Testimony by South Delta Water Agency
At 2005 SWRCB Workshops
Regarding Southern Delta Electrical Conductivity

Introduction

Review of the South Delta salinity objectives and their compliance locations should consider such things as what created the need for salinity objectives, the considerations that established the objectives, the difficulties caused by reductions in summer flow at Vernalis, the feasibility of complying with objectives, and the compliance locations that will be representative of channel conditions after the South Delta Improvement Plan is implemented.

Background

Prior to the operation of the CVP in about 1950 there was no need for salinity objectives in South Delta channels because water quality in those channels was much better than the objectives that were later established. The need for objectives was created primarily by the CVP. The CVP reduced the Vernalis flow and increased the salt load in that flow per the *Effects of the CVP Upon the Southern Delta Water Supply Sacramento-San Joaquin River Delta, California, June 1980* authored by the SDWA and the USBR. This report has been presented to the Board as evidence on numerous occasions.

The SWRCB attempted to minimize the need to mitigate that CVP impact by setting objectives that would adequately but only marginally protect agricultural diverters from crop losses due to high salinity. The Board did not at that time anticipate the problems resulting from measures which further decreased summer flow in order to increase fish flows, or the changes in circulation and water depth in South Delta channels that will result from current plans to increase export rates. They were not aware that all existing South Delta salinity and dissolved oxygen objectives could nevertheless be met if flows in South Delta channels were provided by altering the South Delta Improvement Plan as proposed by SDWA. No water losses to other users are needed. Some parties have contended that existing objectives cannot reasonably be met and that higher salinity should therefore be allowed, but this is not the case.

The existing objectives were established on the basis discussed in the staff report. However, the Board did not adequately consider the need to irrigate cropland in March in dry years or in September when crops such as tree crops typically need to be irrigated after harvest operations are completed. There has been no long term change in crop patterns or in irrigation methodology that affects crop tolerance of high salinity irrigation water. Furthermore, the choice of crops must not be dictated by inadequate salinity control. Crops have to be varied with changes in market demand.

Crop yields must not be degraded by permitting high salinity in South Delta channels. When salinity reduces crop yield it does not reduce the cost of growing the crop, and net dollar returns are typically a small percentage of gross returns.

Salinity needed for full crop yield

Crop yield is affected by the salinity of the soil moisture in the root zone of the crop. For each crop variety there is a soil salinity level below which there is no loss in yield. As salinity rises above that level there is an increasing loss of crop yield. The crop's osmotic root system takes up water and leaves the salt in the soil. As the salinity of the water in the soil therefore rises, it becomes increasingly difficult for the roots to extract the water needed for crop growth. These relationships between soil salinity and yield are well established and easy to explain for established plants. Seedlings are more salt sensitive. The relationship between soil salinity and the salinity of irrigation water is far more complex and often inadequately analyzed. Expert testimony submitted to the SWRCB in 1977 and 1990 covered the basic relationship of root zone soil salinity to crop yield for numerous crop varieties. It also explained the irrigation water salinity that is needed to achieve a given soil salinity under different conditions of soil permeability, depth of root zone, frequency of irrigation permitted by cultural and other requirements, the susceptibility of various crops to root damage by prolonged water application, the potential for solid salt deposition in the lower portion of deep rooted crops if the upper root zone has adequate salinity, but there is not dilution of accumulated salts in the lower root zone. We refer you to that previously submitted testimony. I will repeat some of that testimony today.

Basic soil salinity versus applied water salinity relationships

The basic data on salinity relationships was presented by R. S. Ayers and D. W. Wescot from the United Nations Food and Agriculture Organization, and by Dr. Glenn Hoffman of the U.S. Salinity Laboratory in Riverside, and by Jewell Meyer of the Dept. of Soils and Environmental Science at U.C. Riverside, and by Terry Prichard of the U.C. Extension Service.

As testified by Dr. Hoffman, the basic root zone salinity tolerance data on which the tables are based are difficult to relate to field conditions. They were based in large part on tests using weekly irrigation and 50% leach fractions on highly permeable soils. There was no pretense of coping with such factors as variations in salinity tolerance at different stages of growth, cultural soil compaction, commercially necessary departures from "as needed" irrigation, variations in leach fraction with time during the crop season, root aeration problems which occur when soaking for high leach, soil variations within fields, or soil damage by precipitation.

I will give you an abbreviated presentation of the testimony previously presented. First, the basic tables of yield versus applied water salinity for various crops with various leach fractions; then a map of the permeability of South Delta soils developed by the Soil Conservation Service; then the modification of the tables to account for the considerations not covered by the basic tables, and how these modifications were derived. After that I will discuss the anticipated changes in channel flow regime per the South Delta Improvement Plan and how that requires reconsideration of channel salinity monitoring points.

Yield by crops and achievable leach fractions

Table 5 from my prior testimony is attached hereto. This table addresses the applied water salinity that is needed to provide various levels of crop yield with various leach fractions for a list of crops. The next question is what leach fractions are feasible with South Delta soils and the applicable cultural and soil aeration needs. The Soil Conservation Service furnished South Delta soil maps and characterizations per (at the time) SDWA Exhibit No. 107, also attached hereto. This shows that 40% of the South Delta soils have very low permeability, less than 0.2 inches per hour; and 34% have moderately low permeability, 0.2 to 0.6 inches per hour.

It was then agreed among the parties (including the USBR, SDWA, DWR, and the agricultural experts) that Dr. Glenn Hoffman, Mr. Jewell Meyer, and Mr. Terry Prichard would serve as an advisory committee to determine the applicability of the basic yield versus salinity data in South Delta soils for all crop varieties which have been grown historically in significant commercial quantity and with due regard to inherent limitations. Included with today's SDWA presentation is that Committee's cover letter and report. The report concluded that in 16% of the soils and the crops then planted the leach fraction achieved was less than 0.07, and 68% achieved leaching fractions between 0.07 and 0.23.

The SDWA then took this information and added the complications of typical soil permeability variation within irrigated fields, and culturally necessary deviations from "as needed" irrigation schedules. The resulting table of needed irrigation water salinity for 100% yield on 90% of an irrigated field is shown on Exhibit IV E.

Discussion of coping with considerations cited by Dr. Hoffman

We previously listed complications cited by Dr. Hoffman which affect the ability to cope with salt in applied water, but which are not easily quantified. Some of these complications are discussed below; particularly as they apply to specific crops and growth stages, cultural requirements, and planting and harvesting dates.

Alfalfa is a major crop to supply the many dairies in San Joaquin County. It has severe soil salinity problems. It is a perennial crop with a deep root system. The operations of mowing, raking, and baling have to be done when the ground is dry, and baling can be delayed by lack of dew needed to avoid leaf shatter. These operations prevent irrigation during a substantial portion of the time between monthly harvests. These operations also compact the surface soil and substantially reduce the rate at which irrigation water can percolate into the root zone. Furthermore, water cannot be left on the surface of the ground for more than a few hours at a time because alfalfa plants are then easily drowned. During the necessary time between irrigations the crop is taking water out of the ground, and the salt that was in that water is then increasing the soil salinity. There are typically summer months when these complications prevent any leach fraction from being provided through the lower root zone. The crop is then limited to taking up water and nutrients only through its shallow roots. This delay in leaching salt from the deep root system can also cause high concentrations so that solid salts are deposited at a depth below where cultivation is practical. Over time this can degrade permeability.

Annual crops with shallow root zones have different problems. Beans, tomatoes, pumpkins, squash, and melons, for example, are usually planted on beds between furrows. This prevents the plants from being submerged during irrigation and the furrows drain excess surface water. There is typically no effective rainfall while these crops are grown. The shallow root zone can be cultivated before planting to maintain permeability. Cultural compaction is confined to the furrows which can be re-cultivated until the plants spread over the furrows. However, water soaking in to the beds from the furrows results in salt concentration in the beds. The previous testimony discussed at length the nature of this problem and the ways in which the rise in soil salinity in the beds could be minimized but not eliminated.

It is widely understood that seedlings are more salt sensitive than mature plants of the same variety. A crop cannot be grown if the water supply is too salty for seedlings and young plants. It is difficult to quantify this seedling sensitivity because it is interrelated with the increase in soil salinity that occurs during germination and early growth due to surface evaporation of shallow soil moisture from bare ground. It is not typically practical to maintain surface moisture by sprinkling. Furthermore, to do so often creates a crust above the seeds which prevents emergence of the seedlings.

Asparagus has a massive deep root system. It is not easily drowned, so the root system can be filled with water by prolonged irrigation in the winter. However, asparagus is harvested continuously from February to June. During that period there can be some rainfall that is heavy enough to reach the root zone but that is not assured. During this long harvest period the crop is taking up water and concentrating the salt in the root zone of the soil.

Tree crops such as walnuts, peaches, and apricots, are deep rooted. It is difficult to obtain an adequate leach fraction through the entire root zone in South Delta soils. Furthermore, cultural practices such as weed and pest control and harvesting limit the time that water can be applied. Most tree crops are also subject to drowning with prolonged soaking. They must have enough soil moisture for root hairs to grow before coming out of dormancy in February and March even in dry years. They also often need irrigation after crop harvest in September. They need approximately the same quality of irrigation water as alfalfa and beans from March through September.

Changes in water supply and circulation in South Delta channels

The inflow of the San Joaquin River to the South Delta has been greatly reduced by CVP and other exports from the river system, and by increases in upstream water consumption. Summer flows have been further reduced by increasing spring and fall flows at the expense of summer flows. Water levels and water circulation in South Delta channels have also been altered by increased export pumping and further increases are planned. These changes make it more difficult to comply with salinity objectives. Furthermore, the compliance locations originally located will no longer be correctly located or sufficient in number to be representative of quality at other locations when permanent barriers are installed and export rates increased. When the South Delta Improvement package is finalized and various barrier operation schedules determined these locations must be reconsidered.

Conclusion regarding salinity standards

There has been an effort to facilitate mitigation of CVP impacts on South Delta in-channel water quality by setting standards that are far above pre-CVP water quality and are only marginally adequate to avoid losses in crop yield caused by higher salinity. The complex South Delta soils and the other considerations make it impossible to assure that what is thought to be marginally adequate water quality will in fact be adequate.

SDWA urges that: 1) there be no increase in the Vernalis salinity standard of 0.7 and 1.0 EC; and 2) that the 0.7 EC standard should apply from March 1 through September 30; and 3) that the diverters downstream of Vernalis within the South Delta have the same crops and need the same protection as is needed at Vernalis and should therefore by protected by the same salinity standards; and 4) that the salinity compliance locations must be representative of the water quality throughout the South Delta channels, and that these locations, and the number of locations, must be determined after the range of barrier operations and circulation regimes has been determined per a final South Delta Improvement Plan. No increase in salinity above the aforementioned proposals should be considered because of a belief that the proposed salinity objectives cannot be met. SDWA has proposed feasible and practical methods of compliance which would not degrade quality or supply for any other parties.

Recent developments

I have also reviewed the July 2004 Report entitled *An Approach to Develop Site-Specific Criteria for Electrical Conductivity to Protect Agricultural Beneficial Uses that Accounts for Rainfall* authored by Isidoro-Ramirez, et al.

This report builds on previous studies and tests and analyses by most of the same researchers that were involved in previous testimony before the SWRCB. It does not cite any new field tests or laboratory tests or concepts not previously reported. It develops mathematical formulae for applying previous concepts and data to determine the EC requirement that will marginally avoid yield losses for beans in a particular soil type, but does not cite the permeability and water retention capacity of that soil type (page 10).

It assumes a 15% leach fraction (page 10) or a 15 to 20% leach fraction (page 11, last paragraph). It provides examples using the "usual practices for dry bean" irrigation frequency and timing in Davis (page 10), but seems also to assume that the timing and frequency of irrigation can be changed at times that the beans would otherwise be stressed (page 9, 2nd paragraph, and page 6, 2nd paragraph). It is not clear to what extent and how often the results require a change in local practices.

The analysis of the benefit of soil water dilution by rain water refers to "daily rainfall" (page 4, 2nd paragraph, and page 8, last paragraph). It refers to but does not furnish Davis rainfall records. It apparently assumes that all rainfall will be effective in diluting soil moisture. This contrasts with analyses by others that only assume that part of the rainfall is "effective". For example, there is typically enough dry weather before it is warm enough to plant beans so that moisture from rain in the seedling and shallow root zone has been lost by surface evaporation.

The report asserts (page 4, last paragraph) that "the yield potential is not reduced provided the average rootzone salinity over the season does not exceed 1.0 dS/m." This assertion is not adequately corroborated.

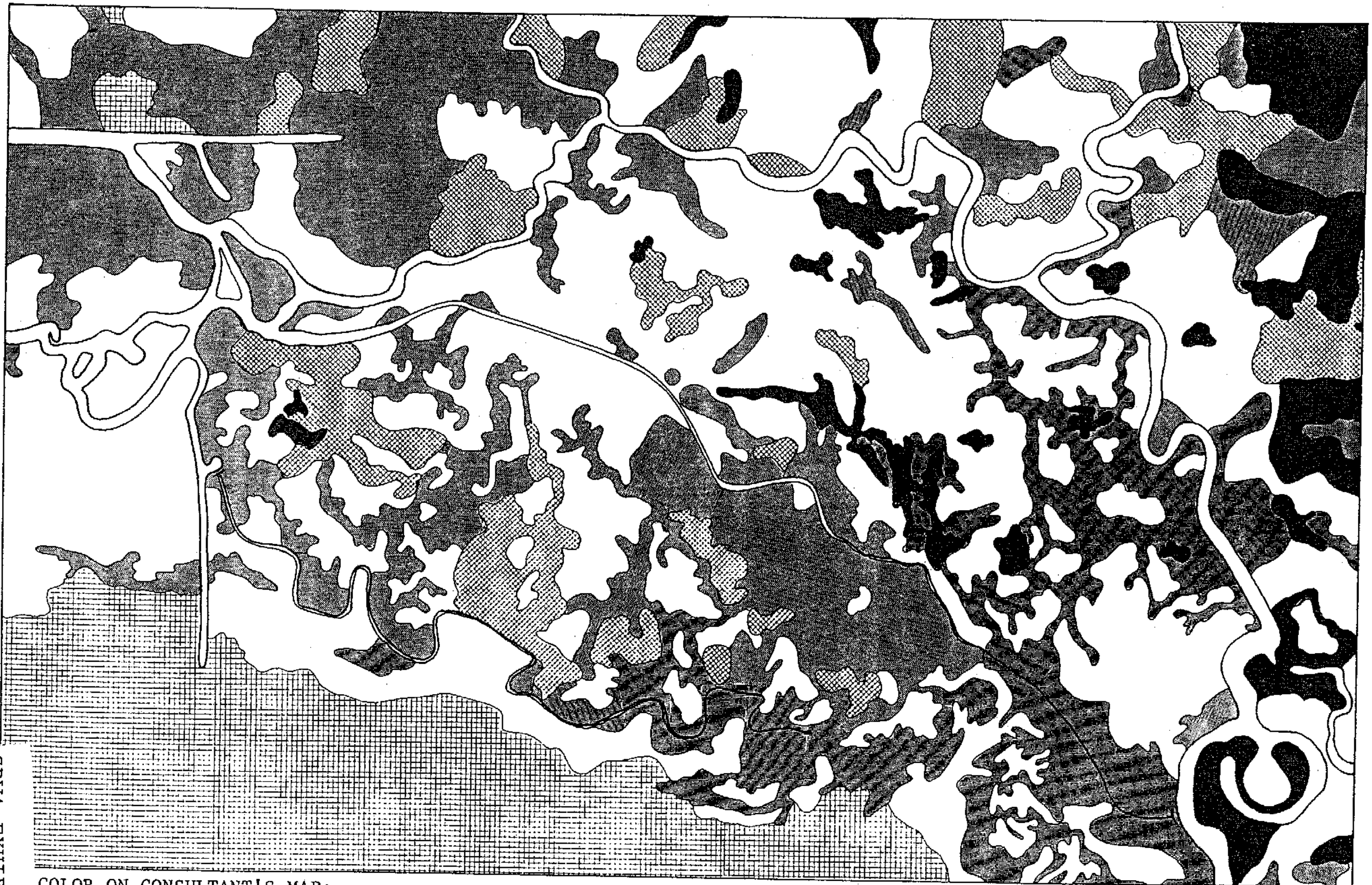
The report does not address the fact that seedlings are more salt sensitive than established plants, and that during germination and early growth the plant is only affected by the soil moisture salinity in the top 2 to 6 inches of soil. The salinity in this shallow zone increases due to surface evaporation. The report only analyzes the distribution of soil salinity in bean plants that have developed a 60 cm deep root system (page 10, last paragraph).

In order to apply this report to South Delta conditions it would be necessary to consider the wide range of soil types in the South Delta with differing permeability and water retention capacity. It would be necessary to correct for the effective rainfall for different crops planted at different times of the year, and for different sequences of rainfall. It would be necessary to consider the sensitivity of seedlings and the root depth of plants in early growth stages and the consequence of surface evaporation during those stages. If the method were applied to other crops, it would have to be adjusted for soil surface compaction by cultural operations and for restrictions on irrigation frequency and soaking time to accommodate cultural practices and plant water submergence tolerance.

Alex Hildebrand

Table 5. Salt concentration of irrigation water, reported as mg/ℓ of total dissolved salts that results in various reductions in crop yield as a function of leaching fraction and rainfall.

Leaching Fraction	No Rainfall — Relative Crop Yield 100%	90%	80%	70%	Normal Effective Rainfall — Relative Crop Yield 100%	90%	80%	70%
ALFALFA								
0.07	480	830	1170	1500	570	980	1380	1770
0.15	1060	1730	2430	3120	1250	2040	2870	3680
0.23	1880	3150			2220	3720		
TOMATO								
0.07	590	860	1110	1360	650	950	1230	1510
0.15	1290	1800	2320	2840	1430	2000	2580	3150
0.23	2310	3280			2560	3640		
WHEAT								
0.07	1430	1810			2800	3550		
0.15	3070	3790			6020	7430		
0.23								
BEAN								
0.07	250	380	510	640	280	430	570	720
0.15	520	790	1060	1330	580	880	1190	1490
0.23	940	1430	1910	2410	1050	1600	2140	2700
CORN								
0.07	420	630	830	1040	430	650	850	1070
0.15	880	1300	1730	2150	910	1340	1780	2210
0.23	1590	2360	3150		1640	2430	3240	
SUGAR BEET								
0.07	1660	2120			1990	2540		
0.15	3580				4300			
0.23								
FRUIT AND NUTS								
0.07	360	500	620	740	440	600	750	900
0.15	780	1040	1290	1550	940	1260	1560	1880
0.23	1400	1870	2340	2800	1690	2260	2830	3390
GRAPE								
0.07	360	630	880	1140	420	740	1030	1330
0.15	780	1310	1840	2370	910	1530	2150	2770
0.23	1400	2370	3340		1640	2770	3910	



COLOR ON CONSULTANT'S MAP:

RED	GREEN	YELLOW	BLUE	BROWN
6 -20	2-6	0.6-2	0.2-0.6	<0.2

SOILS OF THE SOUTHERN DELTA IN VICINITY OF OLD AND MIDDLE RIVERS
CLASSIFIED BY PERMEABILITY, INCHES/HOUR

SDWA EXHIBIT NO. 107

CROP	AVERAGE SDWA ACREAGE 1971-75	YIELD BASIS (% OF POTENTIAL)	IRRIGATION WATER QUALITY REQUIRED [1]					
			Requirement per U.C. Exhibit 2 (Uniform soil and "as needed" irrigation frequency)		Requirement with allowance for soil variability		Requirement with variable soil and with a 4 day delay in alternate irrigations from "as needed" schedule	
			Field-average Leach Ratio (% of applied water) [2]	Irrigation Water Quality Needed	Corresponding minimum LR for 90% of Typical Field [3]	Irrigation Water Quality Needed		
COLUMN A	B	C	D	E	F	G	H	REMARKS
		%	%	EC (TDS)	%	EC (TDS)	(TDS)	
Alfalfa	27,900	100	10	1.0 (640)	7.4	0.7 (450)	Better than 450	
		100	10 (annual average with zero June July, Aug. and 2 irrigations/mon.)	Better than 1.0 (640)	7.4	Better than 0.7 (450)	Better than 450	
		90	5	1.0 (640)	3.8	0.64 (410)	Better than 410	
		90	5 (see note above)	Better than 1.0 (640)	3.8	Better than 0.64 (410)	Better than 410	
Tomatoes	17,200	100 90	15 6	1.7 (1080) 1.0 (640)	11. 4.4	1.5 (960) 0.75 (480)	Better than 900 Better than 450	
Sugar Beets	12,800	100	15	4.7	11.			
Beans	9,400	100 90	16 10	0.7 (450) 0.7 (450)	12. 7.4	0.62 (400) 0.63 (400)	Better than 400	Similar for carrots and strawberries
Corn	7,700	100 90	15 8	1.1 (700) .85 (550)	11. 6.	1.0 (640) 0.7 (450)	Better than 600 Better than 450	Similar for potatoes
Grapes		100 90	15 6	1.0 (640) 0.7 (450)	11. 4.4	0.75 (480) 0.55 (350)		
Inuts, reaches, apricots,	6,200	100 90	13 6.5	1.0 (640) 0.7 (450)	9.5 4.8	0.75 (480) 0.55 (350)		Similar for pears
Lettuce and onions		100	15	0.85 (540)	11.	0.75 (480)	Better than 480	
Seedlings Tomatoes Sugar Beets Onions Lettuce 4	31,000	Good Survival and vigorous growth	The difficulty of achieving good survival increases as water qualities become poorer than 350 TDS and as necessary planting dates involve higher temperatures, winds, and low humidity. Depends also on facility with given soil of shaping and maintaining accurate seed bed shapes.					

1. All cases assume best common irrigation practices with flood and furrow irrigation, and reasonable provision of drain ditches and drainage pumps. All cases assume no long range salinity build up.
2. Average leach ratio, Col. D, determines input to groundwater. Removal of groundwater becomes more difficult when permissible groundwater levels must be below deep root zones and when elevations are near sea level.
3. U.C. Southern Delta Salinity Survey data* is assumed to be representative and is used to determine a leach ratio in Col. F which will be achieved or exceeded in 90% of a typical field which has the average leach ratio in Col. D. This Col. F leach ratio determines the crop yield for 90% of the field with full yield water quality.
4. Seedlings germinated with best established methods on raised row beds by furrow irrigation and planted at appropriate dates for crop.
5. Assumes adequate leach by irrigation, i.e., does not assume rain leach.

Abbreviations EC, TDS, LR are those used in U.C. Exhibit 2.
* See: Exhibit U.C. 7

SDWA EXHIBIT IV E