Delta Mendota and California Aqueduct water. The supply water averaged 234 mg/L in salinity, and the soil water, assuming a doubling or tripling in concentration due to evapotranspiration, would be expected to reach nearly 700 mg/L. However, measurements and model calculations demonstrated the soil water to be 7,000 to 8,000 mg/L. This is water that would penetrate deeper into the profile and that would be captured by drains to be discharged elsewhere or recycled for crop production. The IO-fold increase in concentration is attributed to dissolution of soil minerals, principally gypsum. Although a few crops could tolerate such concentrations for selected periods, the long-term maintenance of irrigated agriculture using such waters is doubtful.

In summary, the major effects of salinity on soil properties are swelling of soil clays, dispersion of fine soil particles, crust formation, and decreases in water-transmission properties. The amount of sodium adsorbed on the soil and the amount of sodium and salt in the irrigation water greatly influence the degree to which salinity affects soil properties.

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Case history: Salton Basin

Jewell L. Meyer **Jan van Schilfgaarde**

The Salton Basin extends 200 miles from San Gorgonio Pass in the north through the Coachella, Imperial, and Mexicali valleys to the Gulf of California. The basin covers a drainage area of about 8,000 square miles and at its deepest point is 273 feet below sea level — about the same as Death Valley.

The desert climate is characterized by long hot summers, short mild winters, and sporadic rainfall averaging only about 3 inches per year. If water can be supplied, the climate and alluvial soil are ideal for many vegetable, fruit, and field crops.

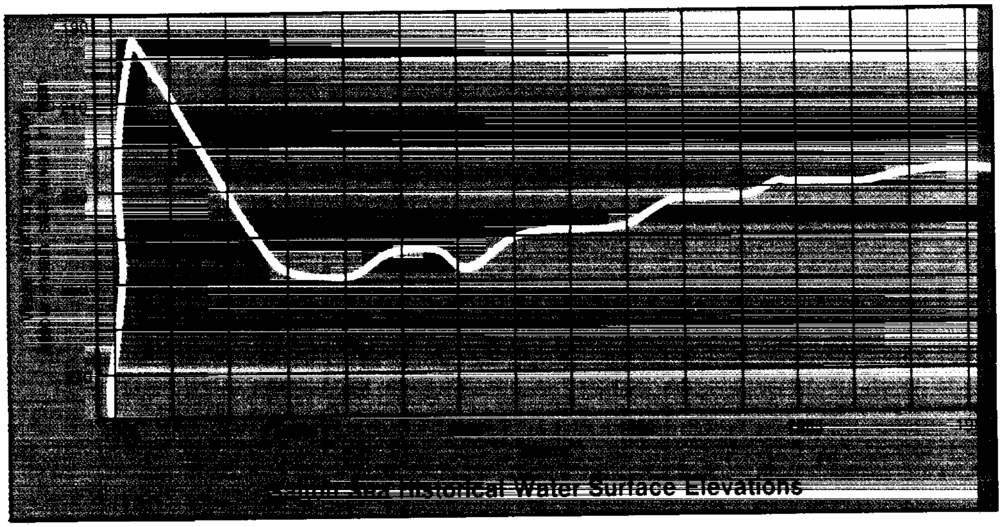
Irrigation water delivery to the Imperial Valley began in June 1901. Within three years, over 150,000 acres were being planted to barley, grain sorghum, alfalfa, and cantaloupes, despite problems with transportation and water delivery, and severe living conditions for the new settlers.

In March 1905, silt that had built up in the Colorado River near the headgates south of Yuma, Arizona, diverted the first of several floods into the canal system. Flood water flowed through the canals and the Alamo River into the Salton Sea, cutting a new, 60-foot gorge, the New River. The Salton Sea, nearly dry in 1904, filled to a level of -195 feet; the sea covered 500 square miles and was 80 feet deep by early 1907, when the Southern Pacific Railway Company finally closed the breach.

The Imperial Irrigation District, formed in 1911, had consolidated most of the mutual water districts under a single entity by 1916 and enlarged its potential boundaries to over ½ million acres. With federal assistance, Imperial Dam was built on the Colorado River and the All-American Canal was constructed. Water delivery to the Imperial Valley through these facilities started in 1943.

In contrast to the Imperial Valley,

The 8,000-square-mile Salton Basin, one of the most productive agricultural areas in the world, as seen by a Landsat camera. The Salton Sea serves as the drainage basin for saline irrigation waters from the Imperial, Coachella, and Mexicali valleys.



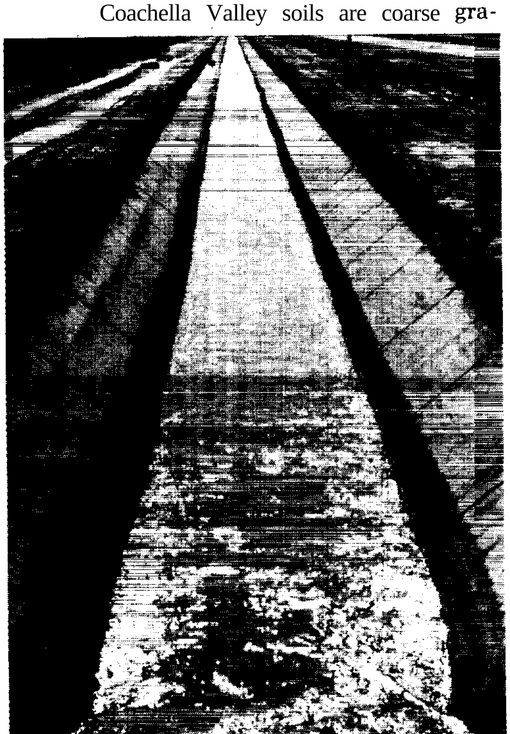
Nearly dry in 1904, the Salton Sea was filled to a level of 195 feet below sea level by flooding of the Colorado River. It later dropped but has risen gradually in recent years to its current level of approximately -227 feet.

development in the Coachella Valley started slowly in about 1900 with use of fresh water from artesian wells. When it was recognized that irrigation by wells would deplete groundwater and limit development, the Coachella Valley County Water District in 1934 contracted with the U.S. Government to construct the Coachella Branch of the All-American Canal to deliver Colorado River water to the Valley. By the time the project was completed in 1948, 23,000 acres were being irrigated. The area irrigated has since expanded to 60,000 acres and pumping of ground water has been greatly reduced.

Coachella Valley soils are coarse granitic alluviums formed from recent outwashes of intermittent streams of the southern Sierra. The Imperial Valley has fine-textured lacustrine or basin soils formed from the intermittent flooding of the Colorado River through the Alamo and New Rivers into the Salton sink. Although their soil conditions differ significantly, both valleys drain into the landlocked Salton Sea, and both have salinity problems where drainage is inadequate.

In Coachella, adverse effects of high water tables and resulting high soil salinity led to a drainage program beginning in 1950. By 1970, well over half of the land was subsurface-drained. Field studies by the U.S. Salinity Laboratory and the water district indicated that, before 1963, irrigation water added more salt to the land than was removed to the Salton Sea in drainage water. As the drainage system expanded, the salt balance shifted in the other direction in 1963. The relatively coarse-textured soils simplified the design and construction of the drainage system, and the closed-conduit water conveyance system helped minimize water spills.

The much finer soils in the Imperial Valley made drainage systems more difficult and more expensive to construct. The open-ditch conveyance system, with essentially no storage except in the canals themselves, made it difficult to avoid some spillage. Leakage from canals added to a water table problem. For example, a study by the Imperial Irrigation District and U.S. Salinity Laboratory estimated that 150,000 acre-feet per year were lost during 1900-48 by seepage from the Coachella Canal before completion of the Coachella Branch of the All-American Canal through the eastern edge of the Imperial Valley.



C A. Beasley

A sophisticated irrigation and drainage system maintains the salt balance in the Imperial Valley. Growers have spent millions of dollars to line irrigation canals and reduce water losses.

As waterlogging and salinity problems increased, open ditch drain construction began in about 1921, supplemented with attempts at subsurface drainage. In the 1940s, federal agencies, the University of California, and local interests cooperated in an extensive drainage program. By 1981, over 27,800 miles of drain tile (tube) had been installed under 427,500 acres of Imperial Valley land — equivalent to drains spaced 125 feet apart.

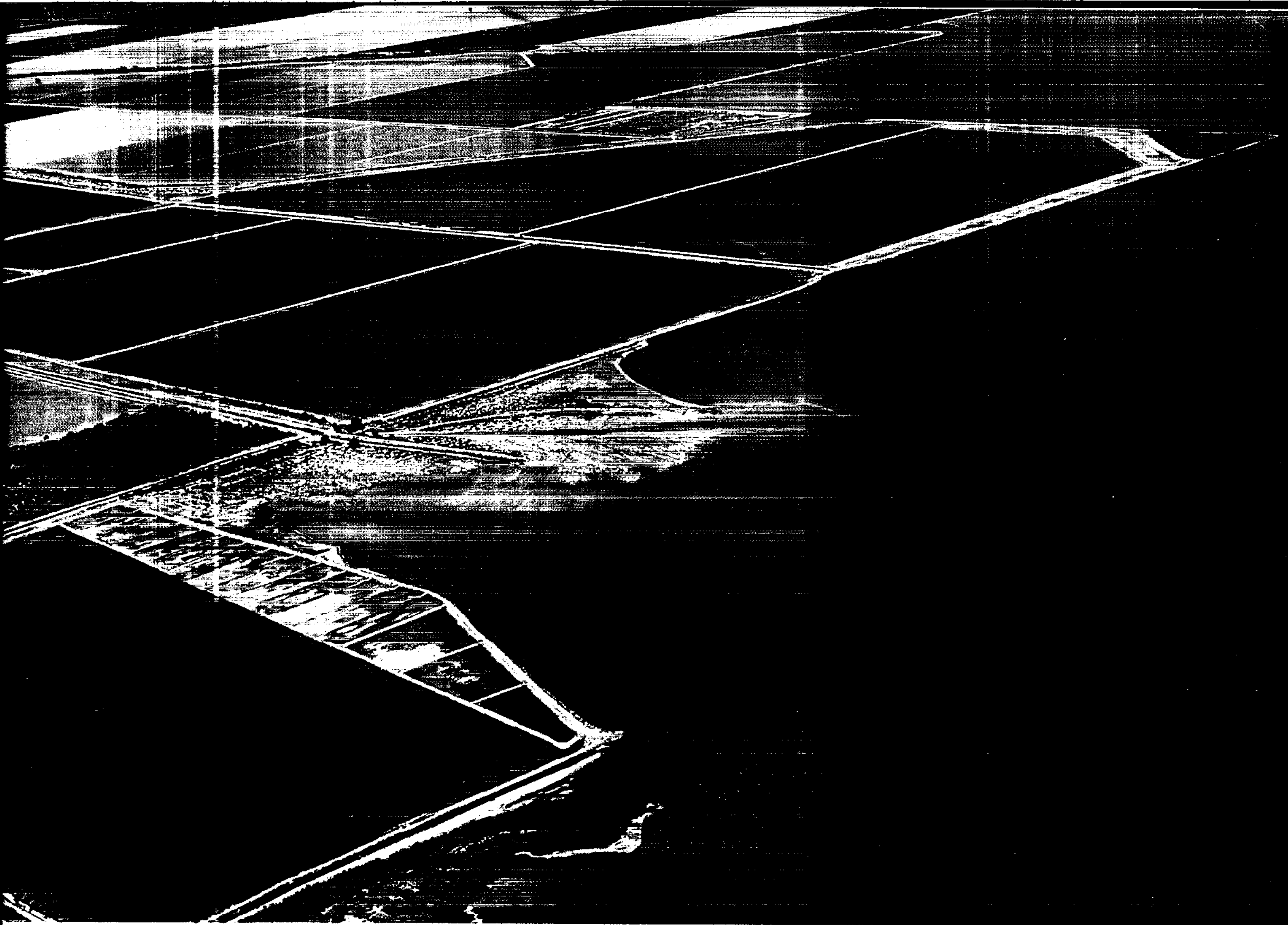
Drainage removes that amount of water that must be passed through the crop root zone to satisfy the leaching requirement. If, for example, a field receives 2 feet of water and the leaching requirement is 10 percent, 0.2 foot of water must pass through the root zone and be removed. Leaching may take place throughout the cropping season as part of normal irrigation, but if not enough is applied or if the soil takes in water too slowly to keep up with crop demand, additional leaching is needed off-season. Between 1946 and 1950, an area of 9,000 to 20,000 acres in the Imperial Valley was leached by continuous ponding. Now, because of better drainage and management, the area ponded is negligible.

Average salt balance calculations determined from input-output studies, as in the Coachella Valley, may be misleading: some fields may be "salting out" while others are adequately leached; also, salts of geologic origin or those stored underground long before irrigation started may affect the salt-output figures while there is still excessive accumulation in the root zone. Extensive calculations made in the Imperial Valley during the 1970s by Rhoades and Kaddah, of the U.S. Department of Agriculture Agricultural Research Service, showed that only one-third of the salt discharged to the Salton Sea came from the root zone. The rest came from the groundwater.

Present situation

The Imperial Valley has 460,000 irrigated acres, 130,000 of which are double-cropped. The Imperial Irrigation District receives 2.8 million acre-feet of water per year in the All-American Canal and delivers 2.6 million acre-feet of this to farm headgates, for an average application depth of 5.6 feet. This water contains, on average, between 850 and 900 mg/L of salt.

About a million acre-feet are discharged to the Salton Sea, with an average salt content of about 3,000 mg/L. Evaporation has concentrated the salin-



The rising water level in the Salton Sea has flooded adjacent farmland and recreational property and has jeopardized the Sea's role as a collecting basin for saline drain water. Evaporation of the land-locked Sea. shown here at the entrance of the Alamo River, has made it more salty than the ocean.

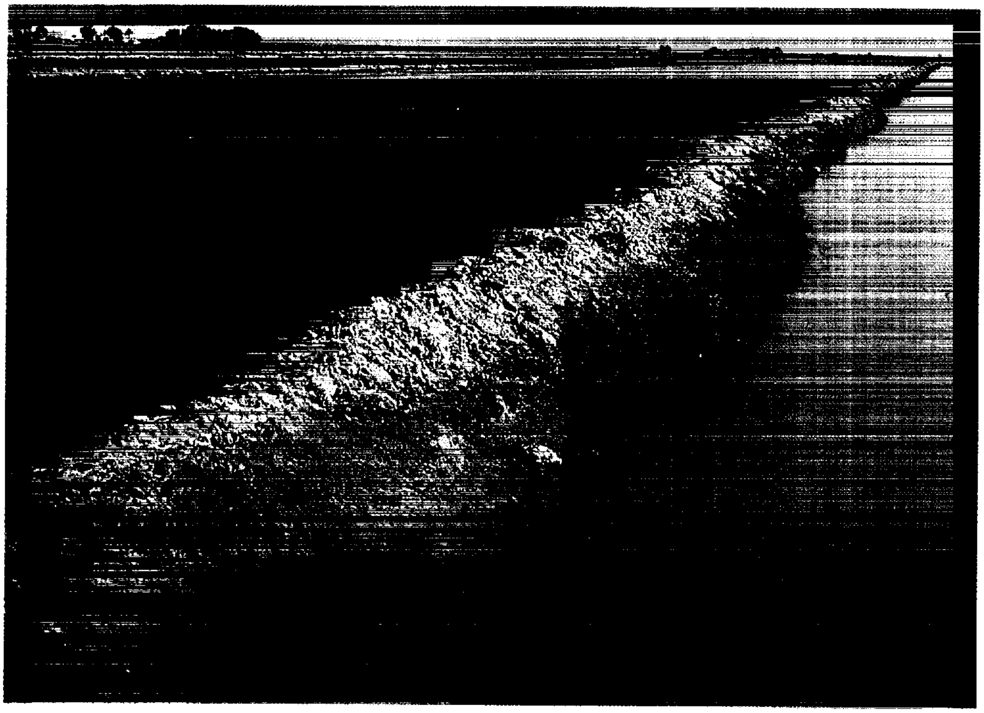
Max Clover

ity in the sea to nearly 40,000 mg/L, slightly more than that of sea water. However, since the drought years of the 1930s, evaporation has not been sufficient to prevent a slow, somewhat irregular rise in the Salton Sea's water level (see graph). Storms have also caused dramatic increases: in September 1976, the water level rose 0.8 foot after a single storm; in August 1977, 0.5 foot. In the spring of 1981 and 1982, the level was above -227 feet. This rise has caused flooding of farmland as well as recreational property near the water.

A question being considered is whether it is technically and economically feasible to reduce the amount of water drained into the Salton Sea without adversely affecting agricultural production. With the present crop mix and production, water use by crops presumably would remain essentially the same, and a reduction in drainage flow would be accompanied by reduced diversions at Imperial Dam.

Recent studies (1984) by researchers

Below: Salt added to Imperial Valley soil by irrigation is leached out by continuous or intermittent ponding. "Berms" hold water in fields.



CA. Beasley

Oster, Meyer, Hermamier, and Kaddah, at the University of California and the U.S. Department of Agriculture Agricultural Research Service, have provided some data on the partitioning of water. In the Imperial Valley, 12 percent of the water diverted becomes deep percolation (leaching water), and runoff (tail water) accounts for 16 percent. In the Coachella Valley, the leaching fraction is somewhat higher, and there is hardly any tail water. Quantitative information from these studies supports the belief that, technically, a reduction in drainage flow is feasible.

Steps have been taken in recent years to initiate water savings and assess the economic consequences of such practices. The federal government finished lining the Coachella Canal in 1981. The Imperial Irrigation District has accelerated its canal lining activities, and it has constructed four off-site reservoirs to provide temporary storage, with plans to construct two more. The District also has established more flexible rules for water orders: instead of receiving a fixed

The UC Mobile Lab monitors water use to help Imperial Valley growers improve irrigation efficiency.

24-hour delivery, an irrigator now can request a reduction in delivery as late as noon of each day and limited changes up to 3:00 p.m. during the final delivery day. Research workers from the Agricultural Research Service are investigating the substitution of drainage water (with 3,000 mg/L salt) for part of the irrigation water and are assessing the potential for "dead level" surface irrigation to eliminate tail water.

The University of California operates a "Mobile Lab" with instruments and equipment, working from the Imperial County Cooperative Extension office in El Centro, to monitor water use and suggest ways to improve irrigation effectiveness. Trained personnel take the lab into the fields of cooperating farmers, where they measure tail water. They also check soil moisture status with neutron probes and recommend irrigation scheduling programs. Measurements in 1983 showed that tail water was noticeably reduced from that observed in earlier years. This reduction was attributed to greater awareness of the problems associated with excessive water use, together with increased off-canal storage and *more* flexible delivery policies by the irrigation district.

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Case history: San Joaquin Valley

Louis A. Beck

Most of the San Joaquin Valley has been farmed in one fashion or another for more than a hundred years The Valley trough was generally dry-farmed until deep-well turbine pumps were developed in the 1930s and 1940s and irrigation became common. Even though much of the land was in production, it was not irrigated every year: there was some pattern of rotation, such as dry-farming for one year, irrigation for two, and fallow for one. Now, almost 5 million acres of agricultural land on the Valley floor are irrigated.

The Valley, about 250 miles long and 50 miles wide, consists of two drainage basins: the northerly San Joaquin Basin, which drains to the San Joaquin River and then to the Sacramento-San Joaquin River Delta and San Francisco Bay; and the southerly Tulare Basin, which normally has no outlet.

Salinity problems in the San Joaquin Valley have adversely affected almost 600,000 acres of agricultural land now in production. Perched saline groundwater within 5 feet of the soil surface causes a loss of 10 percent or more in annual crop production.

This perched water can be controlled by the installation of tile drains — a system of perforated pipes 6 to 8 feet belowground that keep the water level below the root zone. The drains conduct the water to a corner of the field, where it is discharged to a disposal system.

The perched water in the Valley trough is saline, ranging from 3,000 to 25,000 mg/L of total dissolved solids. In other areas where the perched water is not saline, it can be used for irrigation or discharged to watercourses. Saline water must be disposed of so that it does not affect surface or groundwater. It is the lack of safe disposal systems, areas, or methods that causes the drainage problem in the trough of the San Joaquin Valley. The problem area is expected to exceed 1 million acres within the next 50 years.

Development of the problem

The drainage problem became serious in the Valley when a full water supply was assured. In the northern area (essentially within the San Joaquin Basin), problems began about a decade after the Delta-Mendota Canal was built and started to deliver water in about 1950. During the 1960s, tile drain systems were installed to allow farmers to continue normal production. Most of the water from these systems is discharged to the San Joaquin River. Because of the relatively small volume and the dilution in the river, discharge of drainage water causes only slight degradation of the quality of the river and minor changes in agricultural practices.

A water supply to the Tulare Basin was guaranteed when the California Aqueduct started delivering water to the San Luis service area of the federal Central Valley Project and to the State Water Project service area in 1968. Drainage problems began by the end of the 1970s. Now several agencies are starting to implement local interim solutions to solve their drainage disposal problems; drain tile will not help, since there is no river to discharge to or any other system to carry the drainage waters away.

Solution

It was proposed during the 1960s that the state and federal governments together construct drainage disposal facilities that would serve the entire Valley