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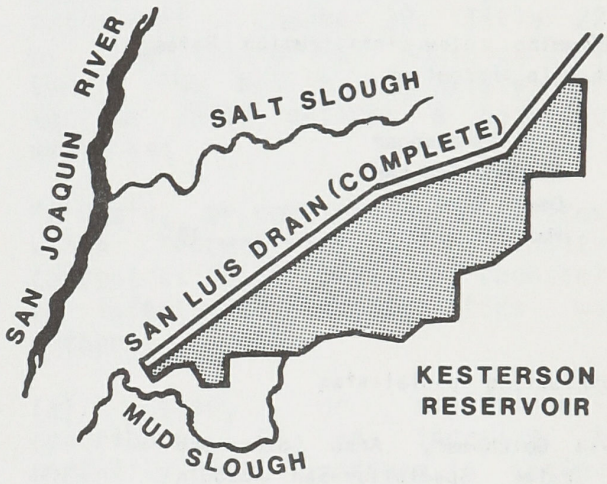
Winter 1984 - No. 61

Kesterson Reservoir: The Cleanup and Abatement Order

by
J. D. Oster and
Gregory R. Smith

On February 5, 1985 the State Water Resources Control Board (Board) issued an order directing the Bureau of Reclamation (Bureau) " to minimize seepage at Kesterson Reservoir," "to alleviate the threat of future surface discharges from Kesterson Reservoir due to inadequate capacity," and "to mitigate the nuisance conditions caused by the operation of Kesterson Reservoir [Order, Appendix P 4 and 5]." The Order also includes instructions for the Grasslands Water District, the Central Valley Regional Board and the Board's Executive Director. The Board's decisions are based on two conclusions: 1) wastewater at Kesterson Reservoir is a hazardous waste, and 2) this water is causing, and threatening to cause, a nuisance to and pollution of water of the state.

Possible effects of the Order related to Kesterson include 1) closure and cleanup of the reservoir with implementation of an acceptable waste disposal alternative; 2) upgrading the reservoir by double lining the pond with clay; or 3) any other acceptable alternative. The Order directs Grasslands to submit and implement a program to control selenium in Grasslands Water District during the time before the San Joaquin Basin plan is implimented.



The Central Valley Regional Board is directed to institute amendments to the San Joaquin Basin plan for the regulation of agricultural wastewater discharges. The Order directs the Board's Executive Director to create a technical committee which is to formulate proposed water quality objectives for the San Joaquin River basin and proposed regulations of agricultural drain water in the basin.

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The Board found that agricultural tile dainage discharged to Kesterson Reservoir (7,000 acre-feet/year) "

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SOIL AND WATER is the quarterly newsletter of UC Cooperative Extension Specialists in Soils, Water, and Biometerology. The subscription cost for four issues per year is $5.00. Checks should be made payable to THE REGENTS OF THE UNIVERSITY OF CALIFORNIA. Mail to: Agricultural Sciences Publications, 6701 San Pablo Ave., Oakland, CA 94608.

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has reached waters of the state through direct discharge to surface waters and seepage to groundwater and by virtue of the location of the reservoir in a wetlands [Order, Summary, p. 1]". Surface discharges from Kesterson into mud slough (an intermittent tributary of the San Joaquin River) occurred during March 1983 after the wet winter of 1982-83 because of limited reservoir capacity. As currently constructed, similar future discharges can be expected in wet years. Seepage was estimated to be about 60% of the measured inflow. The record indicates groundwater in the area is used for domestic water supplies, stockwater and irrigation. Kesterson Reservoir (1,280 acres) is also part of the 5,900 acre Kesterson National Wildlife Refuge an area "of central importance to pacific flyway waterfowl which winter and feed in the area [Order, p. 4]".

The Board [Order, Summary, p. 2] concluded "the wastewater discharged into Kesterson Reservoir is a hazardous waste because it poses a substantial threat to human health and the environment." The selenium concentrations in the 12 ponds known as Kesterson Reservoir range from 60-390 µg/L. All exceed the EPA drinking water standard for selenium of 10 µg/L. Some concentrations of mercury, nickel, hexavalent chromium, zinc, copper, and cadmium exceeded EPA ambient water criteria for protection of human health from toxic effects steming from ingestion through water and contaminated aquatic organisms, or EPA water quality criteria for protection of freshwater aquatic life.

The soluble concentrations of these elements do not exceed the soluble threshold limit concentration as established by the California Department of Health Services (DOHS) whereby wastes may be considered to be hazardous. These hazardous waste criteria establish specific concentration levels for a number of constituents which exhibit toxic effects due to bioaccumulation and persistence in the environment. In determining that the drain water entering Kesterson Reservoir is hazardous, the Board relied on the definition of a hazardous waste in the Health and Safety Code Section 25117, and to criteria given in Article 11 of Chapter 30, Title 22, of the California Administrative Code. The Health and Safety Code Section 25117 defines a hazardous waste as:

"A waste, or combination of wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may either:

(a) Cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness.

(b) Pose a substantial present or potential hazard to human health or environment when improperly treated, stored, transported, or disposed of, or otherwise managed."

According to the Order (p. 33) "Article 11 provides, in pertinent part, that a waste is toxic and hazardous if it has been shown through experience or testing to pose a hazard to human health or environment because of its carcinogenicity, acute toxicity, chronic toxicity, bioaccumulative properties or persistence in the environment...".

The Bureau disagrees with this line of reasoning: 1) "In focusing on the functional definition of hazardous waste, rather than on applicable numerical criteria, the Board staff has ignored the statutory framework for defining hazardous waste [DOI Submittal, P 11].", and 2) "While the general definitions serve as a valuable source of guidance in situations where specific criteria have not yet been set, it is wholly unsupportable for another state agency to ignore specific criteria painstakingly established by the DOHS [DOI Submittal, p. 12]."

Both the Bureau and Board are concerned about several elements, in addition to selenium, which can cause toxic effects. However for the purpose of briefly outlining the physical nature of these concerns, the following discussion only deals with selenium. Before Kesterson was built, little was known about the distribution of hazardous inorganic chemicals, including selenium, in soils and groundwaters along the west side of the San Joaquin Valley, including the area surrounding Kesterson. Based on a recent groundwater survey (Deverel et al, 1984), more is now known. Selenium levels in 32 ground water samples taken at 16 sites within ten miles of Kesterson ranged from < 1 to 5 µg/L (Tables 7 and 8; Deverel et al, 1984). Beneath Kesterson selenium levels are less than 10 µg/L. In the Kesterson ponds, selenium decreases from 390 µg/L, in the ponds which receive drainage water first, to 60 µg/L in the ponds which receive it last. The groundwater data indicate selenium movement into and through the soils beneath Kesterson is slow. The pond data suggest selenium removal processes, such as bioaccumulation in living organisms, are relatively rapid. Based on all the available information, the Bureau argued in part that 1) the underground and surface waters can be adequately protected by close monitoring, patching the ponds to reduce seepage, and elevating the berms and 2) the threat to migratory waterfowl, and hence to humans, can be adequately controlled by eliminating food chain components and continuation of the bird hazing program.

A summary of the Board's position follows (Order, pp. 37-38): "...wastewater in Kesterson Reservoir poses a hazard to the environment because the reservoir has been improperly located, constructed, and managed. The ponds at Kesterson Reservoir are located immediately adjacent to Mud Slough, a tributary of the San Joaquin River, in a wetlands area where the perched groundwater table at times is above the ground surface. The ponds also overlie a groundwater body which is used for drinking water supply. In addition to posing a threat to ground and surface water quality, the location of the ponds clearly poses a hazard to the resident and migratory waterfowl which frequent the area. Kesterson Reservoir is situated in the Pacific Flyway, adjacent to several wildlife refuges in the Grassland area. The reservoir is in an area designated in the Basin Plan as a critical habitat for waterfowl and water-dependent wildlife. Further, the ponds were constructed in a manner which allows more than fifty percent of the inflow to seep into the perched groundwater table and with inadequate capacity to handle flows during certain wet weather events. Additionally, the ponds were managed for the dual purposes of drainage control and as a

wildlife refuge. Vegetation attractive to waterfowl, for example, has been allowed to grow in the ponds. Due to these factors, principally the improper construction and location of the reservoir, we are of the opinion that the facility cannot be operated in a manner which does not pose a hazard to waterfowl and other wildlife.

While we conclude that the wastewater contained in Kesterson Reservoir clearly poses a hazard to the environment because of the improper location and constuction of the reservoir, we are also of the opinion the wastewater could be properly managed in other locations, for example in ponds in certain parts of Westlands Water District, in a manner which did not pose a similar threat to the environment. In this regard we note that Section 66310 (a) (2) of the [Department of Health Services] regulations provides that the Department may grant a variance from the hazardous waste management regulations if a hazardous waste is "handled, stored or disposed of pursuant to regulations of another governmental agency in a manner which is consistent with the hazardous waste management provisions of this chapter and which will not result in a hazard to human health and safety, livestock or wildlife." If ponds were constructed to meet this Board's Subchapter 15 requirements for a Class II surface impoundment [unlined, if the hydraulic conductivity of the soil beneath the impoundment is less than 1 ft/yr], there should be minimal seepage from the ponds, and the ponds should be adequately sized to handle anticipated flows. In addition, ponds could be constructed in a location which did not pose a hazard to waterfowl or to ground and surface water qualities. Features to protect waterfowl, such as adequate pond depth, lack of vegetation, and screening, if necessary, could be included as additional measures to protect waterfowl. We conclude that compliance with the Subchapter 15 requirements for a Class II surface impoundment, together with proper location of waste management facilities and inclusion of features to protect waterfowl, should ensure that the wastewater would not pose a hazard to human health and safety, livestock or wildlife."

In coming to its decision, the Board noted some of the alternative cost are substantial. For example, the Bureau (DOI submittal, section III) estimated cost of preparing Kesterson for use as a wildlife refuge (draining with toxic cleanup) and constructing ponds in the Tulare Basin for drainage disposal is 260 million dollars.

Grasslands

Grasslands Water District is an area of about 52,000 acres in the same area as Kesterson Reservoir. This acreage is used for maintaining the State's native grasslands, and preservation of waterfowl. Land management in the Grasslands Water District includes flooding in the winter and irrigation in the summer. Drainage water flows into the San Joaquin River. Grassland gets its water from several different sources including drainage water from soils high in selenium. No attempt has been made to monitor the selenium, or other heavy metals, entering the district. The latest study by the Fish and Wildlife Service (Order, P 52) "indicate elevated selenium levels are present in the livers of

birds in the area."

Because of the nature of the land in Grasslands Water District, and the hazards posed to waterfowl by selenium, the Board instructs Grasslands to submit a technical report within four months (Order, pp. 62) "detailing the measures the district will undertake to control selenium levels in wastewater entering the district and a time schedule for implementation of these measures."

San Joaquin River

The Central Valley Regional Board has a basic plan, detailing water quality goals for the San Joaquin River near Vernalis. However "the lower San Joaquin River is of such poor quality that beneficial uses cannot be protected and water quality objectives cannot be met is recognized in the Basin Plan. The Basin Plan classifies the lower San Joaquin River from just south of its confluence with the Merced River to its point of discharge in the Delta as a Water Quality Limited Segment [Order, p. 53]".

Discharge of tailwater and tile drainage resulting from irrigation is the major cause of the poor water quality. The Board notes these two types of irrigation flows have distinct water quality problems: tile drainage can contain high salt and trace metal concentrations, whereas surface runoff can contain fertilizers and pesticides. About 84,000 acres in the western San Joaquin Valley have tile drainage. Another 169,000 should have drainage now, but do not. And, 345,000 will need drainage in thirty five years. Most of the water drained from the west side of the San Joaquin Valley ultimately reaches the San Joaquin River. Waste discharge reports by entities discharging return flows into the river have not been required by the Central Valley Water Quality Control Board. The Board concurs [Order, p. 56] "that waste discharge reports can continue to be waived on a temporary basis until sufficient data is collected to characterize return flows and until appropriate water quality objectives for the San Joaquin basin are formulated." The Central Valley Regional Board has undertaken a voluntary program to collect and monitor the water quality of waters being discharged into the San Joaquin River. If necessary, it has the authority to require this information. The Central Valley Regional Board is instructed to finalize its monitoring program within two months from the date of the Order. And, the Central Valley Regional Board is instructed to complete its data gathering within fourteen months of the date of the Order.

Further, the Board instructs its Executive Director to form a technical committee to develop: "(1) proposed water quality objectives for the San Joaquin River Basin, (2) proposed effluent limitations for agricultural drainage discharges in the basin and, (3) a proposal to regulate these discharges." (Order, p. 59). The technical committee shall be formed within thirty days of the Order. The final recommendations of the committee will be presented no later than eighteen months after the date of the Order.

In fulfilling these tasks, the technical committee is instructed to consider the following issues [Order, Pg. 59]: 1) effects of high flow

periods during the winter on effluent limitations; 2) economic considerations of the proposed regulations; 3) whether effluent limitations should be based, in some cases, on mass loading rather than concentration (Order, p. 59); and 4) the total cost of the regulatory program including identification of potential sources of financing.

After the final approval of the report by the technical committee, the Central Valley Regional Board has six months to adopt appropriate amendments to the Basin Plan and should then implement a program to regulate drainage discharge in the Basin.

Time Line Summary

The Bureau:

-cleanup and abate the effects of Kesterson Reservoir.

-upgrade Kesterson Reservoir to meet the...requirements for a Class I surface impoundment, or find some other acceptable waste disposal alternative.

-by May 27, 1985 the Bureau "shall develop and submit a monitoring program to the Central Valley Regional Board."

-within six months the Bureau must "either file a revised report of waste discharge,... or a close and post-closure maintenance plan" for Kesterson Reservoir.

Grasslands: (Order, p. 62)

-within four months, Grasslands "must submit a technical report...detailing the measures the district will undertake to control selenium levels in wastewater entering the district (Grasslands) and a time schedule for such implementation of these measures."

Central Valley Regional Board : (Order, pp. 62 and 63)

-within two (2) months "shall complete the development of monitoring programs for the collection of data..."

-within fourteen (14) months will "complete the gathering of monitoring data..."

-within six (6) months of the Boards final approval of the technical committee's report shall "adopt appropriate basin plan amendments for the San Joaquin River Basin." After adoption the Board concluded that the Central Valley Regional Board should implement a regulation program for the discharge of agricultural drainage waters.

The Technical Committee: (Order, p. 59)

-within thirty (30) days a technical committee composed of the staffs of the State and Valley Regional Boards shall be chosen. The technical committee is charged with developing the following: "...(1) proposed water quality objectives for the San Joaquin River Basin; (2) proposed effluent limitations for agricultural drainage discharges in the basin; and (3) a proposal to regulate discharges."

-within eighteen months, the technical committee "shall submit final recommendations...which fulfill the tasks."

Update

About February 8, 1985, in response to an action sought by Robert James Claus, Superior Court Judge D. Fretz ordered the State to immediately close Kesterson Reservoir, or appear in court on March 15, 1985 to explain why Kesterson should remain open. On February 26, 1985 the Natural Resources Defense Council, Inc. and the Consumers Union of the U.S. filed a petition in Superior Court for Sacramento county seeking an order preventing further discharge of hazardous waste into Kesterson, to take further action to protect Grassland Water District and the San Joaquin River, and to require an immediate cleanup of the environmental contamination of those areas.

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ENVIRONMENTAL CHEMISTRY OF SELENIUM

By

R. G. Burau

Selenium is an essential trace element for animals and humans but at elevated levels of dietary exposure, it causes toxicity. However, it is not known to be essential for plants. In animals, selenium is a component of glutathione peroxidase which detoxifies peroxide free radicals preventing damage to tissues, especially call membranes. In this respect, selenium complements a function of vitamin E. It is also possible that selenium has other functions including participation in the mitochondrial electron transport system in muscles.

Deficiency, expressed in animals as white muscle disease, occurs in calves and lambs in livestock enterprises on both sides of the Sacramento Valley and the northern Coast Range as well as on the east side of the San Joaquin Valley. Livestock deficiency problems are usually associated with forages having low selenium contents because they are grown on leached, acidic soils with higher levels of free iron oxides.

Atmospheric deposition of selenium, especially in the vicinity of coal-fired industrial or power generating plants, is a significant component of the selenium economy of some soil-plant systems. However, in most soils, the selenium content of the parent rock and annual rainfall are the two most important determinants of soil selenium levels. Higher parent material levels and lower rainfall contribute to the formation of soils with higher selenium contents. Magmatic rocks have the lowest selenium content (10-50 ppb) while

sedimentary rocks are generally higher in selenium. Shales have the highest selenium contents (500-28000 ppb). World wide, the average soil concentration is 400 ppb but the soils of the Great Plains area of the United States, where selenium in forage has caused widespread and recurrent instances of toxicity in domestic animals, range from 6000 to 28000 ppb in selenium. The soils of this region are derived from the Cretaceous-age Pierre Shale, the climate is semi-arid, and the seleniferous soils of the area tend to be alkaline. Soil alkalinity is another frequent concomitant of high levels of selenium in soils.

On the west side of the San Joaquin Valley, shallow ground water areas having high levels of selenium have received sediments of Cretaceous-age shale formations on the east side of the Coast Range. The hypothesis of Dr. Barnes of the U.S. Geological Survey, is that these sediments acquired their selenium at the time of their deposition as seleno-sulfides of iron. Later, when these sediments were uplifted and exposed to oxidative conditions, the selenium was released as selenite and selenate salts, whereas the sulfur appeared as sulfates. These materials then eroded into the fans, but the generally low rainfall caused evapoconcentration of the salts at the rim of the San Joaquin Valley bason and this was also the cause of the inefficient transfer of these materials into the San Joaquin River and thus into the ocean by way of the Delta.

The mean values for fresh and marina waters are 0.2 and 0.1 ppb, respectively, although selenium levels in seepage water in seleniferous soil areas around the world are 2 to 3 orders of magnitude greater than these values. The recommended limit for domestic consumption is 10 ppb. (The selenium concentration in the city water supply of Davis, California regularly equals or exceeds this value.) A recent survey sampling by the U.S. Geological Survey of shallow wells and subsurface agricultural drainage waters on the west side of the San Joaquin Valley has shown relatively low or moderate levels of selenium (<10 ppb) in samples from the area around and to the north of Kesterson Reservoir whereas samples from areas to the south, including the Panoche Creek fan have ranged into the hundreds of parts per billion.

When these high selenium waters were brought to the surface and placed in Kesterson Reservoir, selenium was taken up by aquatic biota including phytoplankton, zooplankton and insects which contribute to the diet of higher forms of wildlife in the area. It is important to recognize that the selenium acquired by photosynthetic organisms of both the terrestrial and the aquatic biospheres, is transformed biochemically into organic or carbon linked selenium, especially seleno-analogues of sulfur-containing amino acids such as seleno-cystine, seleno-cysteina, seleno-methionine, etc. It is well known that these or other more elaborate peptide or protein forms of selenium are more effectively taken up from the diet into the tissues of higher life froms than are inorganic froms such as selenite or selenate. The working hypothesis of the U.S. Fish and Wildlife Service scientists is that this food chain transfer mechanism has caused selenium toxicity in aquatic birds of the area expresed not only as hatchling deformities and death but also as toxicity symptoms in adult fowls. There is little doubt that selenium, in one form or another, is the toxic principle causing these problems.

There is an extensive, world-wide literature on dietary levels in domestic animals (sheep, cow, horse, chicken) that give rise to toxic as well as deficient symptoms. Deficiency is likely if the selenium concentration in food is less than 50 ppb; selenium sufficiency is likely in the range 100 to 1000 ppb, but the toxicity threshold is from 3000 to 5000 ppb. By comparison, the literature form selenium response in wild animals is relatively sparse.

Most instances of selenium toxicity in domestic livestock are from consumption of ordinary (as opposed to selenium accumulator) forages and feeds grown on seleniferous soils. Selenium levels in plants are positively correlated with selenium levels in soils (total or extractable) but uptake is also positively affected by pH and soil temperature.

Human toxicity from high selenium levels in the diet derived from food grown on seleniferous soils is relatively rare. Adults in the United States consume approximately 60 µg Se/day from all sources and the recommended dietary allowance is 50 to 200 µg Se/day. A recently completed study of selenium in human diets in China reported no toxic symptoms in individuals taking in 750 µg Se/day or less but individuals consuming 5000 µg Se/day or less but individuals consuming 5000 µg Se/day or more consistently showed one or more symptoms to toxicity. The most frequently observed symptoms were loss of hair or nails and skin lesions. In addition to these visual symptoms, there are analytical techniques available to indicate the level of dietary exposure of individuals. Selenium level in hair is one of the best indicators but blood as well as urine analysis is also useful.

It is most important to recognize that there are levels of selenium in the food and water supply of all higher organisms that are healthy and not toxic. Our knowledge for domestic animals and humans is quite good, but we are not similarly blessed in respect to data for wild animals, especially those in aquatic systems.

MANAGING IRRIGATION AND DRAINAGE WATER IN THE SAN JOAQUIN VALLEY

BY

B. R. Hanson

The problem of salinity/drainage in the San Joaquin Valley is the disposal of the saline subsurface drain water. A valley-wide drain has been proposed by the selenium problem, among others, may prevent its construction thus leaving evaporation ponds as the only disposal method. Regardless of the disposal method, growers in the problem area should manage their irrigation and drainage water to minimize the volume of subsurface drainage water. A systems approach for minimizing this volume is proposed. Components of this approach are water table management through design and management of subsurface drainage systems, design and management of irrigation systems, irrigation scheduling, and leaching.

Water Table Management Through Design and Management of Subsurface Drainage Systems

Traditional drain design recommends installing deep drains to minimize the upward flow of saline groundwater. Grimes et al. (1984) showed, however, that the shallow saline groundwater can contribute much of the crop's water needs for the crops normally

grown in the valley's salt-affected areas. The water table contribution was found to depend on the depth to the water table and the salinity of the groundwater (Figure 1). For salinities between 5 to 10 dS/m, typical of many areas in the valley, the maximum contribution ranged from 30 to 50 percent of the seasonal ET. This suggests that subsurface drainage systems be designed and managed for maximum in-situ use of the saline groundwater by they crop thus reducing the volume of water drained from a field. Design depth to the water table would depend on the salinity of the shallow groundwater. This is in contrast to the traditional design approach, which minimizes this upward flow.

One management scheme for inducing more in-situ use of the shallow groundwater is to simply not operate existing drainage systems during the summer growing season. Any water table decline, then, would be primarily from crop extraction of the shallow groundwater. Grimes et al. (1984) and Ayars (1984) have shown a seasonal decline in the water table under conditions of both artificial and no artificial drainage. This behavior suggests that the recharge to the groundwater at a particular site, mainly from deep percolation, is less than the extraction, mainly from crop water use. Thus, under this approach even though no artificial drainage is provided during the summer, water table levels should decrease yet no drainage water will be generated for disposal.

This management method should have little impact on crop yield provided proper irrigation and leaching practices are used. Table 1 shows data on crop yield, seasonal depth of the water table, and the salinity of the groundwater for various locations in the southern San Joaquin Valley. Although yield differences exist between sites, little or no relationship exists between yield, depth to water table, and salinity. It appears that these differences are more due to the grower's management practices.

Design and Management of Irrigation Systems

Irrigation systems should be designed and managed to reduce the seasonal volume of deep percolation as much as practical yet provide adequate irrigation. For surface irrigations, the volume of deep percolation will depend on a complex interaction between the allowed soil moisture depletion, soil infiltration rate, inflow rate, field slope, surface roughness, and furrow geometry.

A relationship between deep percolation and the above factors is needed to best design and manage the irrigation system to reduce this seasonal volume. Irrigation system evaluations, which are time-and-labor consuming, are normally used to describe this relationship. However, a combination of some minimum amount of rapidly collected data and simple computer simulation models may allow one to readily develop this relationship for a particular field. This approach is currently being investigated in the Imperial Valley and will be reported later.

Irrigation Scheduling Under Saline High Water Tables

Traditional irrigation scheduling assumes soil moisture depletion in the root zone as the crop's water source and negligible salinity effects. Yet, where high water tables occur,

irrigation intervals should account for upward flow of the shallow groundwater. Thus, longer intervals might be used for these conditions.

A statement frequently made is that irrigation frequency should increase as salinity increases. The basis for this statement appears to lie in research that shows the effects on yield of matric and osmotic potentials to be equivalent and additive. Interestingly, no guidance has even been developed on what irrigation frequency should be used as salinity increases. Recent research on this matter (Hoffman et al. 1983, Heller et al. 1973), however, has shown the following:

1. For a given salinity of irrigation water, no yield response occured with irrigation frequency where no plant stress due to matric potential is believed to occur.

2. A yield response to irrigation frequency, regardless of salinity, occurred only when the matric potential appeared to affect plant yield.

Other research has shown that water uptake is greatest in the least salinized part of the root zone under a differentially salinized root zone and that as salinity increases, the transpiration rate decreases.

These results suggest that changing the irrigation frequency will not compensate for yield reductions from salinity effects, that perhaps the irrigation interval should be increased as salinity increases because of a reduced transpiration, and that perhaps irrigation scheduling should be based on the water content of the least saline part of the root zone.

Ideally, where differential salinity levels and differential water contents occur, plant-based measurements should be used for irrigation scheduling. Grimes and Yamada (1982) developed a method using leaf water potential, as measured with a pressure chamber, for scheduling irrigations of cotton. Hanson and Kite (1984) used this method for irrigation scheduling of cotton under a saline high water table. Their efforts increased the irrigation interval by an average of four days during peak ET periods and also was believed responsible for a substantial yield increase. This approach is believed to account for both salinity effects and upward flow.

Leaching

As previously mentioned, water table levels generally decline during the growing season thus suggesting that recharge to the groundwater is less than the extraction. Under these conditions, a seasonal salt balance would show a salt accumulation in the root zone because the mass of salts transported upward in the root zone is greater than that transported down by deep percolation. Thus, the seasonal leaching fraction would be zero, which condition continued over long time periods would soon result in excessive salinity levels.

Two factors appear to control soil water salinity in the high water table areas:

1. Low-salinity irrigation water is generally used in the high water tables areas thus maintaining relatively low salinity levels near the soil surface, where Hanson and Kite (1982) found

about 50% of the soil water depletion occurring.

2. Pre-plant irrigations, commonly done in the winter, appear to leach salts from the root zone, even where artificial subsurface drainage does not exist. Grimes et al. (1984) showed similar preplant salinity levels for two years where preplant irrigation occurred. However, at a site where no preplant irrigation occurred, salinity levels continued to increase with time. Under this approach, the subsurface drainage system would be operated during the preplant irrigation to reduce the salinity of the entire soil profile and to reduce water table build-up during the winter.

Other Considerations

This systems approach assumes the primary source of drainage water to be on-site deep percolation. If, however, considerable lateral inflow or seepage from canals and rivers occurs, then a substantial reduction of the volume of drainage may not be possible.

In-situ use of the shallow groundwater by the crop is a key component to this approach. Also to be considered, however, is using drainage water for irrigation. Several projects conducted by J. D. Rhoades, a research investigations leader at the U.S. Salinity Laboratory, have shown that acceptable crop yields can be maintained by irrigating with low salinity water when the plant is the most salt-sensitive and then with high salinity water when it is the most salt-tolerant.

Future Considerations

This systems approach is based on numerous research results which, in my opinion, show its feasibility. The next step is to implement this approach at the on-farm level.

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Table 1. Cotton yield, water table depths, and groundwater salinity at several locations, San Joaquin Valley.

Site	Yield (kg/ha)	Approximate Average Seasonal Water Table Depth, meters	Salinity of Shallow Groundwater, dS/m
P (1981)[1/]	1236-1324	1.3	27
T (1981)[1/]	1502-1549	1.3	5
T (1982)	1196-1282	1.3	5
S (1982)[1/]	1469-1480	0.8	8
S (1983)	1073	0.8	5
F (1981)[2/]	1078	1.0	10
F (1982)	1281	1.0	10

1/ Grimes et al., 1984
2/ Hanson and Kite, 1982

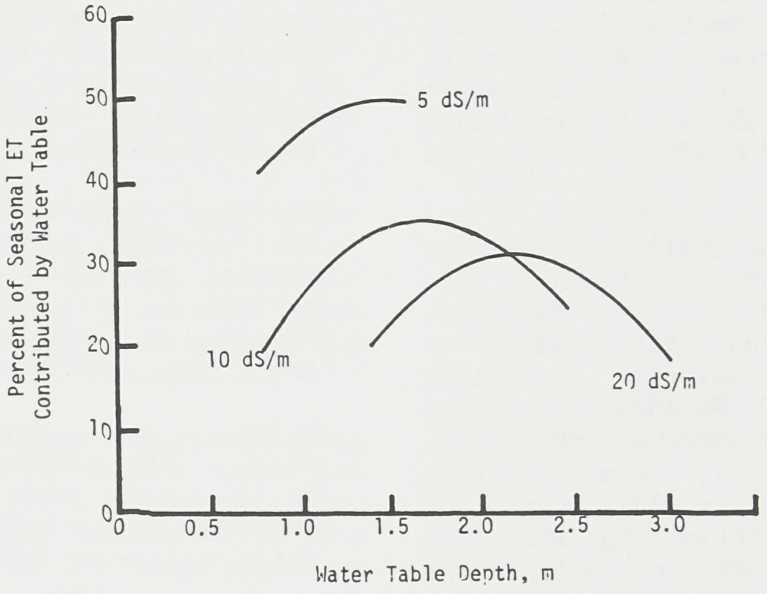


Figure 1. Relationship between seasonal water table contribution, seasonal average depth to the water table and salinity of the shallow groundwater. (Grimes et al., 1984)

DENNIS H. HALL MEMORIAL FUND

Dr. Dennis Heeley Hall passed away unexpectedly on November 22, 1984. Dr. Hall served the University of California and State of California for nearly 29 years with dedication and distinction. His death has resulted in the loss of one of California Agriculture's most productive Plant Pathologists and effective Extension specialists and leaves a great void in the University's applied research and extension program on the diseases of field and vegetable crops.

Born in 1922 in Brigham City, Utah, Dr. Hall obtained a B.S. degree in 1947 in Botany and an M.S. degree in Plant Pathology in 1949, both at Utah State Agricultural College in Logan, Utah. He earned a Ph.D. in Plant Pathology from the University of Wisconsin, in 1955. He was commissioned First Lieutenant in the U.S. Marine Corps in 1943 and served in the South Pacific during World War II. He remained active in the reserves until retirement as a Major in 1959. He taught at the University of Nevada in Reno for two years before attending Wisconsin and came to Davis as an Extension Plant Pathologist in 1955.

Dr. Hall's record in applied research and extension activities during his years at Davis was truly outstanding. He made significant contributions toward the understanding and control of a large number of field and vegetable crop diseases. He made notable contributions to the sweet potato, garlic, and potato industries through use of meristem culture to provide virus free planting stock. He cultured clones and followed them thru field testing and cycles of selection. His countless studies on modifications of cultural practices and chemical control of diseases on numerous crops including onions, carrots, tomatoes, corn, alfalfa, clover, hops, cotton, cereals, Brussels sprouts, sugarbeets and rice are equally distinguishing. Dr. Hall was a good team researcher and spent much effort in pointing out problems to young pathologists and students. As a result much of his research was conducted cooperatively with either experiment station or extension personnel. He authored or coauthored more than 130 research or extension papers on diseases of field and vegetable crops. His excellence in mission oriented research attracted worldwide attention and resulted in his being sought for advice and counsel from all aspects of agricultural endeavor.

Although the foregoing has emphasized Dr. Hall's research accomplishments, he was equally preeminent in his capacity as an extension plant pathologist. He had the ability to present highly technical information in a manner readily understood by farm advisors, pest management operators, growers and other industry colleagues. He was particularly dedicated to helping young farm advisors. His lab was a constant clinic of unknown plant samples and attempts to identify disease problems. Dr. Hall was equally effective in guiding the research of graduate students seeking M.S. or Ph. D. degrees.

Dr. Hall was a complete plant pathologist, a true leader and an inspiration to students and staff. He was intrigued with and dedicated to the understanding of plant diseases and their control. Workers in plant pathology often sought his advice and when he gave it, they listened and acted. Few plant pathologists have

gained the personal and professional respect accorded D. H. Hall by his colleagues.

In recognition of Dr. Hall's outstanding contributions in plant pathology and extension, the Department of Plant Pathology, University of California, Davis, with encouragement from Dr. Hall's wife, Marjorie, has established the "Dennis H. Hall Memorial Fund." An annual award will be made to a graduate student in the department who is doing excellent mission-oriented research on a disease of a field or vegetable crop. The award is envisioned as an inspiration to graduate students and will aide in perpetuating the excellence that characterized Denny's career. Contributions (payable to The Regents, University of California) should be sent to the Dennis H. Hall Memorial Fund, Department of Plant Pathology, University of California, Davis, CA 95616.

OVERCOMING SLOW INFILTRATION RATES WITH DRIP IRRIGATION

William Krueger, Richard Buchner
David Shaw, Herbert Schulbach

Many Sacramento Valley orchards are planted on soils affected by slow water infiltration. In many cases these are silt loams with very fine soil particles. The situation may be further aggravated by years of farming, causing soil compaction and destruction of soil structure. Additionally, water from sprinklers impacting the soil surface can disperse soil particles producing surface sealing, further reducing infiltration. These problems make it difficult to provide adequate soil moisture to meet orchard water requirements. The end result is reduced evapotranspiration (ET) causing premature defoliation and reduced yield.

Previous attempts at shallow cultivation and irrigation scheduling in the orchard described below failed to adequately manage the infiltration problem. Therefore, during the 1984 season we initiated a trial to compare drip vs. sprinkler irrigation.

MATERIALS AND METHODS

The test orchard is located in Glenn County near Hamilton City, California. The soil is Wyo loam described in the Glenn County Soil Survey as a 3-5 ft. deep loam soil over sand and gravel. Ring infiltrometer measurements suggested a steady state infiltration rate of less than .02 inches per hour. The orchard, planted to almonds in 1974, is a 1:1 Nonpareil planting with Neplus and Price as pollenizers, and is irrigated with solid set under-tree sprinklers.

Our drip plot consisted of five rows of 13 trees. Drip system design included a mainline, water meter, irrigation timer and a single 1/2 inch drip lateral per tree row. Each tree was irrigated by six one-gallon-per-hour microtube emitters. Irrigation run times were scheduled using the California Irrigation Management Information System (CIMIS) computerized irrigation program with weather data input from the CIMIS station in Orland (#14). The drip trees were irrigated to meet 100% orchard ET which resulted in water application on a daily or every other day basis. Due to land preparation, we were unable to start the drip

system until May 10th . Until that time trees in the drip plot were sprinkler irrigated with the rest of the block.

The comparison trees (farm practice) were irrigated using a solid set under-tree sprinkler system appling 0.06 inch per hour. Irrigations were scheduled by the grower and, during peak water use, were as frequent as once a week. Water was normally applied until excessive runoff began.

Data collection included neutron probe readings, harvest samples and yield measurements. Soil moisture was monitored throughout the season using a neutron probe which was calibrated to this site. In the drip plot access tubes were placed both inside and outside the drip zone. The sprinkler plot was monitored by placing steel neutron probe access tubes four feet long in representative locations. Measurements were taken at 9, 18, 30, and 42 inches. On August 10th nut samples were collected from 10 individual Nonpareil trees in each treatment. These samples were analyzed for kernel thickness, length, width and weight.

RESULTS AND DISCUSSION

Soil moisture data (Figure 1) illustrates the water penetration problem. In the sprinkler irrigated plots, little if any irrigation water was detected by the neutron probe. The soil moisture drawdown curve in the sprinkler plot is relatively similar to the non-irrigated area in the drip trial! Soil moisture in the drip zone is more encouraging. We were unable to consistantly wet the entire drip zone, but could, at least, get water into the soil profile. Seasonal water use for the drip irrigated trees was 41.4 ac-in compared to 25.3 ac-in in the sprinkler irrigated comparison trees. Drip irrigated trees showed improved crop performance. Nonpareil kernels had increased length, width, thickness and weight compared to the sprinkled tree (Table 1).

In fact, kernel weight was nearly 17% greater in the drip plot. Yield data by variety, on a per acre basis, also favors the drip irrigated trees (Table 2). Nonpareil and NePlus yields were increased by 17.5% and 26.9% respectively while Price yield was reduced by 10.1%. Why Price yield was reduced is unclear. Price trees in stressful conditions can bloom erratically. Perhaps previous season moisture stress resulted in a light bloom and poor set on the Price trees in the plot with little or no effect on the other varieties.

Both the soil moisture data and the yield increase favor drip irrigation for poor infiltration soils, however, there are management considerations. In the drip irrigated plot, localized runoff enlarged the wetted area into orchard drive rows. This has the advantage of wetting more soil, however, it also interfered with cultural practices. Therefore, even the drip systems has to be periodically shut off to allow farm equipment in the orchard. In our test plots, shutting the drippers off 3-4 days in advance allowed traffic in the orchard without causing rutting. Fortunately, we were able to shut the drip system down for four days without apparent moisture stress.

During harvest, neither treatment was irrigated for approximately 10 days. Moisture stress and associated defoliation became severe in the

sprinkler irrigated trees compared to minor stress and defoliation in the drip plot. Presumably, the soil moisture reserve was greater where drip irrigated. Also, post harvest treatment differences were striking. Drip irrigated trees held their leaves well into the fall as opposed to early defoliation in the sprinkled areas.

CONCLUSION

Based upon our data, drip irrigation is a viable technique to manage slow infiltration soils. Not only could we get more water into the root zone, but we were able to minimize moisture stress with less system down time. Our data also suggests that mature sprinkler irrigated almond orchards can be converted to drip irrigation with no loss in production. In fact, conversion to drip irrigation may increase orchard production by doing a better job of irrigating.

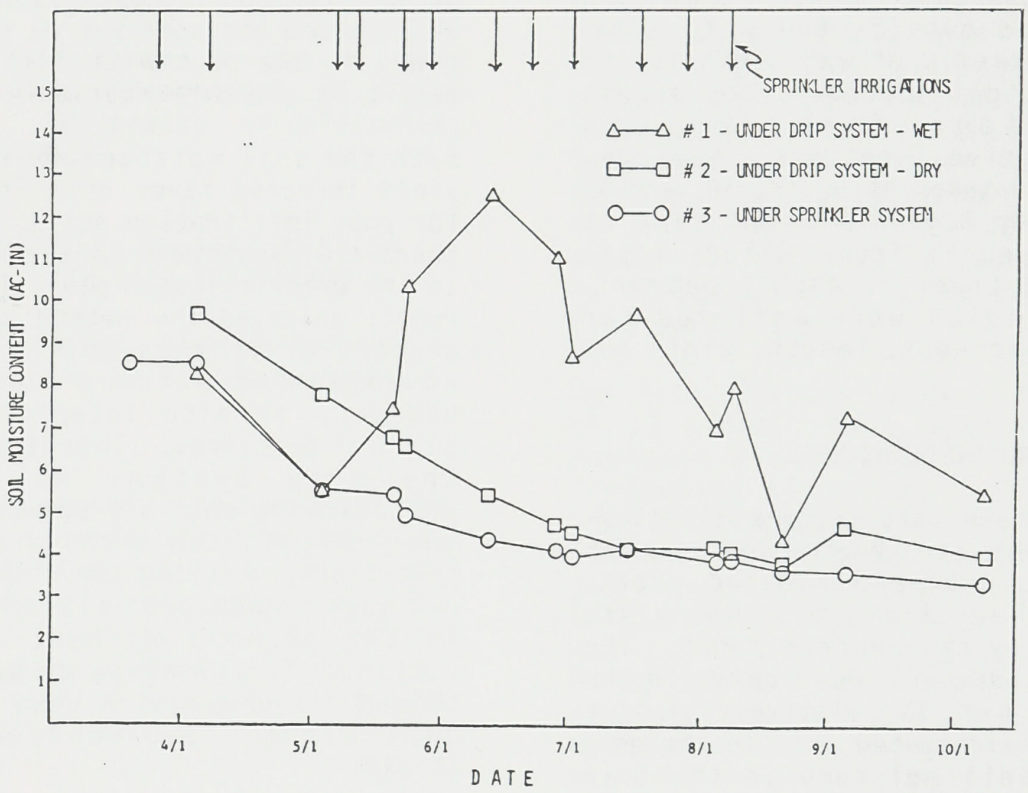


Figure 1. Seasonal soil moisture changes as measured with neutron probe. Data points reflect total soil moisture in a four foot profile. Access tube #1 is located between two emitters, tube #2 is in the middle row away from wetting, and tube #3 is located in a dry, or unirrigated area in the sprinkler plot. Arrows represent sprinkler irrigations.

Table 1. Estimated orchard water use and Nonpareil kernel data.

	Estimated Seasonal Water Use*	Kernel** Length cm	Width cm	Thickness cm	Weight gm
Drip Plot	41.4	2.53	1.29	.80	1.24
Sprinkler Plot	25.3	2.41	1.19	.74	1.06
% Difference	63.6	4.98	8.40	5.11	16.98

*Estimated season water use = gross applied water at 90% efficiency (both systems) + 5 inches of seasonal soil contribution.

**Kernel data are reported as the mean of 10 samples.

Table 2. Almond meat yield; drip vs. sprinkler.

Variety	Meat Sprinkler	Drip	Percent Increase
	---------lb/ac---------		
Nonpareil	2,325	2,731	17.5
NePlus	1,690	2,144	26.9
Price	1,500	1,348	-10.1

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