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.

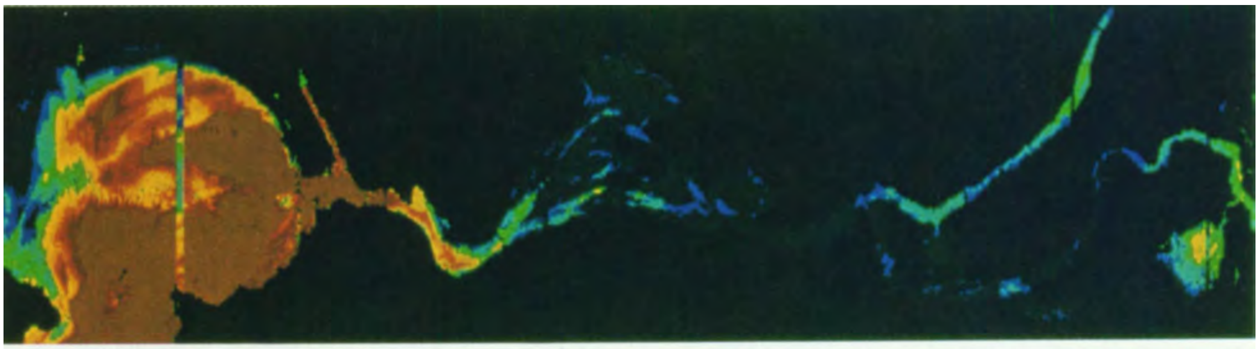
The researchers consider the results of the study highly promising and believe remote sensing will be useful in monitoring water quality in San Francisco Bay and the Delta, but they emphasize that their results are preliminary. Remote sensing has proved that it can scan broad areas quickly and economically 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.

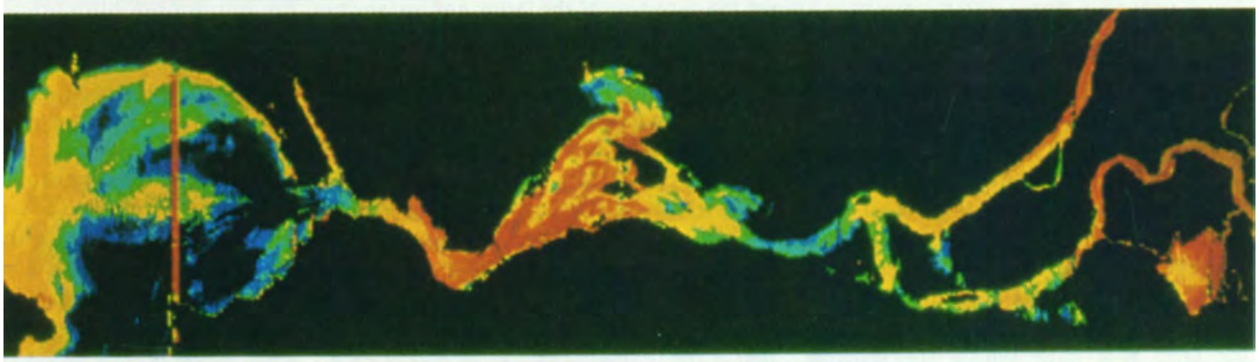
Water quality samples were taken from boats at these 29 sites in the Delta for comparison with remotely sensed data gathered at the same time by an Ocean Color Scanner flown on a U-2 aircraft at 65,000 feet. San Pablo Bay is at the left, Suisun Bay at left center.

Computer-enhanced color-coded maps of remotely-sensed data show the salinity, chlorophyll, suspended solids, and turbidity distribution in the Delta. In all maps, dark blue or green represents the lowest concentrations of these water quality parameters; orange, red, and brown the highest concentrations.

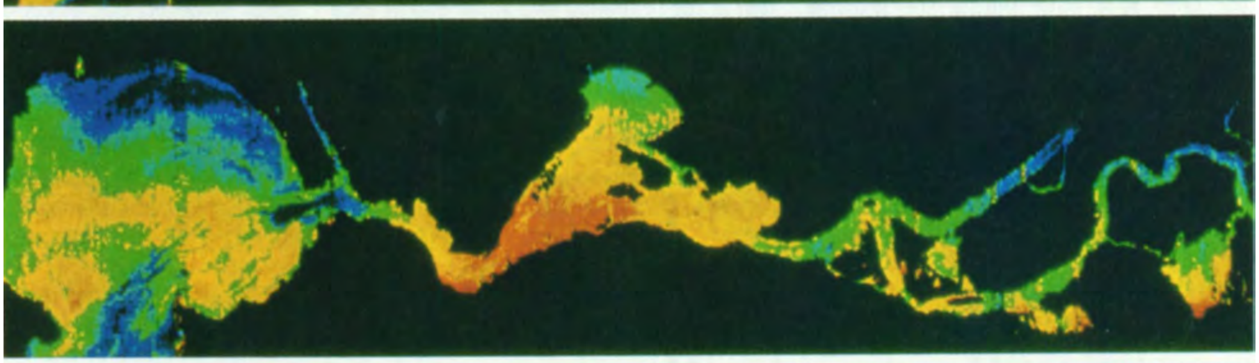
salinity



chlorophyll



suspended solids



turbidity