THE SALTON SEA AND THE IMPERIAL VALLEY: DISASTER AND SUCCESS

Introduction

The Salton Sea is an inland waterbody, without an outlet to the sea, encompassing a surface area of approximately 375 square miles. It is an extraordinary lake, not simply because of its high salt content or its situation well below sea level in the middle of a severe desert - the Dead Sea can claim the same - but also because it is the product of human activity. The result of an engineering accident, the Salton Sea is a vivid symbol of the radical alterations of the regional hydrological system carried out ~~by~~ in the arid west of the United States. Interventions of this sort have, indeed, formed the basis for the settlement and economic development of this huge region. These practices, moreover, have an ancient lineage, reaching back to the foundation cultures of our civilization in the Fertile Crescent of the Middle East. Accident though the Sea may be, the canal systems which created and sustain it are certainly not failures: they support one of the most productive, profitable, and many would say wasteful agricultural areas in the world.

The story of the Salton Sea is one tale within the complex narrative that describes the taming of the Colorado River by American society. That river has been dammed, managed, and consumed for potable and irrigation water to the point that its discharge in the Gulf of California is now a mere trickle, instead of the silt laden torrent it once was. The Bureau of Reclamation's drive to cultivate the arid expanses of the desert areas north of the Mexican border, in accord with its "home building" mission, built the dams and canals that tap the Colorado River upstream of the Salton Sea. The works irrigating the lands near the Salton Sea, however, were begun before the massive works of the U.S. Bureau of Reclamation were constructed, but the logic behind them was the same, and in some ways more compelling: by intervening in the existing hydrological system water could be diverted from where it was not being consumed, to where it could irrigate fertile, but utterly dry soil. This was accomplished in the Imperial Valley, the name given to the agricultural area at the southern end of the Sea, with relatively little work. Although the development of this area was a fine example of the American penchant for land speculation by shady financing, its engineering principles were sound.

The Salton Sea might appear to be of a piece with many of the western water developments that are often criticized as shameless "pork barrel" projects without economic justification, but in fact it is not so. The Imperial Valley development was begun prior to the formation of the Bureau of Reclamation, and it initially flourished without that agency's support. Its geographic situation did not require large dams, pumping works, or other public investments. Its cost/benefit ratio was exemplary.

Given the fact that the a sea has existed off and on for centuries there, it is difficult to arrive at an overall environmental assessment of the Salton Sea. Is it a disastrous modification of the local landscape, an early twentieth century harbinger of the ecological destruction that is currently descried so widely, perhaps a mirror image of the ecological havoc of the now disappearing Aral

Sea, or was it, perhaps, "worth it" to flood a few hundred barren miles of desert to produce a fabulously productive agricultural region? To a large extent, these questions cannot be answered definitively; only given responses based on one's values. But in order to make a beginning, we must first place them in some sort of historical context.

Natural History of the Salton Sink

The Salton Sea is located just north of the Mexican border in the southern Californian dessert (see Figures 1 and 3). Before there was the Salton Sea there was the Salton Sink. That was the name given to the large surface depression that occupies the area and which had been for centuries a dry, crusty, desert bowl (Woerner, 1989). That the area had at one time been a lake is revealed by the surficial formations around it and the fossil evidence of local strata (Cory, 1915).

Prior to the last glacial era, the Salton Sink was beneath the ocean, part of a submarine extension of the rift that extends northward from the Gulf of California. Local strata reveal the presence of several varieties of marine shells which indicate the longstanding nature of the area as an inland arm of the sea. (Figure 2 supplies an summary of the surface geological features.) The Colorado River, which would eventually form the Salton Sea, joined the ocean at just south of where it is now joined by the Gila River, about 100 miles north of the present delta (Cory, 1915).

As the region ~~was~~ gradually rose due to a general continental uplift, the ocean retreated southward and the Colorado River began its work of separating off the Salton Sink from the Gulf. Large silt deposits from the shifting delta of the powerful river built up a barrier between the depression of the Sink and the open water of the Gulf of California (Cory, 1915 and Kennan, 1917). The Gulf presently experiences extremely powerful tides, and it is thought that this tidal action from the south, inferred from ancient shoreline formations, may have aided the construction of this barrier (Cory, 1915).

At some point in this process, it appears that the Colorado River changed its course and emptied into the sink, creating a huge freshwater lake, Lake Cahuilla, with an outlet to the Gulf. The surrounding region exhibits bench formations at an elevation well above the current water level that are indicative of wind accelerated wave action on a lake shore, and the presence of freshwater shells is evident (Cory, 1915).

Eventually, the Colorado, active then as now, shifted course again, leaving the lake to evaporate and become a depression for receiving the occasional flood waters that would overflow the river's banks. Indian folklore has it that the lake disappeared little by little over hundreds of years: during the nineteenth century, it rarely had more than a few feet of water at its lowest point 280 feet below sea level, feed by a few artisan wells, local precipitation, and surface runoff (Hely, 1966). This was the lowest point in the United States, approximately 300 feet below sea level, before it was inundated and ceded that distinction to the Mojave Desert (Woerner, 1989).

Because the area functioned as a blind sump, that is a collection point with no outlet, the mineral content of the small amount of water there grew continuously higher. When the water evaporated under the fierce attack of the desert sun, a saline crust remained. Similar dry lakes, white with salt accumulations, dot the landscape of the Mojave and the Nevada desert, and soil in many areas of the region is highly alkaline. They are a feature peculiar to regions with this combination of desert climate, intensely concentrated periods of rainfall, and local relief. The sink was a place where water entered but did not leave, and it was salty: thus the name.

The evanescent lake followed the pattern of other salt lake beds, filling briefly with water until the flow was cut off, and then quickly evaporating under the desert sun. Gradually, the Colorado, which was prone to tremendous floods and which carried an enormous silt load, raised its bed and its banks to the point that this overflow sink was cut off from the main river. The low hills that separate the Salton Sea from the Gulf of California are the work of this flood deposition by the Colorado. At the same time, the regional geologic uplifting of the terrain caused the Colorado to follow a new, slightly different course to the sea that ensured its virtual isolation from the now enclosed Sink. Since that time, the Sand Hills, low sand dunes, grew in a north-south direction to the southeast of the Salton Sea, providing the major obstacle to future irrigation development. The only connections that remained were the channels of the Alamo and New Rivers, usually dry, but diverting some water into the area during floods on the Colorado (Hundley, 1966).

Geographically, the Salton Sink is part of the Colorado River delta formation from which it is now separated. The present delta of the Colorado River, at the Gulf of California, is a live delta, i.e. its form is changing continually under the impact of each season's flow. Rather, the delta *would* be live if the flow of the river had not been so radically reduced by agricultural consumption upstream in the United States (Hundley, 1966). During the height of the Salton Sea disaster, the entire volume of the Colorado River's flow was diverted to the Salton Sink, leaving the Gulf delta dry. Today, approximately 42 percent of the river's flow below Davis Dam (about 125 miles downstream from Boulder Dam) is diverted to the Imperial Valley.

The Colorado River drains approximately one twelfth of the United States and it carries with it a rich load of sediment. The alluvial deposits it created in the Salton Sink have been estimated to be up to 10,000 feet thick in places and they provide a rich base for intensive agriculture (Hundley, 1966). These facts were recognized immediately by early visitors in the 1840's: only a lack of capital restrained the area's development then.

It is unremarkable that human beings would seek to make the Salton Sink bloom with agriculture. Throughout history, many of humanity's great societies have thrived in hot and dry locations where such rich alluvial material is delivered by great rivers. Often the civilizations that have flourished have grown up directly on the deltas and flood plains of these rivers despite the periodic destruction that ensued from floods; in others the application of hydraulic engineering expertise directed the waters away from the natural course to adjacent fields that might be inundated very infrequently, or perhaps not at all in historical memory. Although writers such as Reisner (Reisner, 1986) deplore and ridicule the development of the Colorado as a monstrous and profligate waste of resources that is somehow irrational, the simple fact is that its floodplain lands are fertile, they just lack adequate rainfall to be arable: engineering can eliminate this drawback. There are valid economic and environmental arguments which may be raised about such development, but their principles are not open to question. Only the extreme heat and desolation of the Salton Sink region are remarkable.

Southern California as a whole does not have a great deal of annual precipitation, and it is often called a semi-desert. The Imperial Valley, Salton Sink, Death Valley and other nearby areas are inland regions located behind the Santa Anna, San Jacinto and San Bernadino mountain ranges that effectively block the inland travel of any rain clouds. The average summer temperature is 92 degrees F and temperatures of 124 F in the shade are not uncommon. The humidity is very low and the winters, when temperatures may drop to 20 F in the night are short. Average precipitation in the Salton Sink is approximately 2.5 inches per year.

Given its disposition as a regional sump, the Salton Sink, in another climate, might have existed as a spring fed lake or pond. The meager groundwater resources that exist, however, have the Colorado River during flood state as their source. Local precipitation is so slight that the continual heat removes most any water that does manage to recharge local aquifers.

The essential economic fact of the Imperial Valley's topography is that it is at a lower elevation than its water source. The southernmost end of the Salton Sea, as it is shown on the USGS 1:250,000 map of 1969, is approximately 52 miles from the Colorado River to the east. The water surface of the Sea at that time the map was made was 231 feet below sea level: between it and the Colorado was a topographical divide with an elevation of approximately 1000 feet, while the river itself was at an elevation of less than 200 feet above sea level. Just north of the Mexican/American border, however, the nearly flat terrain that is the irrigated portion of the Imperial Valley is practically joined to the expanse of the current Colorado delta, a broad, flat area slightly above sea level. There is a broad and well defined slope from the river delta area down to the Imperial Valley. The only obstacle to the free transmission of water from the Colorado to the Valley is the small range of hills, the Sand Hills, running north-south, between the river and the Valley, just north of the Mexican border.

The importance of these facts about the terrain lies in the lack of need for extensive engineering works: if a simple canal could be made to pierce these hills, the flow of water would proceed entirely by gravity. This is in marked contrast to many of the massive undertakings carried out by the Bureau of Reclamation in the arid west. Many of these projects were designed for areas where the water source flows in a deep gorge or canyon, well below the level of the surrounding land to be irrigated. Often there were large mountains intervening. The resulting projects usually included huge dams, pumping works, and canals and aqueducts, while the enormous cost required the construction of additional "cash register" dams to generate hydro-electric power that would pay for the entire works. Judged purely in economic terms, the cost-benefit ratio of these projects was often remarkably low. The Imperial Valley shares none of these characteristics, nor did it partake, initially at least, in government subsidies that are part of the Bureau of Reclamation's way of doing business (Reisner, 1986). However, like the big dam/water projects, there are many reasons for considering the Valley extremely wasteful.

Development of the Imperial Valley and the Salton Sea

The Imperial Valley was to be the first major irrigation, or reclamation project in the arid American west, not including the extinct Native American civilizations that flourished in nearby regions centuries ago (Woerner, 1989). The attitude that one takes towards this tremendous enterprise has much to do with one's basic biases about the proper role of human beings in the world, i.e. whether they are here to subdue and bend nature to their will, or whether they should take a more deferential stance that refuses to tamper with it on a grand scale. The conflict is nicely exemplified by two students of water management in the west, William E. Warne who proclaims himself forever proud to have been a "Bureau of Reclamation man" (Warne, 1971), and Marc Reisner who has written scathingly of that bureau, and who calls Warne and many others, "water mad" (Reisner, 1986). While the exponents of large scale modification are on the defensive in contemporary times because of concerns about maintaining the integrity of ecosystems, in the nineteenth century when the Salton Sea first came to the attention of land speculators, extracting financial profit from the land was the dominant value of the day.

The first American on record expressing an interest in the Salton Sink was Dr. Oliver Wozencraft of Ohio. He passed through the area in 1849 on his way to the gold fields of California during the Rush, and recognized the latent agricultural potential of the area. His plan was to divert water from the Colorado through the channel of the Alamo River which was dry most of the year. This would entail engineering headworks at the Colorado's juncture with the Alamo in Mexico, but it would avoid the need to over come any topographical divide: the Alamo channel already functioned as an occasional overflow for flood waters which flowed by gravity to the Sink.

Nothing came of Wozencraft's plans since he could not gather backers for his scheme. In 1853, William Blake (no less visionary than his namesake) toured the area while working as a surveyor for the Southern Pacific Railroad. He too was aware of the agricultural potential for the area, but his impressions of the feasibility of the irrigation plans was totally negative. He feared that the elevation differential between the Colorado where the Alamo begins, and the Salton Sink itself (approximately 500 feet) was too great for safety. Eventually, he thought, a flood on the Colorado would overwhelm the engineering works and turn the sink into a lake. Subsequent events proved him correct (Woerner, 1989).

With the booming American economy of the 1890s, land speculation in southern California exploded. Local boosters all over the country sought to lure capital into their region, and they often stretched the truth in their descriptions of the real estate for sale. Words such as "desert" and "sink" were avoided in publicity for the area because of their obvious negative connotations. Renaming the Salton Sink the Imperial Valley was a benign bit of promotion: advertising it as a "garden spot on earth" perhaps banked too heavily on expected developments than the barren expanse warranted, but it turned out to be literally true. Response to the advertising was especially strong in the New England area of rocky soil and small farms (Kennan, 1917). It was during this time that Charles Rockwood and the engineer George Chaffey formed a dummy corporation to gather funds and direct promotion of the area for which he foresaw a glorious economic future.

The pace of events moved quickly at the time: by 1900, a small, short canal had been dug to permanently connect the Alamo River channel with the Colorado. The canal and the junction point were on Mexican territory, and the headworks were at Yuma. The Mexican government objected to the use of their land for the exclusive benefit of the Americans, but the government at the time was insecure, feared local insurrections, and feared that taking a hard line would provoke the United States to seize of the Baja peninsula, so it did nothing. The first irrigation water was delivered to the Imperial Valley on June 21, 1901 (Hundley, 1966).

The success of the development scheme was immediate: there were 150,000 acres under cultivation by 1904, and the demand for more land was great, as was the resultant pressure for more water. The farming population grew from 2,000 in 1903 to 20,000 in 1905 (Cory, 1915). Eventually, in 1918, the Coachella Valley at the north end of the Sea received its own extension of the canal which released it from dependence on well water (Humlum, 1969). Unfortunately, the silty nature of the Colorado River worked against the initial schemes, and the first canal was prone to continual silting up. This reduced its conveyance capacity and required repeated and costly dredging. In fact, silting of all the water delivery canals, from the main lines, to the smallest of the networks, was a continual problem for years in the Imperial Valley. A special dredging machine, the Ruth Dredge, which was fitted with a telescoping arm mounted on tractor treads was used to straddle the canals and keep them free flowing (Livenois, 1982).

The Imperial Valley was in many ways the ideal site for "land reclamation"; fertile soil, lack of rainfall, no previous development, a good growing climate, and a water source that was within "striking distance" (a Bureau of Reclamation phrase) of the fields. No pumping or massive damming efforts were required since the river did not run through a deep chasm or gorge, and the fields were down-gradient from it. It is because it was so well suited for reclamation, that the development of the Imperial Valley predates the great efforts of the Bureau of Reclamation: the process was able to proceed without the massive subsidies inherent in federal intervention. The sediment load and periodic catastrophic floods of the Colorado were the only major negative factors, leading as they did to a continual need for dredging and vigilance.

In fact, the federal government was more nearly an obstacle to the development of the region in its earliest days. A report by the U.S. Department of Agriculture in 1902 stated that the soil was excessively alkaline, and that little would grow in it (Kennan, 1917). Since early farmers in the area had already met with great success, the effect of the report, later dismissed as in error due to poor sampling of the area, was merely to dampen enthusiasm for the area. Had the report been issued a few years earlier, the Imperial Valley might never have been.

In order to overcome the limitations of the original canal and intake system, a new intake was built four miles south of Yuma in Mexican territory. The intake was six feet deep and approximately 50 feet wide, and the run to the Alamo was about 3,330 feet. The works were built in great haste because Rockwell and Chaffee feared lawsuits and bankruptcy if the water stopped flowing to the fields or if shortages developed, and no proper headgates were supplied (Hundley, 1966). Headgates function as do locks; they shut off the flow of water when it is desired or needed to restrain flood surges. The danger of floods was considered minimal since of the last twenty-seven years, only three had seen major floods. In fact, several writers from the time, commenting after the disaster, remark with amazement that nobody foresaw the possibility of flood or inundation (Cory, 1915, Kennan, 1917). The speciousness of this reasoning become apparent immediately.

In October of 1905, very high flows in the Gila River, a tributary of the Colorado, raised the level of the river beyond the level that could be accommodated by the new intake. The opening began to grow at once, and rapidly become a gaping 600 foot hole in the river bank. The depth of the connecting canal was scoured to four times its original depth, from six to twenty-four feet, and the Colorado River channel below Yuma was totally dry. All its waters were being diverted into the Salton Sink which was filling at the rate of one-half foot per day. Because of human intervention in an area of unique topographic conditions, the river had readily transferred its load to a new path.

Although most of the area was developed only as agricultural, the losses incurred during this flooding included the Liverpool saltworks, a longstanding factory, and the small town of Salton. The towns of Mexicali and Calexico were wrecked by the torrential flows of the Alamo and New Rivers. Most important for the future of the region, the rising waters threatened to submerge the right of way and tracks of the Southern Pacific Railroad which eventually was forced to move more than forty miles of track to higher ground.

The events in the Imperial Valley inspired panic in wider circles: the railroad was justifiably worried about its assets; the new Bureau of Reclamation (formed in 1902) was concerned that the developments would threaten its planned Laguna Project nearby; investors in Rockwell's dummy corporation, the California Development Company (CDC), feared financial ruin; and other land speculators both north and south of the Mexican border were afraid that the worth of their lands would be jeopardized. Crowds turned out to watch the dramatic waterfalls that formed on the Alamo and New Rivers as their tremendous flows excavated the soft, unresisting alluvial silt forming their channels, "washing away the soil like powdered sugar". These falls, remarkably, were visibly moving *upstream* as the backcutting of the channel proceeded at a rate of 4,000 feet per day at places (Kennan, 1917). It was estimated that the volume of soil removed by these actions was four times that excavated for the Panama Canal, and that forty miles of cut-back channels were created. These channels, the beds of the Alamo and New Rivers, would later "provide a benefit...in excess of their destructive" activity, i.e. they would serve as ideal conduits for subdrainage that would keep the soil salinity to manageable levels (Cory, 1915).

The most apocalyptic fears (not all that outrageous in geological terms) were that the flooding would allow the Gulf of Mexico to breach its separation from the Sink, and so extend northward all the way to Indio, some 150 miles north of its current shoreline. This would have reestablished the ancient configuration of that sea.

The events of 1905-06 in the Imperial Valley were described in terms redolent of Biblical cadences by many: the parallels with the story of the Flood, brought on by mankind's arrogance, were too obvious to miss. Unlike other major flood areas in the world, the Nile River, the Mississippi, the Yellow River, where relatively flat floodplains would be periodically submerged by swollen rivers, this was a "cosmical plunge of a great river...into a basin" (Kennan, 1917). As the attempts to staunch the flow of the flood waters became too great a financial burden for the CDC, an arrangement was made to transfer the bulk of its stock to E. H. Harriman's Southern Pacific Railroad. To some, Harriman was a figure equal in stature to the Flood, and he became the salvation of the area.

In The Salton Sea, written in 1917 by George Kennan, Harriman is lionized as a man of tremendous will, drive, and generosity. Only his selfless dedication to the salvation of the little farmers of the Imperial Valley were responsible for his zeal in spending 1.5 million dollars on men and equipment to halt the inundation. At the time, Harriman was being prosecuted by the Interstate Commerce Commission, and he had been labeled an "undesirable citizen" by the trust buster, President Theodore Roosevelt. The position of the federal government was that the Southern Pacific was legally and financially liable for the damage being wrought, and that it alone must halt the flood. Harriman disputed this of course, but his stance of altruistic savior may well have been an attempt to reap good publicity from a parlous financial situation. The result was that the federal government remained uninvolved in the Imperial Valley at yet another crucial juncture in its history.

With the Southern Pacific in charge, work on stopping the flood was well financed and backed by tremendous engineering resources, although it still proved difficult. Previous attempts by the CDC to halt the inundation by dumping timber and soil into the breach had all failed. The Southern Pacific, spurred by the desire to protect its route and avoid financial damages, pursued its goal with monumental caravans of rail cars filled with spoil to dump into the breach. In August of 1906, it began to dump up to 200 hundred rail cars a day, all filled with rock, gravel, and dirt, into the breach. By November of that year, the flow was halted until a new flood surge destroyed all the levee works and restarted the flooding of the Sink.

In 1907, 1,275 men, seven locomotives, and 175,000 cubic yards of material managed to fill the breach in a conclusive manner. The Colorado River resumed its old path to the Gulf of California, although it now flowed in a channel that had been locally raised as much as twelve feet. In all, there had been six failures over a period of two years that cost the backers of the Valley millions of dollars (Woerner, 1989).

At the time that the flooding of the Salton Sink began, there had been some water in the depression, enough to bring the water surface elevation to about 273 feet below sea level. At its height, the Sea had a surface elevation of 201 feet below sea level and covered an area of 300,000 acres. In 1907, the level of the Salton Sea was falling from its all time high, and it was believed that within fifteen or twenty years, it would disappear (Kennan, 1917). Thus, just as few foresaw the possibility of the Sea's creation, few expected it to remain.

Responses to the Inundation

The devastation and disruption of the flood impressed on local farmers and developers alike the need for more reliable management of their water resource. The primary desire was for a canal that would not flow through Mexican territory on its way to the Imperial Valley. This involved many difficult issues of international water rights to be negotiated with Mexico, and there were many local interests that played both sides of the controversy on both sides of the border.

The reasons why a canal on American territory, an All American Canal as it was finally called, were two-fold. Maintenance of the works would be easier since the instability and sometimes hostility of the Mexican government, which was not reliably stable at the time, would no longer be a factor. In the case of an emergency, resources could be rushed to the spot without prior consultation with a foreign power. The Mexican government often forced companies that crossed the border to repair the canal to pay duties on equipment and manpower, often in a capricious and corrupt manner. An All American Canal would eliminate these difficulties.

The All American Canal was also seen as more fair to American farmers who were currently shouldering much of the cost of flood control work required to keep the public works in good repair. It was believed that the Mexican farmers did not maintain their public works, or develop the required protections against floods. Since much of the Mexican land sloped northward towards the U.S., any flooding that occurred in Mexico was bound to affect the Imperial Valley. Some American investors, such as the Los Angeles mogul Harry Chandler, owned a great deal of land in Mexico near the border. These men fought vigorously against the Canal, claiming it was a waste of money, but in fact because it would end their free subsidy by American farmers (Hundley, 1966).

Because of the regional implications of Colorado River development, the federal government did eventually become involved. A committee was formed to study the problem and it issued its report in 1922, known as the Fall-Davis Report. This document recommended the construction of the All American Canal and a storage dam at Boulder on the Colorado River. Advocates of the canal had opposed provisions for the storage reservoir and dam because they felt that its cost would decrease chances of congressional approval for the entire package. Storage was not essential for the economic viability of the Imperial Valley because the irrigations was accomplished with gravity flow.

The signing of the Colorado River Compact in 1922, negotiated by Herbert Hoover, provided a legal basis for the implementation of the Fall-Davis Report. The agreement apportioned the waters of the river among the several river basin states for use in irrigation. The amount of water that would be left for use by Mexico was not considered, and was left as a further subject for international negotiation. Naturally, the Mexican government feared that the United States would proceed to develop the river basin and leave no fresh water for consumptive use by Mexico unless they brought heavy pressure to bear. Mexico feared in particular that the All American Canal would reduce useable flows into the border region to below what was required for land currently under development. Although the dam at Boulder, now known as Hoover Dam, was completed in 1936, and the All American Canal with a peak capacity of

13,000 cubic feet per second (Humlum, 1969) and its diversion works called the Imperial Dam was completed in 1942, the question of Mexico's water rights was still being thrashed out in the late 1940s. It remains an issue in U.S.-Mexico relations ~~today~~ 1971?! (Warne, 1971).

The All American Canal provided a secure and cheap source of water to irrigate the fertile Imperial Valley soils, and from the time the first waters were delivered, the profits continually broke records throughout the post-war period. The Valley was the perfect site for the development of large scale mechanized commercial agriculture with its completely flat and treeless landscape (Hundley, 1988).

Farms which received water from Bureau of Reclamation projects were supposed to be of 160 acres or less. This reflected the "home making" mission of the Bureau, the goal of settling the west with independent citizen farmers. Although the Valley was initially developed before any federally subsidized water was delivered there, the completion of the All American Canal changed that. The Valley, which had organized the semi-public Imperial Irrigation District in 1911 as a response to the poor management that created the Salton Sea flooding disaster, fought against all restrictions on farm size. They were joined in this fight by large landowners throughout the west who were receiving subsidized water in violation of the letter of the Reclamation law. By its own admission, the Bureau never strictly enforced the acreage limitation, and it was never a serious threat in the Imperial Valley. This aided the region's development as a mechanized agricultural center (Hundley, 1988).

The Current Regime - Quality and Quantity

Concern for the waters of the Colorado River during the development of the Imperial Valley centered almost exclusively on the quantities of water that could be secured for irrigation. Little attention was paid to what was later to become a significant problem, the concentrations of minerals, principally salt, that the water contained. Salt is very harmful to most agricultural crops, and the amount of water required for healthy plants increases with the salt concentration. Developments upstream of the Valley are continually increasing these concentrations. The two factors that raise the salinity of water in the All American Canal are the extensive development of the Colorado Basin by the Bureau of Reclamation, and the natural saltiness of some of the basins that are developed. As mentioned earlier, salton sinks abound in the desert landscape of the arid west: they have been forming for millennia, and many regions have a high salt content in their soils, or have extremely alkaline soils. Without development, these minerals would remain locked within the inert and unused soil.

Development of these desert lands with irrigation releases accumulated salts and minerals and concentrates them further. Water from the Colorado is reused several times in its course towards the sea, and each step raises its mineral content. Water is removed from the river bed or impounded behind dams for irrigation for application to fields: A great deal of the applied water evaporates under the intense sun, while still more is transpired through the leaves of the crops. The water that is left in the ground to percolate through the soil back to the flowing river has a much higher mineral content than the water originally applied. In its journey through the soil complex back towards the river, additional salts are added in regions where the soil is already highly saline.

The "recycled" water continues on its trip down the river and is impounded several more times behind irrigation dams (seven in the Lower Colorado Basin alone). Dams present a large surface area for evaporation, and they are a principal means by which the mineral concentration is increased again. Farmers cope with the problem by over watering their crops: caught in a vicious cycle, they must use additional water to flush salt from their fields which increases the salinity of water downstream. It is not uncommon for fields to receive more than ten feet of water for irrigation. In the Imperial Valley, farmers have installed hundreds of thousands of tile drains to carry off the excess water that is applied to flush out salts. They have also developed the practice of planting at mid-height on the side of the furrow: salt is carried by capillary action to the furrow apex where it collects without harming crops (Warne, 1971).

Water that finally reaches the All American Canal often contains salt in excess of public health limits on potable water (1,000 ppm). Definitive guarantees of water quality were never included in any of the water agreements negotiated with Mexico by the United States, and it is predicted that by the year 2,000, the salinity of water at the U.S.-Mexican border will be near 1,350 ppm (Warne, 1971). Increasing salinity of the irrigation waters delivered by the

All American Canal also have significant impacts on the Salton Sea itself. The salinity of water which is delivered to Mexico in the Colorado River continues to be an area of diplomatic dispute.

The Hydrological Regime

After the monumental efforts of the Southern Pacific Railroad halted the inundation of the Salton Sink, most people felt that the great lake that had been formed would disappear relatively quickly under the intense heat of the desert. The water level peaked at approximately 195 feet below sea level, and rapidly fell off after that before 1910, reaching a low in the year 1922. Contrary to the opinions of contemporary writers, the Sea then showed an increase in water surface elevation that subsequently stabilized in the 1950s (see Figure 4). Clearly, the Salton Sea receives significant inputs of water, and the hydrological regime of the area has been altered greatly by agricultural development (Hely, 1966).

While the Salton Sea was initially seen as a tremendous disaster, flooding industry, potential farmland, and some settlements, it later became a great resource. In 1955, the Salton Sea Recreational Area opened, providing space for marinas serving a thriving fishing and recreational boating industry. The location's proximity to a developing winter resort area in nearby Palm Springs, and the Sea's large stock of covina fish made it a desirable vacation stop. The Imperial Valley Irrigation District took on the new responsibility of maintaining the Sea's level at a suitable elevation, regulating wastewater disposal directed towards the Sea, and searching for the delicate balance between the needs of the agricultural industry and the new requirements of its recreational uses. The Sea now requires a stable water elevation and a level of salinity that will not harm the fish population or render the water noxious for recreational use (Odens, 1977).

The Salton Sea lies within a catchment area of approximately 8,360 square miles (53,504,000 acres), a small portion of which is inside of Mexico. The surrounding drainage divide is principally determined by the San Bernadino and San Jacinto Mountains. Data from the USGS indicates that the average annual runoff from this terrain is less than two inches per year (USGS, 1989). The current surface area of the Salton Sea is approximately 375 square miles (240,000 acres). If we assume that all the runoff reaches the Sea, there is an annual surface input of approximately 891,733 acre-feet of water. Initial and recent estimates of the rate of evaporation from the Salton Sea are in the range of six feet per year, giving an annual evaporation loss of approximately 1,440,000 acre-feet (Hely, 1966). (A summary of the water budget is provided in Figure 5). There is a clear deficit in water inputs that must be made up for the Salton Sea to maintain its current level, and in fact, during the 19th century, the inflow from the Colorado River in flood and local runoff accumulated standing water in the Sink only occasionally.

The available inputs from local groundwater are not enough to make up the input deficit: The area is underlain by relatively impermeable alluvial deposits, and wells draw little water except in the Coachella Valley at the north end of the Sea. Direct groundwater inflow is estimated to amount to approximately 50,000 acre-feet per year, with an additional 80,000 to 110,000 acre-feet of through seepage into the Whitewater River in the Coachella Valley, which enters the Sea at its northern tip (Hely, 1966).

An additional water input is precipitation that falls directly on the water surface of the Sea, amounting to approximately 2.5 inches per year. This provides an additional 50,000 acre-feet of water. A significant deficit still remains, and is heightened by the fact that the initial assumption that all catchment runoff enters the Salton Sea is certainly not true. In fact, because of the extreme heat and low humidity of the region, rain falling on the ground is likely to be quickly evaporated from the surface, or to be less immediately returned to the atmosphere from drying of the soil in subsequent days. This accounts for the very small amounts of groundwater available, most of which is from artesian wells in the Coachella Valley or has its source in the Colorado River.

In fact, hydrological studies carried out by the USGS indicate that 90 percent of the inflow to the Salton Sea is drainage from the Imperial Valley's irrigated fields. The productive field areas are underlain by miles of tile drains, and are divides by many small canals that serve to quickly carry away all irrigation water that seeps through the soil unused by the crops. Without this subsurface drainage infrastructure, the soil would drain too slowly to flush out the minerals deposited by the saline irrigation water. The result would be less productive, or destroyed agricultural land. This has occurred all over the world where irrigation of poorly drained soils is common: Iraq, the Punjab, and lately in the Central California Valley (Cantor, 1970). Between 1,000,000 and 1,250,000 acre-feet of water flow to the Sea through the Alamo River, New River, and subsidiary drainage channels. The Alamo and New Rivers were scoured during the initial inundation to a sufficiently low elevation that they provide a suitable hydraulic gradient for accepting field seepage and delivering it to the Sea. It is the massive redirection of Colorado River water by way of the All American Canal, and formerly by the Imperial Canal, that supplies the annual water inputs that have maintained the Salton Sea at its current levels (Hely, 1966).

Evaporation comprises the largest loss from the lake volume since there are no surface outflows, and subterranean outflows are restricted by the impermeability of the local underlying strata. Although the Salton Sea is located in one of the hottest places on earth, its evaporative loss rate is definitely not the highest; Lake Mead, for example, shows an annual evaporative loss of nearly 7.25 feet per year, more than one foot more than the Salton Sea.

Measuring evaporative losses is extremely difficult if precise weekly or monthly data is required, because of the myriad variables involved, e.g. temperature, wind speed, wind direction, solar declination and azimuth, and so on. For annual estimates, however, the use of sunken evaporation pans has proven sufficient if the regional coefficient of 0.69 is applied to the raw data (cf. Leopold). The difference between Lake Mead and the Salton Sea is accounted for by several factors that are specific to the Sea. The salinity of the

Salton Sea, which has been approximately that of ocean water for more than thirty years (less salty than the Dead Sea, thus it supports fish), depresses the rate of evaporation. Lake Mead and the Salton Sea have very different shapes; Lake Mead consists of long, narrow arms, while the Sea is a single body of water that is relatively broad. As the distance from shore to a point on the water surface increases, the positive effect of wind on evaporation decreases, that is, wind force tends to decrease from its peak at the shore region. Thus, the large central area of the Salton Sea is less subject to wind driven evaporation. Finally, Lake Mead is a controlled reservoir, with water exports from its lower levels where the temperature is lower. This removal of cool water raises the overall energy level of the reservoir, increasing its evaporation rate. These are the dominant factors in explaining the discrepancy in evaporation rates between these two desert lakes (Hely, 1966).

Just as the water level of the Sea has been stabilized, the salinity of the water has also reached an equilibrium, although an unstable one. The initial high concentration of salts and minerals in the water was due to the re-suspension of material from the ancient lake bed and leaching of salts from the submerged strata. Salinity now fluctuates within a narrow range, although the long-term trends are for it to increase. This is because the salinity of the Colorado River is itself increasing, as mentioned above, while the volume of the Sea remains relatively constant. If salinity levels are to remain constant, large schemes will have to be developed for the removal of water with high concentrations of salts or for controlled evaporation within enclosed areas.

Increased salinity will harm the recreation value of the Sea, and it could significantly affect the evaporation rate in the negative direction, leading to flooding of the shore areas.

A further ramification of increase water levels would be that the drainage canals from the irrigated fields would no longer have a sufficient gradient to remove the seepage from the fields: waterlogging and soil salinization could result. One solution to those two problems would be for farmers to irrigate with less water, but that would mean less flushing action in the soil, less healthy crops. The entire system comprises a hydrological analogue of the economic zero-sum game. Any action produces only losers among the conflict ridden consumers of the Colorado River water.

Conclusions

My initial conception of the Salton Sea when I began this examination of its history and its nature were that it was an unmitigated disaster. The fact that it had come into being through an engineering accident (which was, in fact, the result of a lack of proper engineering) seemed to be a sardonic comment on the destructiveness of the entire enterprise. It appeared to be the direct ancestor of the contemporary environmental debacle in the Aral Sea, brought on by similar hydrologic interventions for similar goals, i.e. supporting commercial agriculture in dry climates with fertile soil, with reversed results for the Sea. The disaster of the Aral, however, is the disappearance of an ancient and fertile sea. The situation of the Salton Sea, turned out to be more ambiguous.

The current climate of opinion is not favorable to massive dam and irrigation, or reclamation, projects in this country and much of the world. This is bound to influence one's opinion of the Imperial Valley and the Salton Sea. The budget of the Bureau of Reclamation was finally slashed for budgetary, not environmental reasons, but the two are related. It is difficult to imagine a development such as the Imperial Valley being approved today, with the detailed environmental reviews required, not to mention the power of public opinion mobilized by environmental advocacy groups. More importantly, water projects, like other public works expenditures, are always zealously supported by those who will directly benefit from them, but the Bureau of Reclamation's projects constitute a massive subsidy to farmers. In the 1940s, farmers in the Imperial Valley paid the incredibly low sum of $3.50 per acre-foot for water, and proceeded to apply ten to twelve feet of it to their fields, with highly profitable results (Reisner, 1986). This unrealistic pricing of the water resource allowed farmers to be very wasteful at no cost: the environment of the Colorado River, and perhaps the national economy as well, were the losers.

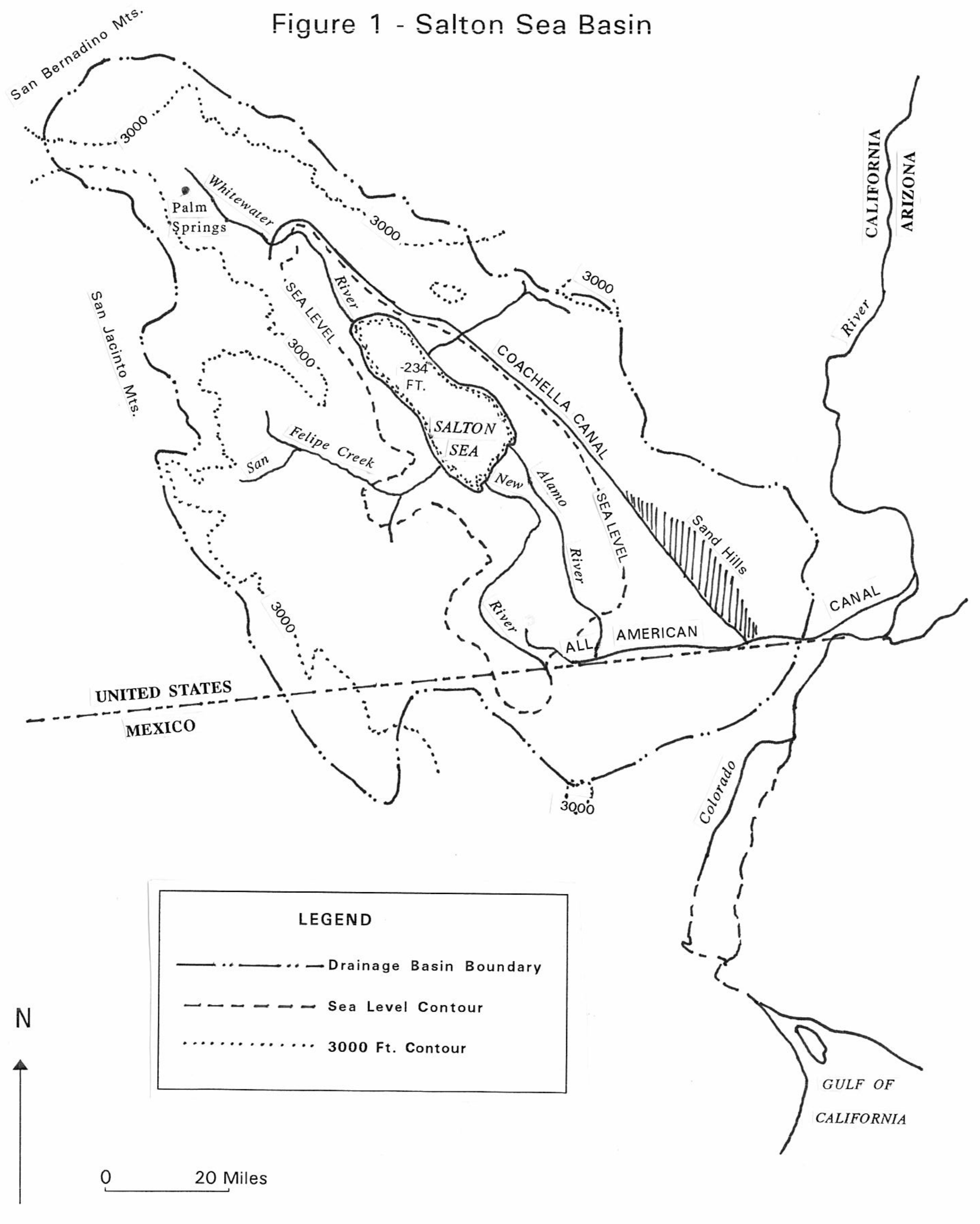
The Imperial Valley and the Salton Sea predate these developments. Even so, an evaluation of the Salton Sea and the Imperial Valley cannot be separated from an evaluation of the entire project of the Bureau of Reclamation. Although the Valley predates the Bureau's work, local farmers needed to over water their lands just as much before the completion of the All American Canal as after: the canal just insured the economic viability of doing so. The Salton Sea may have been formed by accident, but it is likely that it would have formed over time anyway. The necessity of draining the irrigated fields could not be avoided, and short of pumping the water back to the Colorado River, there was no place else for it to go except to the Sink. Flooding the Sink would clearly have been more economical.

No impact assessments were made of the Sink in the early 1900s, so it is not known if any unique resources were submerged. It is known that the resulting agricultural developments were fabulously successful. If we were, however, to weigh the various pros and cons related to the development of the Imperial Valley, we would arrive at a list something like this: On the positive side there is a large agricultural region producing inexpensive produce for national consumption; a vital recreational resource has been created, albeit, unintentionally; and land that was waste is now productively used (an unabashedly utilitarian point of view). On the negative there is the fact that degradation of the water quality in the Colorado River is increased; destruction of the river delta in Baja California is abetted; water is used wastefully, i.e. not as efficiently as it could be used if market forces were more strict; the "natural" landscape has been radically altered solely to serve the interests of human beings; and unique habitats may have been destroyed. The dependence of any evaluation of these factors on personal philosophy is clear since the negatives, for the most part, are largely the result of other developments on the Colorado of which the Imperial Valley is just one. Whether on not one views the flooding of a piece of dessert that has been repeatedly flooded in recent geological time as a disaster or a boon is similarly a question of values. Perhaps, as with many environmental problems, the issue is that no single insult is deadly; it is the slow accumulation of "acceptable" changes that brings disastrous change. Even though the Imperial Valley was not originally part of the drive to tame the Colorado, it became involved in that system, and the original impetus to make the dessert bloom certainly arose from the same urge to alter nature to suit man's ends. The paradoxical nature of the Valley is that it appears innocent compared to the later depredations of the Bureau of Reclamation, but the Salton Sea, born of engineering hubris and incompetence, shows it to be a close spiritual relative. In this sense, we can say that the Imperial Valley was both an economic success, and part of a larger ecological disaster.

As long as farming is an economical activity in the Imperial Valley, the Salton Sea will remain. The Irrigation District will continue to manage its resources to try and please the farmers and the users of the Sea, and it will have to deal with the policies that are set by other users of the Colorado River since they will have a great impact on what the Valley, at the end of the line, receives for its use. By turning the Salton Sea into a recreation resource, the Irrigation District has created a situation where many may feel that we would lose much were the Sea to disappear. It is an historical irony, that as with many anthropogenic changes to the environment, later generations come to take the present landscape for granted and to feel at home with it. What began as a disaster, and what cannot be simply reversed, comes to be protected, and perhaps even loved.

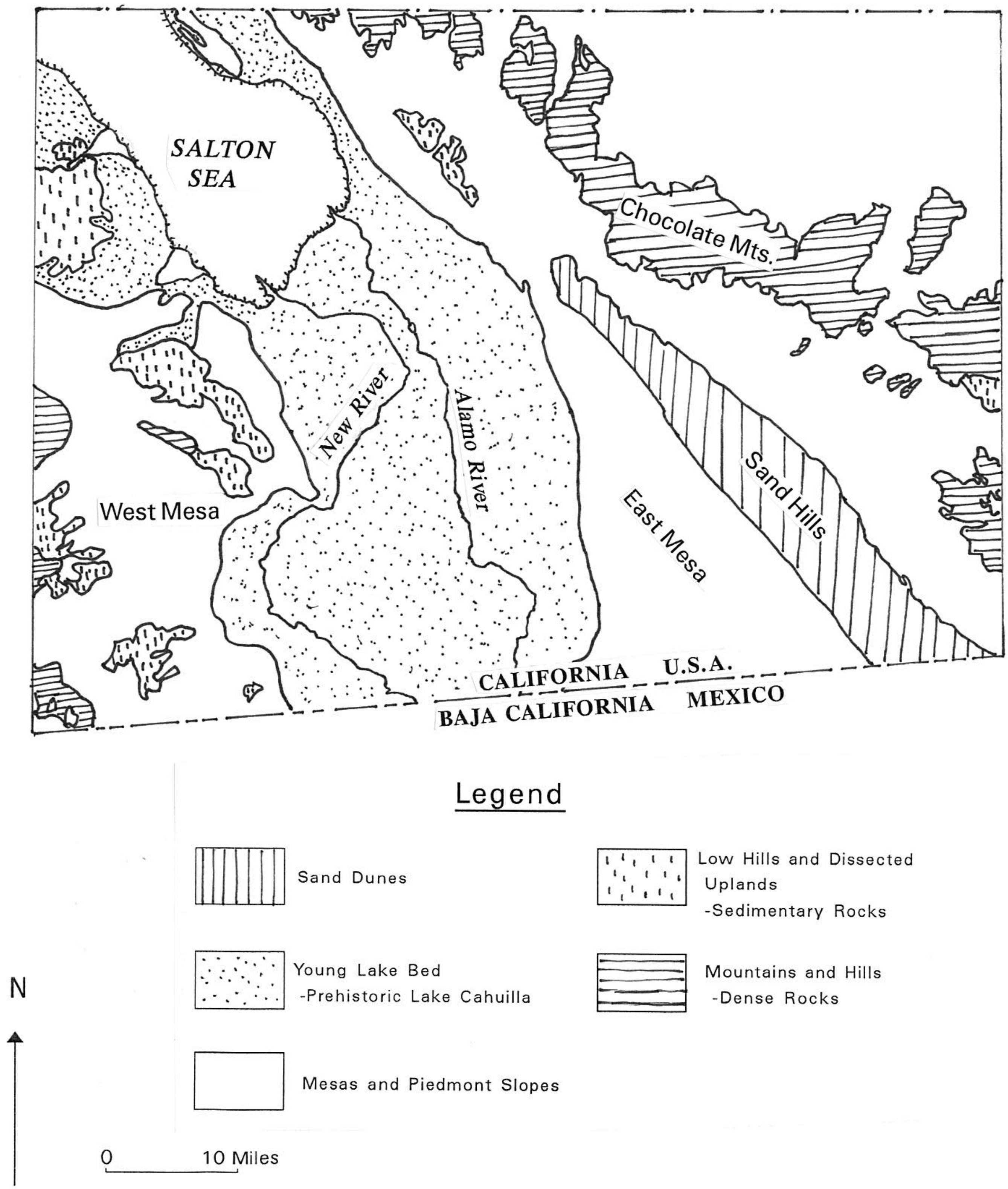
FIGURES

Figure 1 - Salton Sea Basin



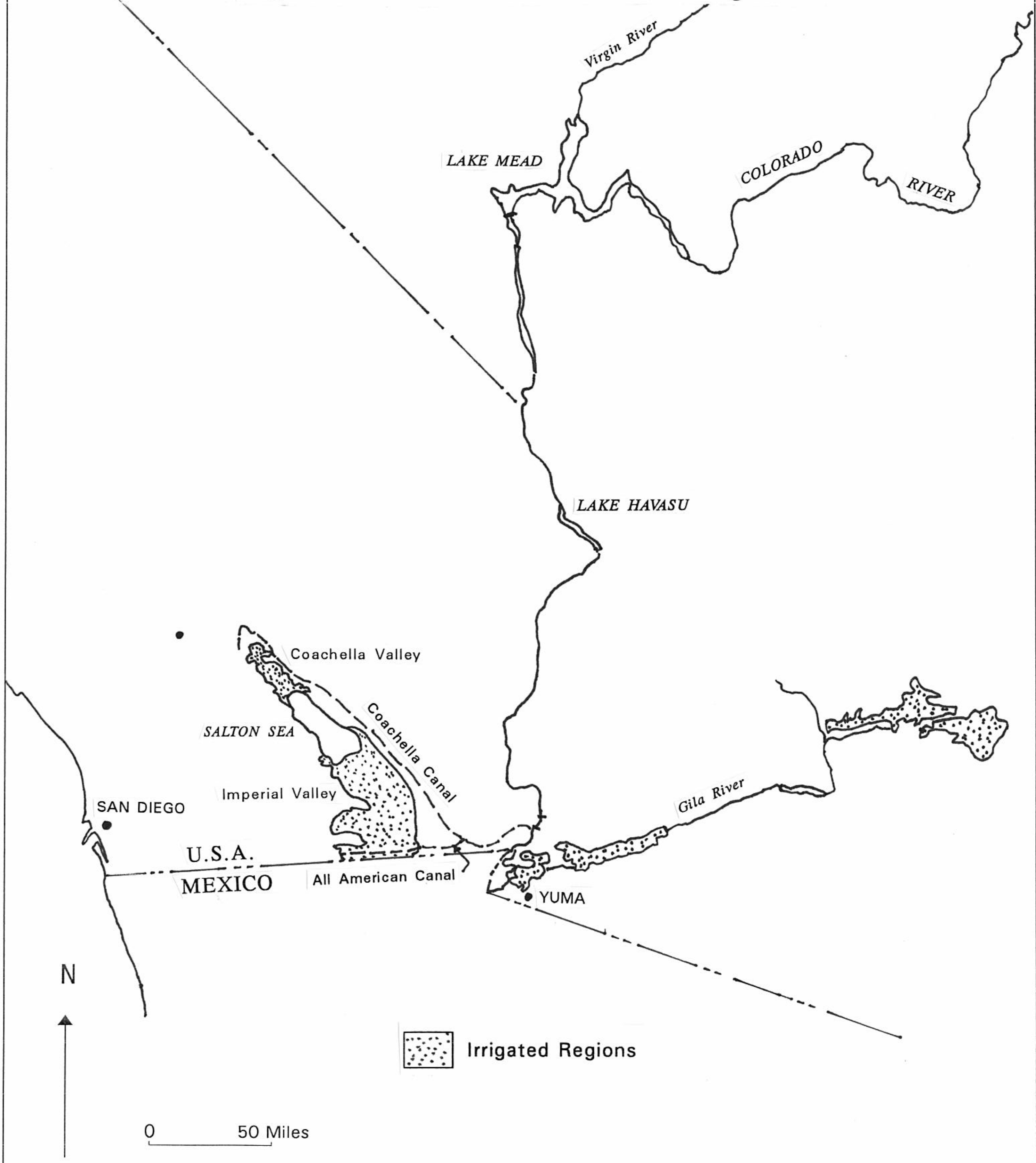
From: Hely, USGS

Figure 2 - Land Forms in the Salton Sea Basin



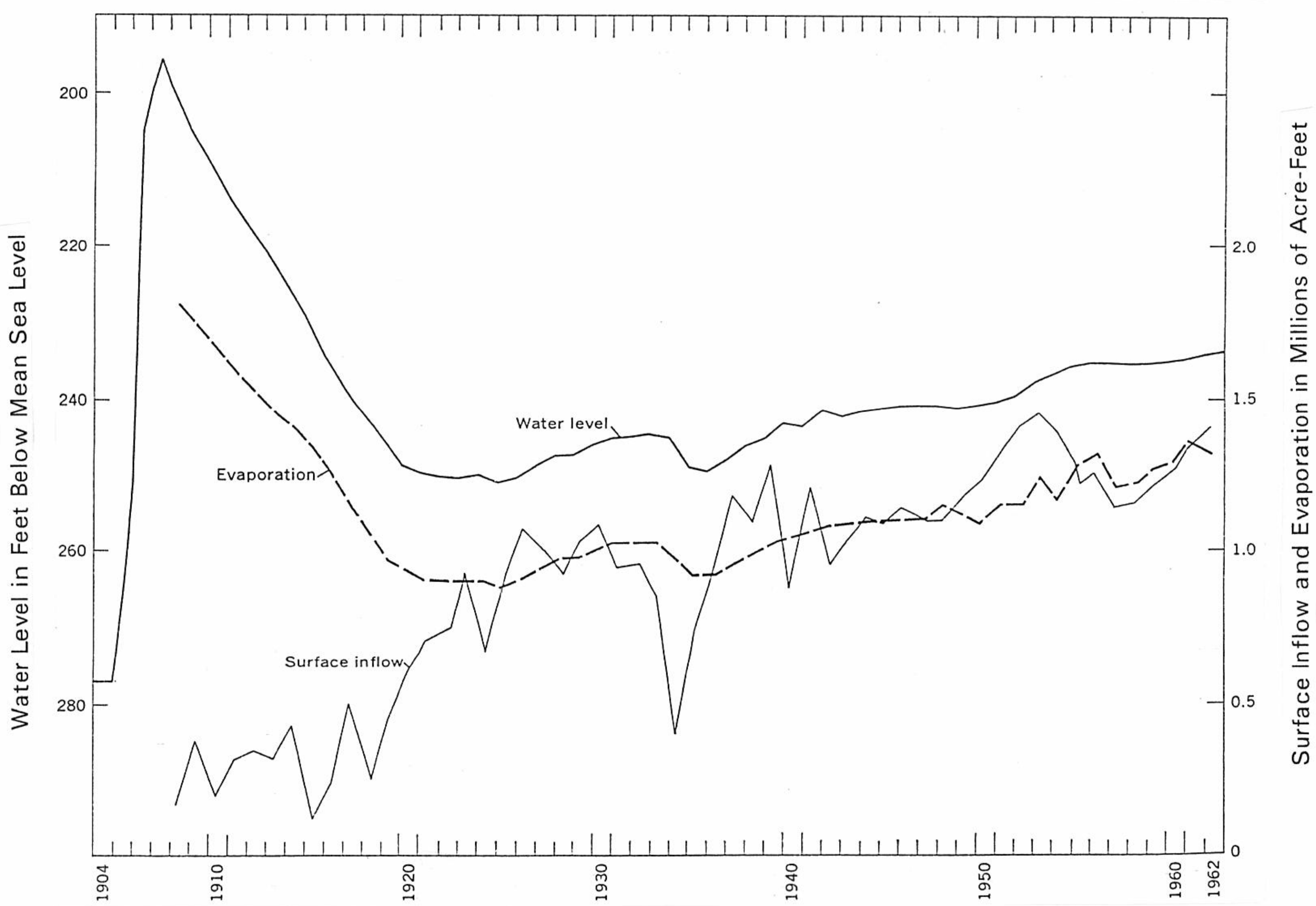
From:USGS

Figure 3 - Colorado River Basin Region



From: Humlum

Figure 4 - Flucuations in Surface Level, Evaporation, and Inflow



1929 Datum

Source: Hely, USGS

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