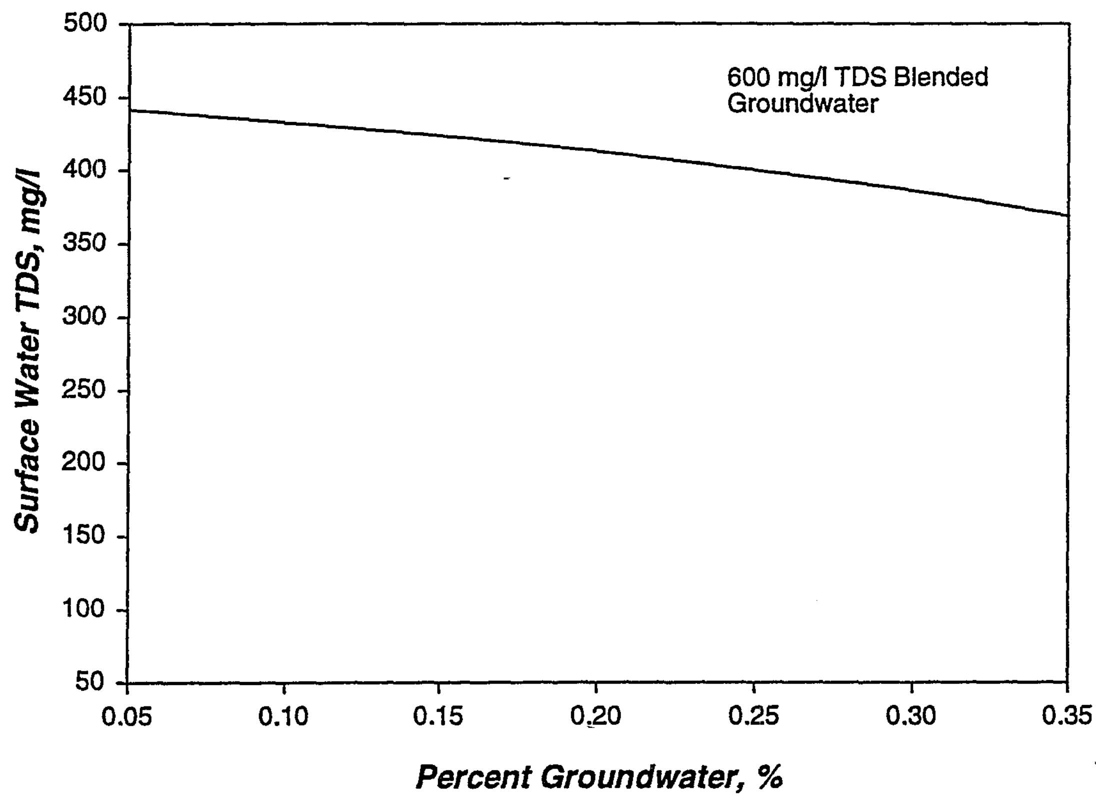
Figure 2.

Surface Water Quality Required Relative to Blend Ratios For 450 TDS Blended Water



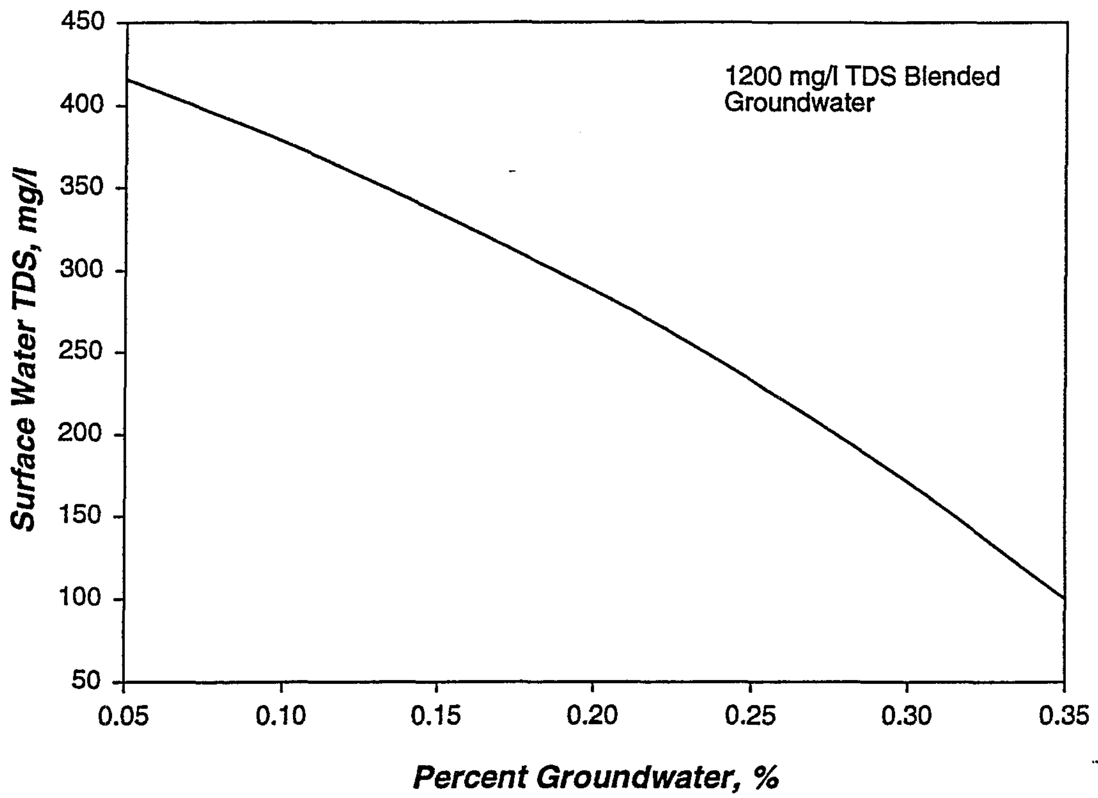
Notes:
Blend ratios calculated with assumed groundwater TDS of 600 mg/l based on Westside groundwater basin water quality which consists mainly of lands in the Westlands Water District on the west side of the San Joaquin Valley.
DWR estimates the groundwater quality of the Westside basin to be in the range of 600-2,500 mg/l TDS, based on active monitoring data.

References:

California Department of Water Resources, 1980, "Ground Water Basins In California," Bulletin 118-80.
Westlands Water Distict, 1995, "December 1994 Groundwater Conditions," Water Conservation Program Report.

Figure 2

Surface Water Quality Required Relative to Blend Ratios For 450 TDS Blended Water

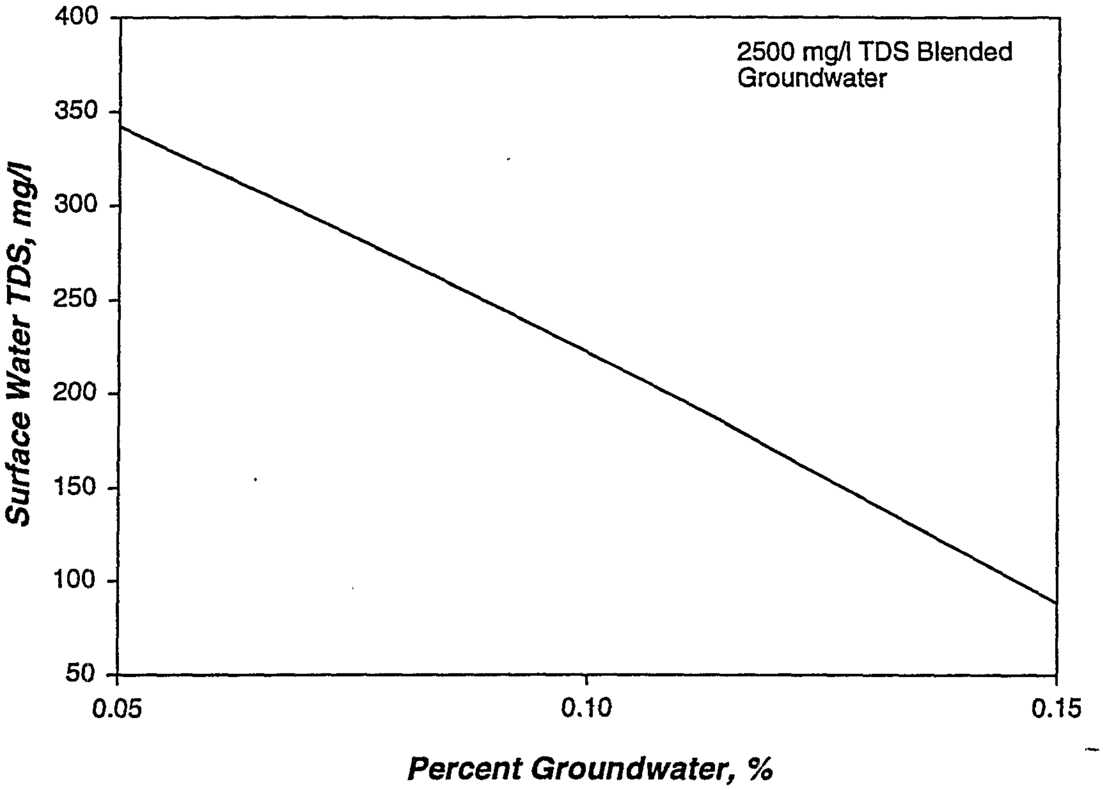


Notes:
Blend ratios calculated with assumed groundwater TDS of 1200 mg/l based on Westside groundwater basin water quality which consists mainly of lands in the Westlands Water District on the west side of the San Joaquin Valley.
DWR estimates the groundwater quality of the Westside basin to be in the range of 600-2,500 mg/l TDS, based on active monitoring data.

References:

California Department of Water Resources, 1980, "Ground Water Basins In California," Bulletin 118-80.
Westlands Water Distict, 1995, "December 1994 Groundwater Conditions," Water Conservation Program Report.

Surface Water Quality Required Relative to Blend Ratios For 450 TDS Blended Water



Notes:
Blend ratios calculated with assumed worst case scenario ground water TDS of 2500 mg/l based on Westside groundwater basin water quality which consists mainly of lands in the Westlands Water District on the west side of the San Joaquin Valley.
DWR estimates the groundwater quality of the Westside basin to be in the range of 600-2,500 mg/l TDS, based on active monitoring data.

References:
California Department of Water Resources, 1980, "Ground Water Basins In California," Bulletin 118-80.
Westlands Water Distict, 1995, "December 1994 Groundwater Conditions," Water Conservation Program Report.

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Table 1, Parameters of Concern and Their Effects on Agricultural Water Quality

Parameters	Effect	Source	Affected Factors	Geographic Area of Concern
Salinity (TDS & EC)	high	seawater, agricultural drainage	crop yield, soil structure, management.	All irrigated areas in Western & Interior Delta.
SAR	med	seawater, agricultural drainage	crop yields, sensitive crops (tree crops, beans, etc.), management.	All irrigated areas in Western & Interior Delta.
Chloride	med	seawater, agricultural drainage	crop yield, plant necrosis, management.	Fresh market produce irrigated areas.
Boron	med	groundwater	crop yield, drying and chlorosis, management.	
~~Alkalinity~~ pH (Calcium Carbonate)	med		greenhouses, $CACO_3$ precipitation, ~~soil infiltration, management.~~	
Turbidity		delta & tributary watersheds during flood events	sedimentaion of open channels, clogging of sprinkle & drip systems,	

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			soil crusting.	
Nutrients		wastewater discharge	algae in drains, clogging, NO_3 - beets, grapes, etc..	
Temperature			rice crop yield (cold water effects on germination)	Irrigated rice acreage in the North and Central Delta.

SOURCE: Initial report of the Water Quality Technical Advisory Committee, Bay-Delta Oversight Council, Draft, December 1994

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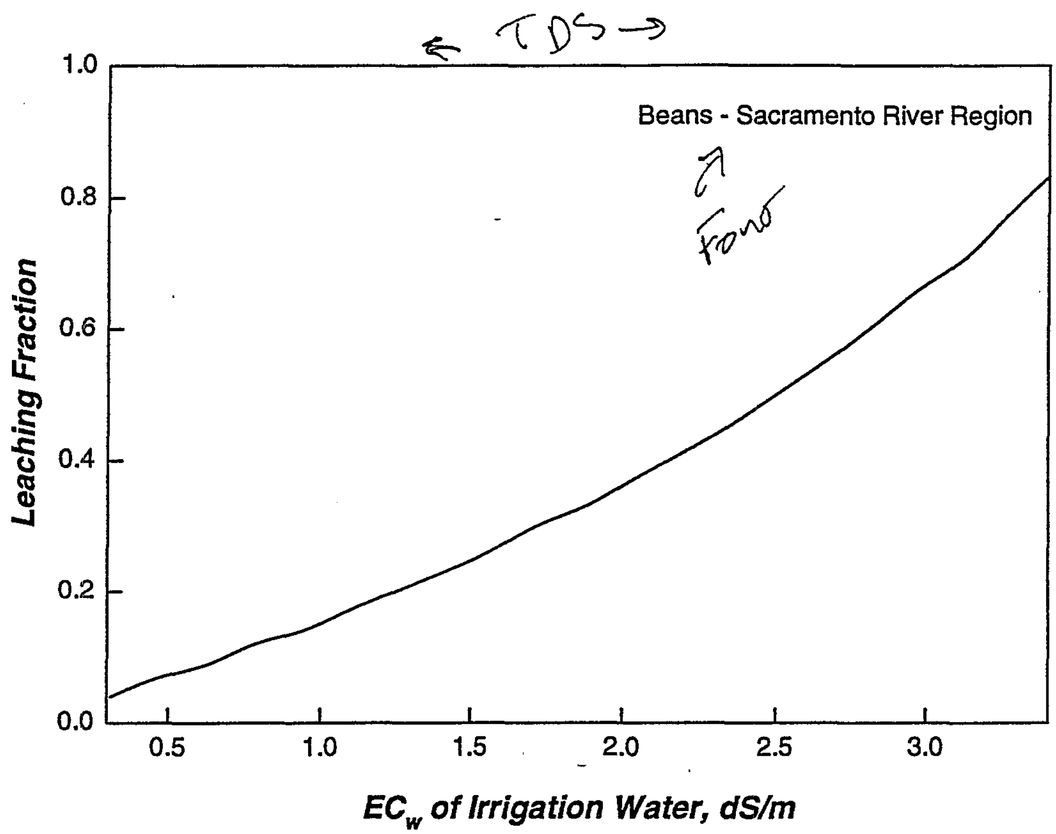
Figure 3

Leaching Requirement Relative to Irrigation Water Quality



Assume:
ECe for 90% Yield Potential of Beans = 1.5 dS/m, FAO 29, 1985.
LR = ECw /(5*ECE - ECw), Eq. 9, FAO 29, 1985.

Note:
Leaching requirement may be satisfied by irrigation inefficiencies during water application.

~~Wavy line due to spline fit to data - will be corrected~~

Curve fit later

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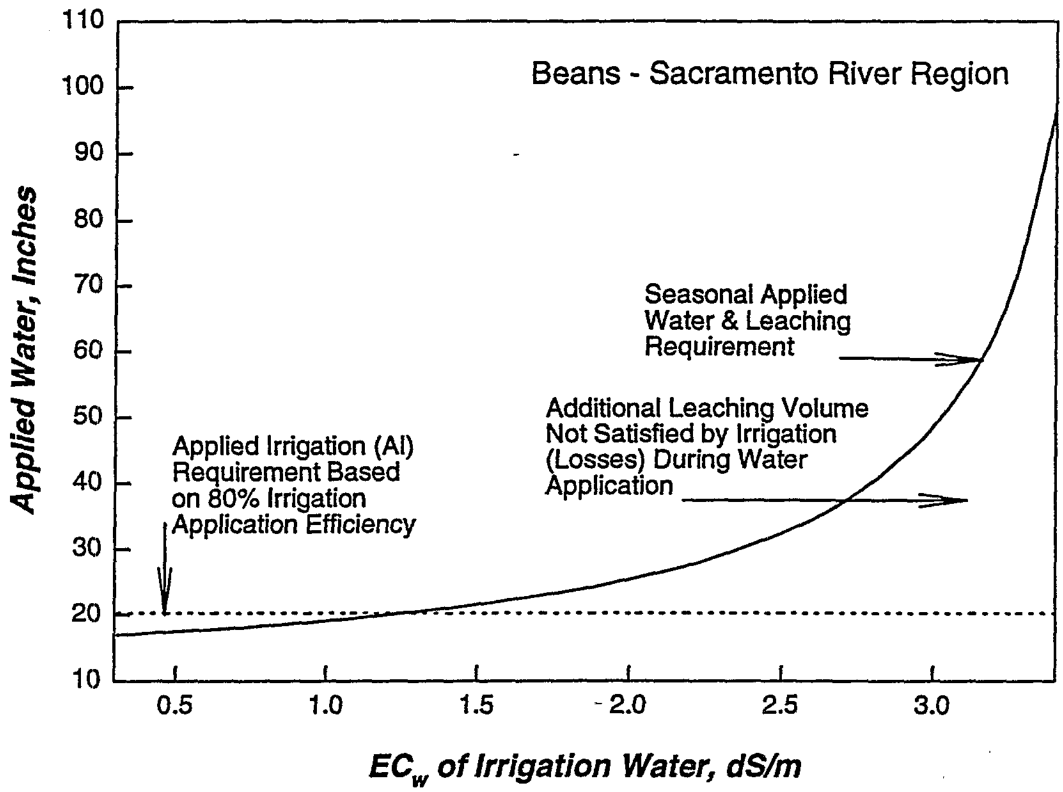
Figure 4.

Drainage Volume Relative to Irrigation Water Quality



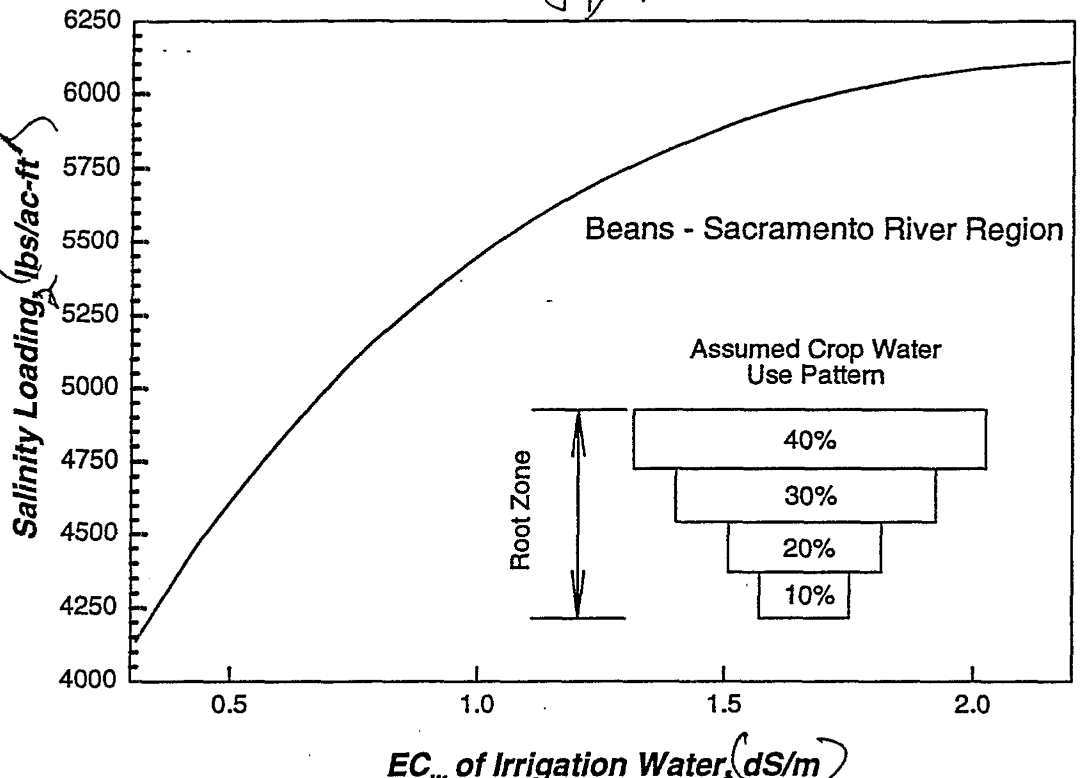
Assume:
ECe for 90% Yield Potential of Beans = 1.5 dS/m, FAO 29, 1985.
Evapotranspiration (ET) requirements for Beans in the Sacramento River Valley is based on a seasonal ET estimate of 16.2 inches from Table 22, DWR Bulletin No 113-3, 1975.
LR = ECw /(5*ECE - ECw), Eq. 9, FAO 29, 1985.
Irrigation system has an application efficiency of 80% and high distribution uniformity.

Note:
Leaching requirement may be satisfied by irrigation inefficiencies during water application as depicted in some cases.

Figure 5

Soil Salinity Loading Relative to Irrigation Water Quality

TDS

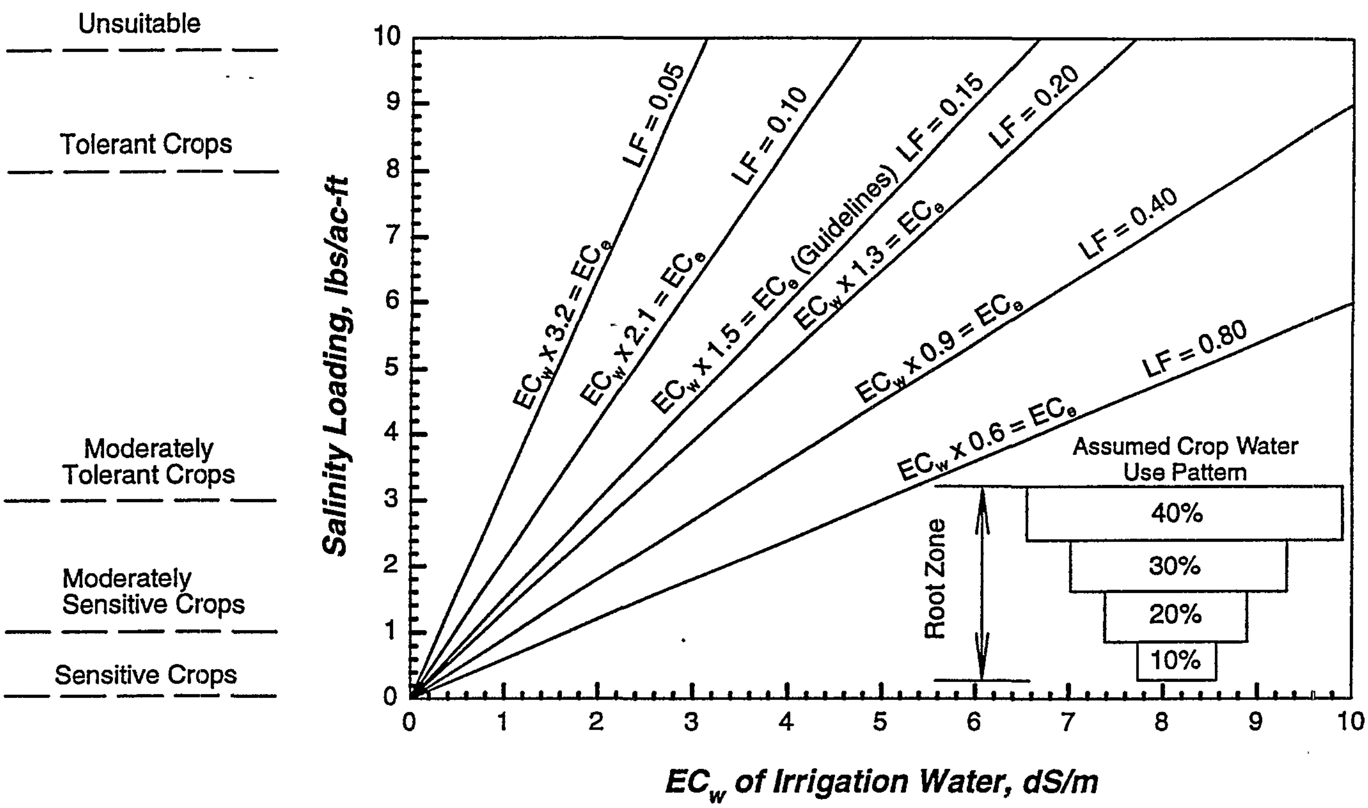


Assumptions:
ECe for 90% Yield Potential of Beans = 1.5 dS/m, FAO 29, 1985.
Evapotranspiration (ET) requirements for Beans in the Sacramento River Valley is based on a seasonal ET estimate of 16.2 inches from Table 22, DWR Bulletin No 113-3, 1975.
LR = ECw /(5*ECE - ECw), Eq. 9, FAO 29, 1985.
Irrigation system has an application efficiency of 80% and high distribution uniformity.
Concentration Factor is for soil-water below the root zone versus concentration of applied water.

Assume crop water use extraction pattern of 40-30-20-10 as depicted.

Figure 6.

Effect of Applied Water Salinity (EC_w) on Soil Salinity (EC_e) at Various Leaching Fractions



Source:
Ayers R.S., and D.S. Wescott. 1985. Water Quality for Agriculture FAO Paper 29.

Note:
Leaching Fraction (LF) is based on general crop rotations.
For a particular crop estimates use the methods presented in the source document.

(Fig. 7 to be added)

D-032615

Table X 2 Guidelines For Water Quality Goals of Parameters For Irrigation
(Adapted from Ayers and Westcot, 1989)

Parameters	Units	Water Quality For Irrigation[1] Degree of Restriction on Use: None	Slight to Moderate	Severe	Drinking Water Standards[7] U.S. EPA: Primary MCL	Secondary MCL	MCL Goal	Basin Plan Water Quality Objectives RWQCB: Point 1	Point 1
Salinity									
EC_w[2]	dS/m or mmho/cm	<0.7	0.7 - 0.3	>3.0					
TDS	mg/l	<450	450-2000	>2000		500			
SAR[3]									
= 0 - 3	EC_w	>0.7	0.7 -0.2	<0.2					
= 3 - 6	EC_w	>1.2	1.2 - 0.3	<0.3					
= 6 - 12	EC_w	>1.9	1.9 - 0.5	<0.5					
= 12 - 20	EC_w	>2.9	2.9 - 1.3	<1.3					
= 20 - 40	EC_w	>5.0	5.0 - 2.9	<2.9					
Chloride[4,5]	ug/l					250,000			
Surface Irrigation	SAR	<3	3 - 9	4 -10					
Sprinkle Irrigation	me/l	<3	>3	>3					
Boron	mg/l	<0.7	0.7 - 3.0	>3.0					
Alkalinity (Calcium Carbonate)[6]	me/l	<1.5	1.5 - 8.5	>8.5					
Turbidity	NTU				0.5 or 1.0				
Temperature									
Nutrients									
Ammonia									
Calcium									
Magnesium									
Nitrate[7]	mg/l	<5	5 - 30	>30					
Phosphorus									
Potassium									

Other standards and Regulations

grid

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Table X Guidelines For Water Quality Goals of Parameters For Irrigation

[1] Adapted from University of California Committee of Consultants, 1974.* and Ayers and Westcot*. The basic assumptions of the guidelines are discussed following these notes.

[2] EC_w means electrical conductivity of the irrigation water, reported in mmho/cm or dS/m. TDS means total dissolved solids, reported in mg/l.

[3] SAR means sodium adsorption ratio. SAR is sometimes reported by the symbol RNa. See Ayers and Westcot* Figure 1 for the SAR calculation procedure. At a given SAR, infiltration rate increases as salinity EC_w increases. Evaluate the potential permeability problem by SAR and ECw in combination. Adapted from Rhoades* and Oster and Schroer*.

[4] For surface irrigation, most tree crops and woody plants are sensitive to sodium and chloride; use the values shown. Most annual crops are not sensitive; use the salinity tolerance in Ayers and Westcot* or equivalent.

[5] For overhead sprinkle irrigation and low humidity (<30 percent), sodium and chloride greater than 70 or 100 mg/l, respectively, have resulted in excessive leaf adsorption and crop damage to sensitive crops, see Ayers and Westcot*.

[6] Overhead sprinkling only.

[6] NO^3 - N means nitrate nitrogen reported in terms of elemental nitrogen.

[7] J. B. Marshak, 1995. California Reqional Water Quality Control Board, Central Valley Region. A Compilation of Water Qualit Goals.

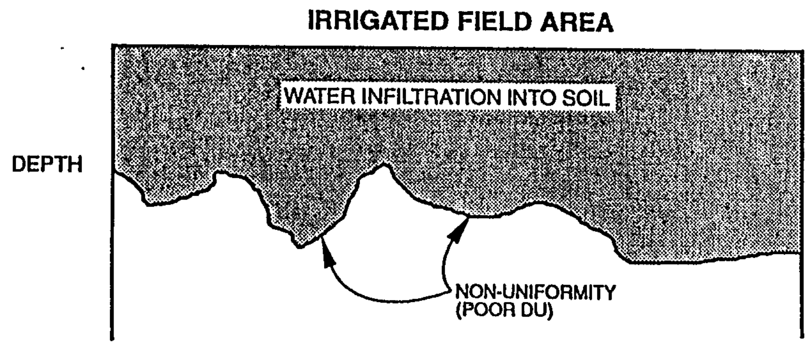

FIGURE A: The concept of non-uniformity

NOTE: Regardless of the irrigation method, there are differences in the amount infiltrated. Some sprinklers and emitters are always partially plugged and have pressure differences. Water sits at the head end of a furrow longer than at the tail end. These are just a few of the many causes of non-uniformity.

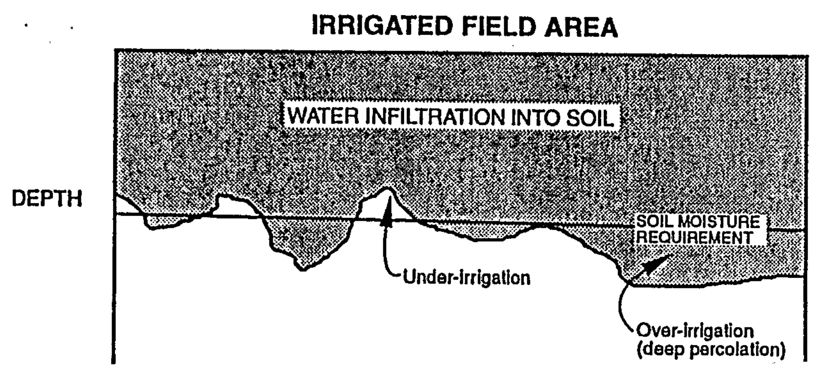

FIGURE B: The concept of adequacy of irrigation.

NOTE: In the case shown above, some of the field receives enough water and some is under-irrigated. The deep percolation is "lost" to that field, along with nutrients which have leached down with the water.

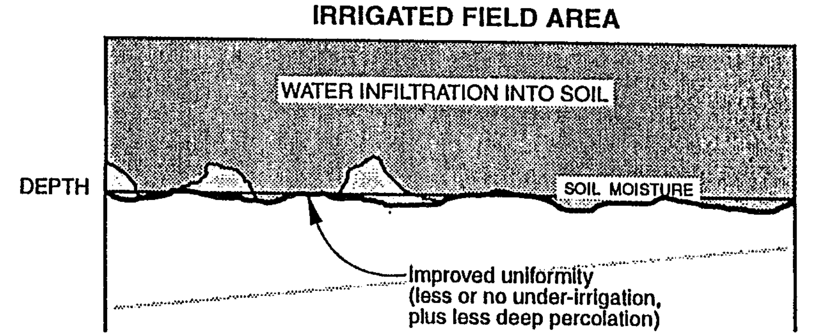

FIGURE C: The concept of improved uniformity

NOTE: The same amount of water as for Figure B, but now with a better DU. The result is less or no under-irrigation, plus less deep percolation.

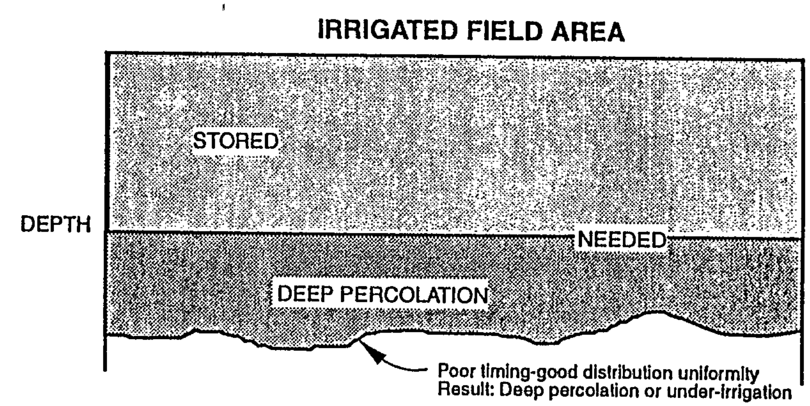

FIGURE D: The concept of irrigation efficiency and distribution uniformity

NOTE: A good DU, but the water was not shut off at the correct time, resulting in large amounts of deep percolation

SOURCE: ITRC. Cal Poly, San Luis Obispo, 1993,
Ag Irrigation Management Manual.

FIGURE X 7

TWO-DIMENSIONAL SKETCHES REPRESENTING THE CONCEPTS OF IRRIGATION UNIFORMITY AND APPLICATION EFFICIENCY

CALFED BAY-DELTA PROGRAM
AGRICULTURAL WATER QUALITY SUBTEAM REPORT

2061_01

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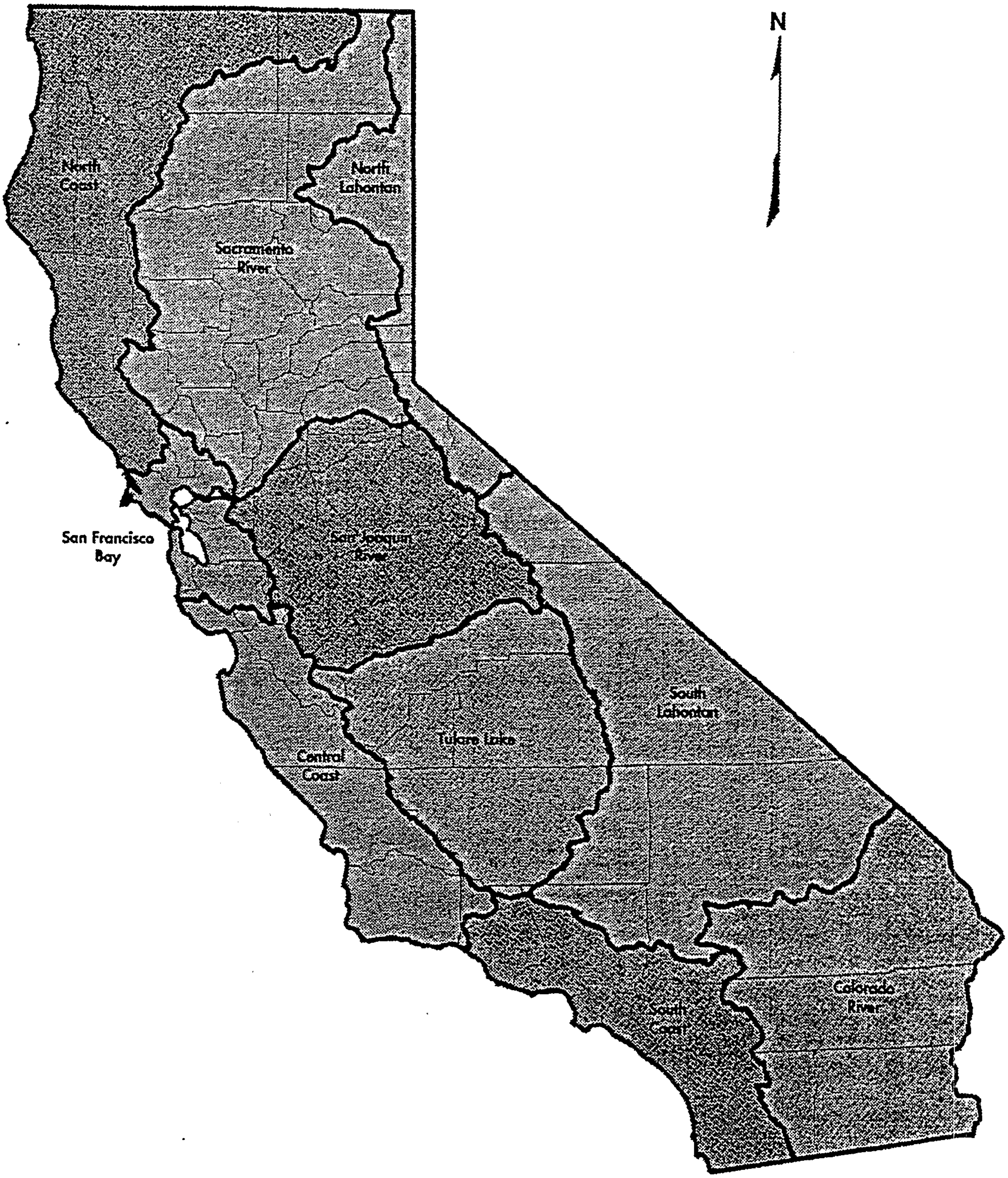

SOURCE:
CALIFORNIA WATER PLAN UPDATE
BULLETIN 160-93
DWR, OCTOBER 1994

FIGURE ~~X~~ 8
DWR HYDROLOLGIC REGIONS IN CALIFORNIA
CALFED BAY-DELTA PROGRAM
AGRICULTURAL WATER QUALITY SUBSTEAM REPORT

2045_14

Percentage of Acreage Harvested 1993

Summary of All Regions

Crop	Acres (1,000)	Percentage	Rank
All-Hay & Pasture	1,934	24%	Major
Cotton	1,186	15%	Major
Other Field Crops	1,159	14%	Major
Grains	665	8%	Intermediate
Grapes	532	7%	Intermediate
Almonds	477	6%	Intermediate
Rice	470	6%	Intermediate
Tomatoes	319	4%	Intermediate
Other Fruits & Nuts	310	4%	Intermediate
Other Vegetables	328	4%	Intermediate
Citrus	280	4%	Intermediate
Walnuts	175	2%	Minor
Melons	91	1%	Minor
Avocados	47	0.6%	Minor
Celery	11	0.1%	Minor
Strawberries	8	0.1%	Minor
Lettuce	7	0.1%	Minor
Total	7,999	100%	

Source:
CALFED Water Quality TAC from County Agricultural Commissioners (CAC) reports, various years.
[a] *CAC, 1993 Report Data: Annual Bulletin. Compiled harvested acreages do not include portions of Riverside and San Bernadino Counties in the South Coast hydrologic area. Acreages for flowers, christmas trees, and various ornamentals although substantial were not available for inclusion.*

Note: The South Coast hydrologic area is within the geographic scope of agricultural water use related to the Delta and currently receives SWP water, therefore it is included in this harvested acreage summary.

Percentage of Acreage Harvested 1993

Sacramento River Region, 1993

Crop	Acres (1,000)	Percentage	Rank
Rice	450	22%	Major
Other Field Crops (Wild Rice, Milo)	434	22%	Major
All Hay & Pasture (Alfalfa)	392	20%	Major
Grains (Wheat)	278	14%	Major
Tomatoes	130	6%	Intermediate
Other Fruits & Nuts (Apricots)	112	6%	Intermediate
Almonds	89	4%	Intermediate
Walnuts	76	4%	Intermediate
Citrus	14	1%	Minor
Other Vegetables (Onions)	12	1%	Minor
Grapes	11	1%	Minor
Melons	10	0.5%	Minor
Cotton	0	0%	----
Total	2,008	100%	

Tulare Lake Region

Crop	Acres (1,000)	Percentage	Rank
Cotton	684	32%	Major
Other Field Crops (Oat Straw)	283	13%	Major
All Hay & Pasture (Alfalfa)	282	13%	Major
Grains (Barley)	197	9%	Intermediate
Citrus	162	8%	Intermediate
Grapes	151	7%	Intermediate
Almonds	116	5%	Intermediate
Other Vegetables (Watermelons)	108	5%	Intermediate
Other Fruits & Nuts (Figs)	82	4%	Intermediate
Walnuts	32	2%	Minor
Tomatoes	17	1%	Minor
Melons	8	0.4%	Minor
Rice	0	0%	----
Total	2,122	100%	

San Joaquin River Region

Crop	Acres (1,000)	Percentage	Rank
All-Hay & Pasture (Alfalfa)	673	22%	Major
Cotton	502	16%	Major
Other Field Crops (Corn)	427	14%	Major
Grapes	370	12%	Major
Almonds	272	9%	Intermediate
Grains (Wheat)	183	6%	Intermediate
Other Vegetables (Carrots)	173	6%	Intermediate
Tomatoes	165	5%	Intermediate
Other Fruits & Nuts (Apricots)	111	4%	Intermediate
Melons	74	2%	Minor
Walnuts	66	2%	Minor
Citrus	46	1%	Minor
Rice	19	1%	Minor
Total	3,081	100%	

South Coast Region[a]

Crop	Acres (1,000)	Percentage	Rank
All-Hay & Pasture (Alfalfa, Irri Pasture)	587	75%	Major
Citrus (All)	59	8%	Major
Avocados	47	6%	Major
Other Vegetables (Onions, Broccoli, & Cauliflower)	34	4%	Intermediate
Other Field Crops (Corn, Beans)	15	2%	Intermediate
Celery	11	1%	Intermediate
Strawberries	8	1%	
Lettuce	7	1%	Intermediate
Grains	7	1%	Minor
Tomatoes	6	1%	Minor
Other Fruits & Nuts (Peaches, Apples)	4	1%	Minor
Cotton	0	0%	----
Rice	0	0%	----
Total	785	100%	

Table ~~XX~~ 4 Factors Affecting Selection of Irrigation Method Under Saline Conditions

Water Application Method	Application	Pattern of Salt Accumulation	Leaching Effectiveness	Special Considerations
Furrow	Row crops, low to medium infiltration-rate soils.	High in ridges between furrows, may increase indirection of slope if irrigations are non-uniform.	Effective leaching beneath furrow channels, salt left in ridges. Leaching requires more water than for methods with lighter, intermittent applications.	None
Corrugation	Close growing crops.	Leaves saltier strips between corrugation channels unless entire field surface inundated.	Similar to furrows above.	None
Border dike	Close-growing crops.	Leaves salt in dikes that separate borders.	Areas between dikes leached uniformly, but more water required than for light, intermittent, applications.	None
Sprinkle: set	Most crops, all but very fine-textured soils.	No salt concentrations in root zone, if system designed and managed properly.	Uniform leaching, Can be used to leach salt accumulations left by other irrigation methods.	May encourage disease in sensitive crops, e.g., beans. Salty irrigation water may leave harmful deposits on leaves.
Sprinkle: Mobile	Most crops, except trees, and vines. Can be used to irrigate fields on rolling topography.	No salt concentrations in root zone. If system designed and well managed.	Uniform leaching. Same as for set sprinklers.	None
Micro-irrigation (Drip, trickle, sub-irrigation)	Because of high initial costs, used mostly for high value crops or crops with high irrigation labor costs.	Salt concentrations at outer fringes of the soil mass wetted by each emitter.	Soil mass wetted by each emitter is well-leached. Difficult to leach all soil to depth of root zone.	When automated for light, frequent irrigations, saline water can be used, because low matric stress compensates for osmotic stress.

Source: Tanji, K. K.. 1990. Agricultural Salinity Assessment and Management, ASCE Manual No.71.