# MITIGATING AGRICULTURAL IMPACTS ON GROUNDWATER THROUGH DESALINATION

William E. Warne[1] Neil M. Cline[2]

During the closing decades of the Nineteenth Century, there was a growing realization that Federal programs for the settlement and development of the Nation's western frontier were inadequate to overcome the problem of aridity in the lands beyond the 25-inch rainfall line which waveringly followed the 100th meridian.

The Homestead Act of 1862 had been successful in the settlement of the Plains States. In the dry valleys to the West, however, settlers seldom could comply with the five-year residency and development requirements in order to get the title to their homesteads. Not lacking in ingenuity, they diverted creeks and streams whenever they could reach them to water their crops. Contests, sometimes even gun fights, accompanied helter-skelter efforts by riparian land owners to divert water from the erratic streams. New concepts arose to govern the water developments, and old ones were modified to fit the circumstances. The diverter who was first in time became also first in right. The water was considered to be the common property of all the people, and rights attached only to its use. A water right extended indefinitely, so long as the water was being beneficially used in the place and for the purpose for which it had been acquired.

After 20 years of agitation in the western states and territories, Theodore Roosevelt, on coming into the Presidency in 1901, endorsed efforts to

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1) Staffer of the Bureau of Reclamation in Washington D.C., 1935-1943 and Assistant Commissioner, 1943-1947. He was Assistant Secretary of the Interior for Water and Power, 1947-1951; and Director of the California Department of Water Resources 1959-1966.
2) General Manager, Santa Ana Watershed Project Authority (SAWPA), Riverside, California.

establish a national program. His support led to the Federal Reclamation Act of June 17, 1902. The Department of the Interior quickly organized the Reclamation Service, which later became the Bureau of Reclamation, and began the task of bringing order to western irrigation development by establishing at least one reclamation project in each of what are now the eleven western states. These projects, for the most part, were highly successful in regulating the water sources, and in founding sound agricultural communities among which towns and cities grew. The Service helped in the development of institutions such as irrigation districts, and the era of ditch bank shoot-outs was left behind.

After World War I, homesteads in the reclamation projects were in great demand among the returning servicemen. Frequently, scores of applicants competed for each plot that was open for settlement. Even the agricultural depression that set in during 1920 and led to defaults in settlers' repayments of their construction charges, did not dim the enthusiasm for the federal reclamation program. The Congress enacted moratoria on repayments, extended the repayment periods of the water users' contracts from 10 to 20, and then to 40 years. The Reclamation Project Act of 1939 added a ten year development period during which the construction charges, always to be repaid without interest, were postponed.

When in December of 1928, the Boulder Canyon Project Act was signed by President Calvin Coolidge the most ambitious river control project undertaken to that time was placed in the hands of the Bureau of Reclamation. This project broke ground in many fields. The Colorado River drained parts of seven of the eleven original reclamation states. Its flows varied from flood to drought in every year and its annual flows fluctuated by eight or ten magnitudes. It had entrenched itself in grand canyons so that its waters over hundreds of miles could not be reached by people on the rims.

The Bureau proceeded to design and build Hoover (nee Boulder) Dam, a structure without precedent in size, incorporating in the design and plan multiple uses of the water to be impounded in Lake Mead, a

reservoir of a capacity to conserve roughly twice the average annual flow of the river, in order to generate electric energy, supply municipal water to the Los Angeles Basin, Southern Nevada, and Central Arizona, and to protect downstream irrigation projects from flood and drought. The dam paid for itself in 50 years and has built a Colorado River development fund with the excess power revenues.

The Bureaus's success put it in line for a major role in the development of the river basin projects in the West in the period of 1933 to the post World War II years, when it built the Central Valley Project in California, the Grand Coulee Dam - Columbia Basin Project in Washington, and the irrigation and power phases of the Missouri Basin development, the latter in cooperation with the Corps of Engineers, which would build the main stream dams. The opportunities for further developments in the West on the order of these, however, were being exhausted.

In 1950, the Bureau was flying high. Its reputation was near its zenith. Its staff experts were cooperatively loaned to design projects in China, Thailand, Jordan and elsewhere. But the Bureau domestically was confined to the West, and its leaders could see little challenge of scale ahead in that region but development of the Upper Colorado River. They were penetrating Alaska, and examining Hawaii, but programs demanding the full scope of the Bureau's expertise for various reasons did not seem imminent.

In the Summer of 1950, an interior official, returning to Washington from an assignment in Guam, was booked on a bucket-seat military transport that refueled on Johnston Island enroute to Honolulu. The refueling stop was extended by the necessity to make some minor repairs that took all afternoon. The Naval Officer who was in charge of the depot and airfield that covered most of the island, learned that his unexpected visitor had some jurisdiction over water programs of the Department of Interior. For want of something better to do, he ordered up a jeep and took his visitor to inspect the 50,000 gpd desalter that supplied fresh water from the sea. The desalter had rendered the desert island highly

useful as a refueling, and supply base during the Pacific War.

The Navy officer was used to shipboard desalters throughout his career, and thought nothing special had been done when the Navy brought the technology ashore at Johnston Island at the outset of the war. It was all in a day's work. The Interior official, however, was amazed at what he saw.

This was the time in the United States when anything seemed possible and nothing impossible. There were whispering that atomic power might be harnessed to electric generators and produce electricity at costs lower even than the initial rate set on falling water to be used in the generators at Hoover Dam, which was half a mill per KWh. The two technologies, desalination and atomic power, might be tied together to solve many of the water problems that Interior was wrestling with in the West, and that were beginning to appear in other regions of the Nation.

On arrival back at his desk in Washington, the official called together a group of department water experts. A task force was formed under Goodrich W. Lineweaver, an Assistant Commissioner of Reclamation, studies were begun, and in a few months a draft of an authorization bill for research and development of desalination technologies was produced.

By the time the bill was cleared by all of the reviewing agencies and considered in the various committees in the House and Senate, some more realistic appraisal of the chances to obtain virtually free electric energy from atomic fission, and thereby make the water produced by energy-intensive desalting processes cheap enough to use in irrigation, had begun to appear. Nevertheless, Public Law 448, 82nd Congress, Chapter 568-2nd Session, as approved by President Harry S. Truman on July 3, 1952 retained the production of irrigation water for agriculture as the leading objective of the new program that it placed in the Department of Interior. The initial appropriation of $125,000 to finance the program was made during the 1953 fiscal year.

A new Secretary placed the water research and development unit in his office, not in the Bureau of Reclamation. This unit became the Office of Saline Water, later the Office of Water Research and Technology, and nurtured other desalination technologies to go with distillation. Its work attracted world-wide attention. It is rightfully credited with the inspiration of the development of the Persian Gulf desalters that supply potable water to all of the cities along the South Shore of the Gulf and those bordering the Red Sea. The desalting boom that has placed reverse osmosis plants in most of the municipal water distribution systems of the cities on the coasts of Florida can be credited to the program, although the OWRT was phased out a decade ago, and its diminished remnants scattered in other interior agencies.

The Bureau of Reclamation had little part in the interior's desalination push, but when the controversy over the quality of Colorado River water that the United States was delivering to Mexican irrigators became a threat to peace along the border, responsibility for the design, construction, and operation of the world's largest reverse osmosis desalination project at Yuma, Arizona, was placed in the Bureau. The Colorado River historically has been the Bureau's charge. The Water Treaty of 1944 between the United States and Mexico, fixed the quantity of water that the United States must deliver to Mexican water users at roughly 1,500,000 acre feet per year. The language was not clear on the subject of the quality of those waters; at least the quality provisions were differently perceived.

Degraded drainage water was pumped from the groundwater aquifers under irrigated lands of the Bureau's Wellton-Mohawk Project at the lower end of the Gila River basin directly into the Colorado River below Imperial Dam. During periods of low flow in the Colorado River these brackish drain waters elevated the salinity of the water delivered to Mexican users to levels that the irrigators said damaged their crops. Protest riots followed in Mexicali. A State Department study brought a "definitive solution" which involved extending the Wellton-Mohawk drain paralleling the river channel clear to the Gulf of California, and, in order to

preclude the loss of the use of most of the drain waters, which were needed to fill out the allocations of water that had been made to both United States water users and to those of Mexico, the report recommended a giant desalter.

The report led directly to the Colorado River Salinity Control Act of 1964, which directed the Bureau to construct the desalter. After 18 years, the desalter in 1992 has begun operating at about one fourth of its capacity. A part of the delay in completing the great facility and beginning desalination of the drainage water was due to a period of high flows in the Colorado River which made the wastage of the drainage water of no significance to the managers of the river, especially since the diversions into Central Arizona had not yet begun. Requirements of the treaty were readily met during the wet cycle without the expense of operating the desalter.

Nevertheless, the Yuma Desalter was the first employment of the desalination technologies in mitigation of water problems incidental to irrigated agriculture. The treaty obligations, and the hostility engendered in Baja, California towards the United States irrigators, who were their nearest neighbors, may have motivated the Congress, but, the Bureau was finally using the new technologies as an element in its traditional western water management program, as had been anticipated in 1950.

Another and far more pervasive influence on water resources development, whether in the arid West or elsewhere in the Nation, has been the sensational rise in the influence of environmental concerns. Environmental activists have successfully challenged and, in instances, upset such time-honored precepts as first in time is first in right, extension of water rights so long as the water is beneficially used, and the primacy of municipal users and irrigators in the pecking order among water users. The very foundations of some State and Federal water projects in the West have been shaken by the application of the doctrine of Public Trust in the Mono Basin litigation seeking to curtail long-established diversions by the cry of Los Angeles streams feeding the saline sink. For more than a

decade in California, new water developments, planned for the Central Valley Project and the State Water Project have had to be shelved. Released of stored water during drought periods to mitigate environmental and fishery problems have been made at the expense of shorting water deliveries under contracts with municipal and agricultural water users. These contracts of long standing are the bases of the repayments that make the projects economically feasible.

Sea water desalination has been turned to by an increasing number of coastal towns and cities in California as a result of the impacts of the drought, now in its sixth year, unbridled population growth, which has outrun the developed water supplies, and the reallocation of project water to fish and wildlife and other environmental uses.

Concomitantly, overused groundwaters have been degraded, by seepage of agricultural wastewaters into the aquifers from which both municipalities and farmers pump. In instances, health officers have been forced to close down wells.

A new order of desalination plants using membrane processes has begun to appear in such places as the Santa Ana Watershed in Southern California and the Salt River Valley in Arizona. It seems that after all desalination technologies may have a significant place in preserving and further developing irrigation in the West. Desalting sea water for coastal populations averts demands for exchange of water from agricultural users; a practice growing in popularity despite dangers inherent in cannibalizing farm communities. The appearance of toxic elements in groundwater basins that have been used for community services present critical problems, not only in the West, but widely in industrialized regions of the Nation. Desalters can restore these waters.

Reclamation Commissioner Dennis B. Underwood, in testifying before the Senate on Environment and Public Works on Senator Paul Simon's S. 481 last year, gave his enthusiastic support to reauthorization of a revival of research in and development of desalination and other advanced water

technologies to meet the emerging problems associated with water quality. In Section 2, the Declaration of Policy in the Simon bill closely follows the statement in the original 1952 Act. It places uses of the water sciences for agriculture first. The Commissioner said the Bureau was now ready to press forward with demonstrations of how desalting could help meet currently developing water supply problems in the West. When questioned, he said that the Bureau was also prepared to carry the program to other parts of the country where needs are frequently great. The urge to escape the western regional cage remains.

Just as Hoover Dam propelled the Bureau of Reclamation into the forefront of the era of vast river basin developments, the Yuma Desalter may serve to make the Bureau the leader in the new era of water development.

Here are thumbnail case histories of some of the new order of desalination projects that are making their appearance in this decade in the Pacific Southwest.

Groundwater resources have been and remain the most reliable water supply throughout Southwestern United States. Historically groundwater was the only source of supply for most of the 100 years of active farming that has occurred in this region. However, as urbanization has occurred, particularly in Southern California, there has emerged a problem with groundwater quality attributed primarily to agricultural practices, landfill operations, industrial programs, wastewater discharge and sea water intrusion. The accumulation of total dissolved solids (TDS) and nitrate in addition to volatile organic compounds in the groundwater supply has caused thousands of wells to be abandoned. Continuing degradation is expected to occur as contaminants in the vadose zone are leached to the water table, or are conveyed as plumes in subsurface flow.

In the arid southwest, where competition for available water resources has always been intense, the potential loss of any water resource is unacceptable. The Metropolitan Water District of Southern California (MWD) in an aggressive program

to control the pervasive diminution of supply has introduced its "Groundwater Recovery Program" to assist local agencies in combating the loss of groundwater reserves. The Groundwater Recovery Program provides that if a local water agency constructs a groundwater recovery system to salvage brackish water, MWD will purchase the supply and will pay, in 1992-93 up to $572 per acre-foot for the water. MWD will in turn market the water to its customers at the wholesale rate of $322 per acre foot, so that the local user pays the same as if the water were imported from Northern California or the Colorado River. Under this program MWD buys high and sells low. Metropolitan expects to expand this program to 200,000 acre-feet per year in the next decade.

This innovative and progressive program has stimulated the consideration and implementation of many new brackish water desalting systems in recent months. Some examples:

ARLINGTON DESALTER, Riverside, CA

The Arlington Basin contains about 300,000 acre-feet of water degraded by agricultural leachate from historic citrus grove operations. The average quality of the supply is 1100 mg/l TDS and 90 mg/l Nitrate. Because of the quality, all pumping has been discontinued which will result in impaired groundwater seeping to the surface and draining to the Santa Ana River and elsewhere, thereby contaminating downstream and adjacent water supplies.

The Santa Ana Watershed Project Authority (SAWPA) a joint powers agency of 5 local water districts that manage the water resources of the Santa Ana River, has constructed the Arlington Desalter facility. This plant is designed to produce 4000 acre feet of desalted supply that is blended with 2000 acre feet of untreated groundwater to yield a total of 6000 acre feet per year of potable supply available for direct groundwater replenishment uses.

The facility is a reverse osmosis plant fed by 5 wells. The brine is discharged to the Santa Ana River Interceptor, an industrial discharge line that is tributary to Orange County's treatment works, where the brine is commingled with local waters, and ultimately discharged to the Pacific Ocean. The average cost of the desalted water: $400 per acre foot.

TUSTIN DESALTER, Tustin CA

The City of Tustin, CA has lost six wells in the last several years to excessive nitrate and TDS. In cooperation with the Orange County Water District (OCWD) the City has installed an ion-exchange system and a Reverse Osmosis desalting plant operating from water supplied by the impaired wells. The annual production for domestic use is about 3500 acre feet per year at a cost of $500 per acre foot. A second stage of this program is currently in design stage and will add another 3200 acre feet of water to the city's drinking water supply. The proposed facility will use reverse osmosis technology to treat impaired water supplied by three wells. The estimated cost of the product water is $480 per acre foot. The new plant is anticipated to be under construction in 1993 and on line in 1994.

IRVINE DESALTER, Irvine CA

The vast Irvine Ranch area of Orange County, California has been intensely farmed for over a century. In the early years the ranchers relied upon local groundwater, and since the early 1950's have used large quantities of imported Colorado River water for irrigation to raise both citrus and a wide range of row crops.

A combination of heavy fertilization, irrigation with relatively high (600-700 mg/l TDS) mineralized Colorado River water, and recent contamination, including TCE, believed to have originated from several military installations on the Ranch, has caused the OCWD and the Irvine Ranch Water District to enter into an agreement to construct, operate and, in cooperation with MWD, fund a 6700 acre foot

per year desalination facility. The desalter is expected to cost about $30.0 million, and will provide potable water for local use for an estimated $600 per acre foot. Anticipated completion date is 1995.

SAN JUAN CAPISTRANO, CA

The San Juan Basin in South Orange County California was at one time pumped heavily to support citrus and field crops. Naturally occurring groundwater quality was marginal, and has further degraded with time due to the agricultural return percolation. The current quality in the ranges from 2000 mg/l adjacent to the Coast to 350 mg/l in the upper basin area. A management plan to utilize the basins storage capacity in conjunction with artificial and natural recharge has been devised. It is planned that up to 5000 acre feet per year will be pumped in the lower basin which will cause some controlled sea water intrusion. The water will be desalted using reverse osmosis technology and used for potable purposes in the San Juan Capistrano area. The management plan anticipates that on an emergency basis, the short term yield of the basin will be increased to 10,000 acre feet per year. The plant is expected to be on line by 1994. Estimated costs of product water $550 AF.

OCEANSIDE, CA

The City of Oceanside, California in San Diego County is planning to construct a 2.0 MGD desalination facility to salvage impaired groundwater that has degraded as a result of agricultural activity. The site design work has been completed, the production and monitoring wells have been constructed and site preparation has begun. The bids to construct the proposed reverse osmosis plant are expected to go out in the fall of 1992. Estimated water cost: $400 AF.

CHINO, CA

The lower Chino Basin, in San Bernardino County, California is the location of the largest concentration of dairy stock in the United States. There are currently 300,000 dairy cattle occupying about 15,000 acres. The mix of historic agricultural activities in the Chino Valley and the on-going dairy operations has resulted in widespread loss of local groundwater resources to TDS and nitrate. To prevent further deterioration of local supplies and to protect the nearby Santa Ana River, SAWPA is preparing to construct the Chino Desalination System. The project will include two 6.0 MGD desalination units using either reverse osmosis technology or an electro dialysis reversal process. The quality of local groundwater ranges from 800 mg/l TDS to 1100 mg/l TDS and nitrate from 50 mg/l to 300 mg/l. The treated water about 12,000 acre feet per year will be utilized by nearby cities to offset imported water requirements. The estimated cost of the project is $48.0 million. The product water will cost an estimated $570 per acre-foot. The plants and support systems are presently being designed, and are expected to be on line in 1994.