Delta farmlands are crisscrossed with drainage ditches. Here, a main drain leads to the levee where a pumping station lifts water back into the channel.

Subsurface movement of water and salt in Delta organic soils

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Quality of the water flowing through channels of the Sacramento-San Joaquin Delta unquestionably is crucial to Delta agriculture, but information has been lacking about the relationship between channel water quality and soil salinity. The question concerns subsurface irrigation, the primary method used in Delta peat soils. (See page 5.) It involves siphoning channel water over the levees and directing it through shallow spud ditches. Water percolating from these ditches raises the water table to a level that replenishes the root zone moisture supply.

It has been conjectured that the channel water may not directly replenish the root zone moisture. According to this line of thinking, irrigation water percolating downward from the spud ditches may displace groundwater upward, so that groundwater rather than channel water moves into the root zone. Groundwater quality in the Delta usually is much worse than channel water quality. Therefore, if this displacement process does occur, it could have serious implications for soil salinity, especially if quality of the irrigation water supply should deteriorate significantly.

Test procedures

A study was begun in 1977 to see whether this displacement does indeed take place. To measure water movement, a grid of piezometers was installed between two spud ditches, down to the "blue" clay which underlies the organic soil. During irrigation, the hydraulic head was measured at each point on the grid and, since water flows in the direction of decreasing hydraulic head, the flow pattern of subsurface water could be determined. To illustrate that pattern at any given time, lines of equal hydraulic head (equi-potential lines) were sketched on a diagram showing a cross-section of the field, as in figures 1 to 3.

The flow patterns at a site on Bouldin Island are shown in figures 1 to 3. The distance between spud ditches was 16.5

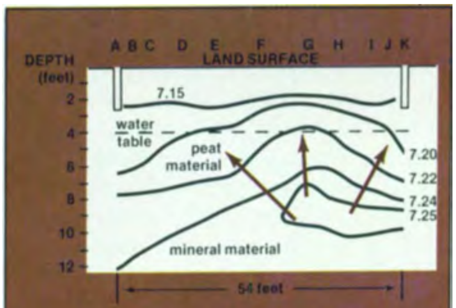

Figure 1. Equipotential lines before irrigation at Bouldin Island. The arrows indicate general direction of water movement. Letters A, B, C, etc. represent the columns of piezometers, which were more closely spaced near the spud ditches to obtain more detailed flow patterns at the start of irrigation. The number given with each equipotential line is the hydraulic head along that line in meters.

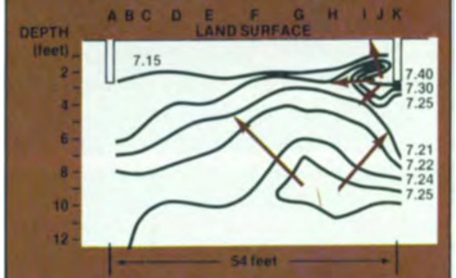

Figure 2. Equipotential lines 15 minutes after start of irrigation.

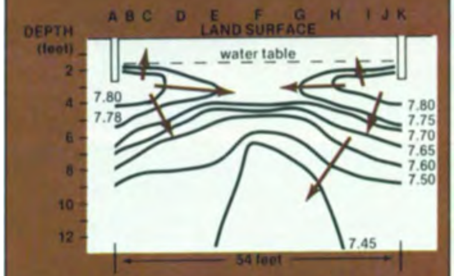

Figure 3. Equipotential lines about 12 hours after start of irrigation.

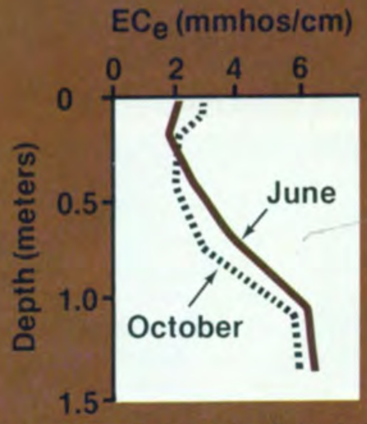

Figure 4. Changes in soil salinity during irrigation season.

meters (54 feet) and the depth of the peat profile was about 2.1 meters (7 feet). (In this case, piezometers also were installed in the mineral material because it was less compacted than at other sites.)

Before the irrigation, the subsurface flow was as shown in figure 1. The pattern of equipotential lines reveals upward movement of water into the root zone; this apparently is because of evapotranspiration. Below the water table, upward movement also is occurring. In this case, the cause appears to be artesian water at the 2- to 3-meter (7- to 10-foot) depth between rows G through K. The source of this water is unknown. Tests showed that it contains a significant amount of sulfate, in contrast to the low sulfate concentrations found at similar depths in other locations.

Flow patterns

Irrigation water first reached the spud ditch at "K." Figure 2 shows the subsurface flow pattern 15 minutes after arrival of the water. Note that in the vicinity of the spud ditch, lateral flow is more rapid than vertical. This is shown by the fact that saturated conditions exist at the 3-foot depth about 1 meter horizonally from the spud ditch, but the soil is still unsaturated at 0.3 meter directly beneath it.

The flow pattern 12 hours after the arrival of the irrigation water (figure 3) again shows primarily lateral movement between the 2- to 4-foot depths. The water table is nearly at its maximum height, just below the root zone. Downward flow is occurring below 4 feet, and it appears that the applied water is moving into the area where the artesian flow originally existed.

The significant lateral movement of subsurface water shown in both figures 2 and 3 apparently is the result of cracks in the peat soil. These fissures were observed between 2 and 4 feet below the surface during soil sampling. They apparently result from shrinkage of the soil during drainage which does not reverse itself upon wetting.

These subsurface cracks provide channels for rapid lateral water movement away from the spud ditch, creating what is in effect high hydraulic conductivity of the soil at the 2- to 4-foot depth. Since hydraulic conductivity of the soil below 4 feet is much less, water moves horizonally away from the spud ditches more rapidly than it moves downward.

Because soil profiles vary widely in the Delta, this experiment is continuing at different locations to determine if similar flow patterns occur elsewhere. At all sites thus far, fissures in the peat soil have been found and irrigation water movement from the spud ditches has been primarily lateral.

The conclusion based upon these flow patterns is that little if any upward displacement of groundwater occurs. Thus, the irrigation water is directly responsible for replenishing the root-zone moisture supply.

Soil salinity

Samples were also obtained throughout the irrigation season to monitor changes in soil salinity. Figure 4 shows the soil salinity profile at the start and end of the growing season for one sampling location. These data indicate that above the 1-foot depth, the soil salinity increased during the irrigation season. This would be expected since no leaching of salts from the upper root zone occurs during subsurface irrigation. However, below the 1-foot depth, salts were removed during the growing season. This trend was the same at all sampling locations. This information and other data obtained from a winter leaching site indicate that salts which accumulate near the surface are leached down out of the top foot of soil during winter flooding. Further removal of these salts from the lower soil then occurs with each irrigation during the next growing season.

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Mapping Delta water quality by remote sensing

The quality of water in the Delta, and the effect that various uses might have on that water quality, is a matter of great interest to a number of state, federal, and local government agencies. Of particular interest is an area at approximately the point where salty tidal water moving up the Delta from San Francisco Bay meets fresh water from the Sacramento and San Joaquin rivers.

Known as the region of "high biological activity" because of its abundance of fish and plant life, the shifting, constantly changing area is difficult to map and monitor. In the fall of 1978, a team of University of California scientists was asked to determine if remote sensing, combined with information gathered on-site, could be used to measure water quality in San Francisco Bay and the Delta, and to locate the region of high biological activity.

R. N. Colwell, professor of forestry and associate director of the Space Sciences Laboratory at U.C. Berkeley; A. W. Knight, professor of water science at U.C. Davis, and Siamak Khorram, remote sensing specialist at Berkeley, designed an experiment to measure salinity, suspended solids, turbidity, and chlorophyll in the Bay and Delta.

Information was collected on September 14, 1978, by means of an Ocean Color Scanner (OCS) flown on a NASA U-2 plane at an altitude of 65,000 feet. The aircraft also took conventional color and color infrared photographs. Water quality samples were taken simultaneously from boats at 29 predetermined sites in the study area. Statistical comparisons were then made of the data. Parameter estimation models were developed and tested, and separate color-coded maps were prepared for each of the four water quality parameters being analyzed.

As shown in the accompanying photos, the area of high biological activity was clearly discernible on computer-enhanced imagery of the OCS data. The area could not be reliably identified by high quality aerial photography taken with either conventional color film or infrared color film.

The researchers consider the results of the study highly promising and believe remote sensing will be useful in monitoring water quality in San Francisco Bay and the Delta, but they emphasize that their results are preliminary. Remote sensing has proved that it can scan broad areas quickly and economically and provide reliable information on certain indicators of water quality. The technique using OCS data has limitations, however — primarily that it cannot probe beneath the water's surface.

The project was funded by the Water Resources Center at U.C. Davis and by a grant from the NASA-Goddard Space Flight Center. It is anticipated that proposed follow-on activities will map and monitor water quality conditions for the entire San Francisco Bay and Delta region.