Presentation of William R. Johnston, P. E.[1]
Concerning Southern Delta Electrical Conductivity Water Quality Objectives

Introduction

The staff of the California State Water Resources Control Board has concluded, based on recommendations by stakeholders, that the Southern Delta Electrical Conductivity (EC) Objectives established to protect the agricultural crops irrigated with San Joaquin River water diverted from the Southern Delta, should be reevaluated. This presentation will summarize 1) the evolution of the existing Southern Delta EC Objectives, 2) research and crop changes that have taken place since the existing objectives were established and 3) recommend whether or not changes should be made to the existing objectives, based updated research and current cropping patterns. "The SWRCB based the southern Delta EC objectives on the calculated maximum salinity of applied water which sustains 100% yields of two important salt sensitive crops grown in the southern Delta (beans and alfalfa) in conditions typical of the southern Delta (surface irrigation of mineral soils) per the University of California Guidelines and Irrigation Paper 29 of the Food and Agricultural Organization of the United Nations".

Water Quality Concerns for Southern Delta Agricultural Crops

There has been concern about the quality of Delta water for the irrigation of agricultural crops, since before the development of either the U. S. Bureau of Reclamation's Central Valley Project (CVP) in 1944, or the California State Water Project (SWP) in1968. In 1959, D-935 was adopted to authorize the CVP to store and divert water from the San Joaquin River at Friant Dam. In 1961, D-990 was adopted to authorize the CVP to store and divert water for most of the then authorized CVP service area. In 1967, D- 1275 and D-1291 were adopted to authorize the California Department of Water Resources (DWR) to store and divert water from the Feather River and the Delta. These water right decisions also required the two projects to control the salinity level of the water in the Delta to certain levels. As early as 1974, Warren Schoonover, recognized that it is inefficient to provide Delta agricultural water users high quality water through releases from upstream reservoirs (Schoonover, 1974). Mr. Schoonover recommended to the California Department of Water Resources that in order to put the available resources to the most reasonable and beneficial uses, that Delta water users contract with the CVP or SWP and obtain a land delivered water supply.

Prior to the construction of the CVP and the SWP, the concern about Delta water quality related to salinity intrusion from the Pacific Ocean through the San Francisco Bay and Estuary. During dry years, such as 1931, water with a salinity level of 1000 parts Chloride (estimated EC = 1.56 mmhos/cm), extended into the Southern Delta as far as the Grant Line Canal and Upper Roberts Island (DWR, 1995). This would have been the concentration of irrigation water Delta water users would have had available during years

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such as 1977 and 1992 if the CVP, SWP and other upstream projects had not been releasing stored water.

Testimony Regarding Delta Agriculture (SWRCB D-1485 Exhibits)

As with prior Bay-Delta proceedings, one of the more controversial issues confronting the SWRCB during the D-1485 hearings was the issue of "What appropriate salinity level should be required to protect the beneficial use of water for the irrigation of agricultural crops in the Delta?" The focus was on the principal crops being grown at that time, corn, beans, and alfalfa, the types of soils, mineral and peat, and the methods of irrigation, surface and subsurface. Considerable attention was paid to corn and beans as the most salt sensitive crops being grown and the practices being followed in the irrigation of corn on Delta peat soils. The University of California Agricultural Extension Service experts on Delta agricultural and water matters testified regarding these issues (Meyer, et al, 1973, 1974 1975, and 1976) (Ayers and Branson, 1975) (SWRCB, UC Exhibits, 1976).

The UC Experts explained that the application of irrigation water, of any quality, adds salt to the soil being irrigated; that the plants use the soil water leaving behind the salt; and that eventually this salt must be leached from the crop root zone to maintain maximum crop yields, regardless of the quality of water used to irrigate the crops. It was pointed out that if a shallow table is present, it is most important to have adequate leaching and good on-farm water management practices to avoid salt accumulation in the crop root zone.

Mr. Ayers explained the procedures developed by the United States Department of Agriculture Salinity Laboratory and the University of California to determine the salt tolerance of various agricultural crops (Ayers & Branson, 1975).

Mr. Carlton discussed the irrigation of peat soils, which generally lie below sea level. It was explained that the peat soils are difficult to leach because these soils are found on Delta islands surrounded by water that is higher than the surface of the soil. This water, surrounding the islands, consists of river water, poor quality drainage water from the irrigated lands and diluted ocean water. The area is also impacted by the tidal fluctuations from the Pacific Ocean. In addition, the level of the peat soils was dropping at that time about one to two inches per year, making it more difficult over time to leach these soils and to maintain water tables below the crop root zone.

Mr. Kegal confirmed that peat soils are difficult to farm under ideal conditions. He explained the irrigation and leaching processes practiced in the Delta peat soils. Mr. Kegal also explained that the irrigation of higher (in elevation) mineral soils of the Southern Delta were also difficult to irrigate as most have poor water infiltration rates. Mr. Kegal further explained that the leaching process that removes salt from the irrigated land contributes directly to reducing Delta water quality because as the drainage water is removed by pumping from the islands and it adds salt directly to the Delta water supply.

Mr. Meyer reviewed the Corn Studies that were conducted to gather data that would be helpful to the State Board in establishing agricultural water quality objectives for the Southern and Central Delta. Mr. Meyer reported that the UC studies showed that the soils, crops, farming practices, and water management practices were highly variable throughout the Delta. He concluded that of the salts that needed to be leached from the soils to maintain crop yields, 80% came from applied water and 20% from the decomposing peat. He also reported that leaching could not be done with sub-irrigation practices applied on the peat soils, and that leaching had to be accomplished during the winter season by flooding or from winter rain.

In regard to the mineral soils, Mr. Meyer stated that the natural leaching fraction ranged from 5% to 50%. He said the salt tolerance tables (Ayers and Westcot, 1976) would be applicable where the leaching fraction is 15% to 16%, which can be achieve normally with the over application of water in normal irrigations and with winter precipitation. The South Delta Salinity Study, Meyer, et al. (1976), (Exhibit UC-7) shows that in the study of nine mineral soil locations in the Southern Delta during the hydrological dry year of 1976, the highest soil salinities and lowest apparent leaching fractions occurred at locations where the irrigation water supply from Middle River was the highest quality (0.7 mmhos/cm) during that year. Good leaching and low salt accumulations were accomplished in all locations where the irrigation water supply averaged 1.1 mmhos/cm. In general, there was no increase in soil salinity. This report indicated that the main factors controlling salt accumulation in the test plots studied in 1976 are management and soil properties as well as the quality of the irrigation water. The authors concluded that the wide variability of soils contributed more to the variability in the salt accumulation than did the variability in the water quality. These results were obtained even though historical data show that the 1976 water year was classified dry and the salinity of the San Joaquin River water at Vernalis exceeded 1.0 mmhos/cm from about the end of April through July (Steiner, 2004).

Despite the above findings, the authors concluded the report with the following statement that appears to conflict with the reported data.

> “This study has shown that salinity is a problem now in the South Delta. Given the wide variety of soils in the South Delta, good yields and diversity of crops appear to be related to water quality and levels of farm management.”

Granted, water quality will impact crop yield, but all of the studies show that soil type, groundwater quality, depth to groundwater, and farm management have far more to do with potential crop yield than the quality of water used to irrigate the Delta crops, especially within the range of salinity levels being considered in these proceedings.

Discussion at December 6, 1976 Hearing

Following the testimony of the UC Experts at the Board Hearing on December 6, 1976, the Board members seemed to be most concerned with protecting the Delta crops grown on the difficult to manage peat soils. One of the important questions asked of the UC Experts was,

> "If the water quality guidelines as presented in exhibit UC-1 and UC-2 need to be modified for use of subsurface irrigation as stated on page 8, line 26 and 27 of the UC-2 exhibit (FAO-29), can you suggest a way to modify?"

Mr. Ayers developed a four page answer to that question that basically stated that to achieve a 100% yield with surface irrigation of corn on mineral soils, with a 16% leaching fraction, water with a salinity of 1.13 mmohs/cm (about 723 mg/l) would be needed (Ayers, 1976, UC-8). Mr. Ayers then, in answer to the question posed by the Board, calculated the quality of irrigation water for the subsurface irrigation of peat soils, with leaching and water management as found at the study site. Mr. Ayers concluded that the range of water quality needed for 100% yield would be from 0.34 to 0.68 mmhos/cm (218 to 435 mg/l).

The establishment of the Vernalis Water Quality Objective at 0.7 mmhos/cm (448 mg/l) appears to have been established to lean heavily toward the quality required for the subsurface irrigation of peat soils. This was not much of a concession since, using the tables in (Ayers and Westcot, 1976 or Ayers and Westcot, 1985) to estimate the yield of corn, an irrigation water with salinity levels between 0.42 and 0.85 mmhos/cm (269 and 544 mg/l) will produce a 95% yield.

The Board rejected a proposal by Mr. Alex Hildebrand on behalf of the South Delta Water Agency, that the objective should be established with a 3-day average of 500 ppm TDS, a 30 day average of 450 ppm TDS and an annual average of 400 ppm TDS.

Subsequent Evaluations of Salt Tolerance of Corn

Subsequent to the adoption of D-1485 by the SWRCB, Hoffman, et al. (1983) reported the results of a three year field experiment to establish the salt tolerance of corn in the Sacramento-San Joaquin Delta of California, Maas, et al. (1983) reported on a greenhouse experiment to evaluate the sensitivity of corn to salt at various growth stages, and Hoffman, et al. (1986) evaluated the use of irrigation waters of various salinities in corn growth in the Sacramento-San Joaquin Delta. Hoffman, et al. (1986) reported that

> "Corn production on the organic soils of the Sacramento-San Joaquin Delta of California was affected by the salinity of the irrigation water and the adequacy of salt leaching. Full production was achieved on soils that were saline the previous year, provided the electrical conductivity of the irrigation water (EC_i) applied by

> sprinkling was less than 2 dS/m and leaching was adequate from either winter rainfall or irrigation to reduce soil salinity (Ec_{sw}) below the salt tolerance threshold for corn (3.7 dS/m). For subirrigation, an Ec_i up to up 1.5 dS/m did not decrease yield for leaching had reduced EC_{sw} below the threshold. If leaching was not adequate, even nonsaline water did not permit full production. In agreement with previous results obtained in a greenhouse, surface irrigation with water of an electrical conductivity of up to 6 dS/m after mid-season (end of July) did not reduce yield below that of treatments where salinity of the irrigation water was not increased at mid-season. Results also reconfirm the salt tolerance relationship established in the previous three years of the field trial. The earlier conclusion that the irrigation method (Sprinkler or subirrigation) does not influence the salt tolerance relationship was also confirmed."

In addition, Pritchard, et al, (1983), concluded,

> "At the soil water salinity threshold for corn grain (3.7 dS/m), the average ratio is 1.7 which results in a maximum value of 2.2 dS/m for EC_i without yield loss under normal conditions. With subirrigation and below normal rainfall, as in 1981, the maximum value of Ec_i would be 0.8 dS/m".

Finally, researchers from the University of California, Department of Land, Air and Water Resources (Isidoro-Ramirez, Berenguer-Merelo,and Grattan, 2004) developed criteria for evaluating the required irrigation water quality (EC_i) necessary to protect agricultural beneficial uses when taking into account annual precipitation. This study evaluated beans as the agricultural crop most sensitive to soil and water salinity. This new UC model study builds upon the principles and assumptions described by Ayers and Westcot , except that the prior analyses have not taken into consideration any leaching that results from precipitation The UC Davis model determined how the EC of a given irrigation water supply affects crop production, in this case beans, on Yolo silt loam soil in Yolo County, where annual precipitation averages about 17.3 inches per year. Most of the mineral soils in the Delta, being irrigated with San Joaquin River water, where beans and corn are grown, are similar in texture to the soil modeled and the annual precipitation is about 13.8 inches per year (Stockton). I have personally observed that in San Joaquin Valley soils without a shallow saline water table, when the annual precipitation is 10 to 12 inches, sufficient natural leaching takes place to prevent salt buildup in the crop root zone.

These researchers concluded that

> "When an EC_w of 1.1 dS/m is considered over the 53-year rainfall series, the model predicts that the seasonal mean EC_e is is 0.94

> dS/m. In 80% fo the years, the mean seasonal EC_e is less than 1.0 dS/m, the yield threshold for salt-sensitive bean. For 50 of the 53 years, the seasonal mean EC_e for individual years is 1.05 or lower, which would result in a predicted yield reduction of 1% or less. However, this predicted reduction in yield potential is less than the error associated with the yield threshold value itself.
>
> "Over the entire 53-year period of record, yield reduction for beans is predicted to be noticeably reduced during only 3 years when applying irrigation water with an EC of 1.1 dS/m. All three years occurred during the period of drought in the 1970s. These three outliers translate into reductions in the potential yield of 2, 4 and 6%. Again, however, these predicted values are within the statistical uncertainty of the salinity threshold value itself. Moreover, such losses, if real, could be avoided by winter leaching.
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> "Given these results, and taking into account all the other factors that potentially impact crop yield (e.g., weather, water stress and biotic stresses) and the conservative nature of all inputs into the model, the use of 1.1 dS/m as the treshold EC value for irrigation water is considered protective for beans, and thus all other agricultural uses of the water in the Davis area."

Southern Delta Service Area

One important factor in establishing the water quality objective for any beneficial use is the reasonableness in efficiently achieving the objective. I have reviewed soil types, land use, farming patterns, cropping patterns, and parcel relationships in the Southern Delta Service Area. Maps of the Vernalis, Tracy, Lathrop, Union Island, Stockton West, and Holt Quad Sheets, respectively, (See San Joaquin River Group Authority Maps) show the area of the Southern Delta irrigated with surface water and groundwater in 1996. The maps of the same Quad Sheets show the 1996 areas planted to beans, and to corn. These data have been compiled from DWR land use and crop reports. All of the irrigated soils in the Southern Delta where beans are planted are mineral soils (McElhiney, 1992). In addition, none of these soils where beans are grown are subirrigated. All are irrigated with a variety of surface irrigation methods.

Studies were conducted regarding the economics of leaching and reclamation of organic soils in the Delta (Pritchard et al, 1985; Pritchard, et al, 1992). However, the fact that organic soils may be more difficult and costly to maintain a salt balance in the crop root zone is irrelevant in regard to the questions raised by the SWRCB for this matter. The studies have shown that the economics of maintaining a favorable salt balance is related more to the specific soil and climatic conditions than to the quality of applied irrigation water. This is particularly so in the Delta where the surface of organic soils is oxidizing and the elevation of the soil surface on the Delta islands is sinking. This causes increasing static head on the subsurface groundwater and over time, it causes additional salt up into the crop root zone. As this happens, it becomes more and more difficult to maintain salt balance or reclaim these organic soils, regardless of the quality of the applied water. It is also clear that the more the Delta soils are leached, more salt will be returned to the Delta channels which further degrades the Delta water supply

Current Workshops

The SWRCB has asked, as part of the 2004-2005 Periodic Review, whether or not the SWRCB should amend the 0.7 mmhos/cm and 1.0 mmhos/cm Southern Delta Electrical Conductivity (EC) Objectives in the Water Quality Ojectives for Agricultural Beneficial Uses to be reflective of salinity tolerances of crops currently grown in the Southern Delta? (SWRCB, Sept. 30, 2004).

Proposed Vernalis Water Quality Objectives

I believe that the research conducted since the 0.7mmhos/cm water quality objective was adopted by the SWRCB show that the 0.7mmhos/cm is not justified as reasonable, beneficial or necessary to insure the viability of the crops grown in the Southern Delta service area on mineral soils in 2005. It is therefore recommended that the Vernalis agricultural salinity objective be changed to 1.1 dS/m for the entire year, as shown in "Table 2 (PROPOSED)". This recommendation takes into consideration crop type, soils, irrigation methods, and available annual precipitation. This water quality objective will provide water of sufficient quality to allow 100 % yield for all crops grown in the Southern Delta, including beans, the most salt sensitive crop currently grown in this area, assuming normal precipitation and all other reasonable farming practices are followed (Grattan, 2002 and Isidoro-Ramirez, et al., 2004)

Table 2 (PROPOSED)
Water Quality Objectives for Agricultural Beneficial Uses

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER (RK1 [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
San Joaquin River at Airport Way Bridge, Vernalis *-and-*	*C-10 (RSAN112)*	*EC*	*Maximum 30-day running average of mean daily EC (dS/m)*	*All*	*1Jan-31Dec*	*1.1*
San Joaquin River a Brandt Bridge site *-and-*	*C-6 (RSAN073)*		***-or-*** *If a three-part contract has been implemented among the DWR, USBR, and SDWA, that contract will be reviewed prior to implementation of the above and, after also considering the needs of other beneficial uses, revisions will be made to the objectives and compliance/monitoring locations note, as appropriate.*			
Old River near Middle River *-and-*	*C-8 (ROLD69)*					
Old River at Tracy Road Bridge	*P-12 (ROLD59)*					

[3] Use San Joaquin Valley 60-20-20 water year hydrologic classification index (see page ??) to determine water year type.

The Board also asks if there is any reason to change the methodology for determining compliance with the Southern Delta EC Objectives to ensure the protection of agricultural beneficial uses? The methodology for determining compliance needs to be modified to apply the San Joaquin Valley 60-20-20 water year hydrologic classification index, rather than the 40-30-30 Sacramento River index, to determine each water year type for the San Joaquin River Basin.

Conclusions

- Based on observations of excellent production of agricultural crops through significantly different years with varying water quality, with varying water conditions and water supplies of different quality, that have occurred since 1976, the salinity problems impacting crop yields in the Southern Delta are no better or worse in 2004 than they were in 1976. (San Joaquin County Agricultural Commissioner Reports. 1988-2003).
- Even under the best circumstances, it is difficult to manage poor soils with a shallow water table. Poor soils, shallow water tables and other factors (eg. unattended crop pests, adverse weather conditions, poor fertilization practices, inadequate weed control, deficit irrigation) all contribute to farming problems and ultimate crop yield far more than the quality of the water supply within the salinity ranges under consideration in this discussion.
- A Vernalis water quality objective of EC equal to 1.1 dS/m (mmhos/cm) is sufficient to protect all agricultural crops grown in the southern Delta service area.
- The proposed water quality objectives are adequate to provide 100% yield of the agricultural crops irrigated with San Joaquin River water in the Southern Delta service area with good water management. Proper irrigation and annual precipitation provide adequate leaching of the irrigated soils (Grattan, 2002, Isadoro-Ramirez, et al, 2004).

Recommendation

It is recommended that during all times the Vernalis EC objective should be set at 1.1 dS/m which is sufficient to protect the beneficial use for irrigation of all crops grown in the area where San Joaquin River water is used at or down stream of the location of the Vernalis monitoring point.

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