Salton Sea Management Project
Evaluation of Salinity and Elevation Management Alternatives

Prepared for

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DISCLOSURE

This project has been funded wholly or in part by the United States Environmental Protection Agency (USEPA) Assistance Agreement No. CL999106-01-0 to the State Water Resources Control Board (SWRCB) and by Contract No. 4-054-250-0 in the amount of $95,000.00. The contents of this document do not necessarily reflect the views and policies of the USEPA or SWRQB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

EXECUTIVE SUMMARY

BACKGROUND AND PROJECT SETTING

In 1993, the counties of Riverside and Imperial, the Imperial Irrigation District (IID), and the Coachella Valley Water District (CVWD) entered into a Joint Powers Agreement, creating a public agency known as the Salton Sea Authority. The Salton Sea Authority directs and coordinates actions relating to improvement of water quality, stabilization of water elevation, enhancement of recreational and economic development potential of the Salton Sea, and other beneficial uses, recognizing the importance of the Salton Sea to the dynamic agricultural economy in Imperial and Riverside counties. In 1994, the Salton Sea Authority received a grant from the U.S. Environmental Protection Agency's (USEPA) Clean Lakes Program to conduct environmental and economic analyses of salinity and elevation management options for the Salton Sea. The general goal or purpose of the management project is to stabilize the salinity and elevation of the Salton Sea at levels that maximize the economic, environmental, social, and cultural attributes of the region. This document, the Final Report for the Clean Lakes Grant, summarizes management alternatives proposed to date, screens these proposed alternatives against criteria established by the Salton Sea Authority, and presents environmental scoping issues raised during the public review period.

The Salton Sea is the largest lake in California and is a regionally important feature from both environmental and economic standpoints. It is located in the southeastern corner of the state within the geologic feature known as the Salton Basin, a natural basin located approximately 278 feet below mean Sea level (-278 feet msl). The Salton Sea receives drainage from approximately 8,000 square miles of Riverside, Imperial, and San Diego counties and the Republic of Mexico. It is a closed basin; water only leaves the Sea via evaporation. Inflow to the Salton Sea consists of agricultural drainage, storm water, and wastewater and is generally in hydrologic balance with evaporative losses. The closed nature of the system has resulted in changes in the salinity and water surface elevation of the Salton Sea over time. The salinity of the Sea is currently 44 parts per thousand (ppt) and is expected to continue to rise. The increasing salinity is due mainly to high evaporation rates, low rainfall, and the discharge of saline agricultural wastewaters into the lake. Elevation of the Sea varies as a result of changes in inflows and weather conditions that alter its hydrologic balance.

The Salton Sea and surrounding area provides important habitat for many wildlife species. The Salton Sea is characterized by both terrestrial and freshwater wetland vegetation communities. Typical vegetation communities occurring in the Salton Sea area include Sonoran creosote bush scrub, desert saltbush scrub, desert sink scrub, stabilized and partially stabilized desert dunes, tamarisk scrub, freshwater marsh, cismontane alkali marsh, Sonoran cottonwood-willow riparian forest/nonnative tamarisk scrub intermediate, open water, mud flats, ruderal, and agricultural lands. Sensitive habitats are those which are considered rare within the region or that support sensitive plants or animals. Sensitive habitats found in the Sea area include wetlands and non-vegetated aquatic habitats ("waters of the U.S."), which include freshwater marsh, cismontane alkali marsh, Sonoran cottonwood-willow riparian forest/nonnative tamarisk scrub intermediate, open water, and mud flat habitats.

There are numerous invertebrates, amphibians, reptiles, fish, birds, and mammals that are found in aquatic and terrestrial habitats adjacent to the Sea and in the surrounding Imperial and Coachella valleys. The Sea and adjacent wetlands, river systems, natural habitats, and agricultural fields provide foraging and roosting opportunities for large numbers of migrant and resident birds. There are also important fishery resources present in canals, irrigation ditches, rivers, and the Sea itself. The Salton Sea is currently reported to support eight species of fish, including the federally endangered desert pupfish (*Cyprinodon macularius*) and four important sport fishes, tilapia (*Oreochromis mossambiqus)*, bairdiella (*Bairdiella icistia)*, sargo (*Anisotremus davidsoni)*, and orangemouth corvina (*Cynoscion xanthulus).* There are also several sensitive fish, reptile, bird, and mammal species found at the Sea and adjacent areas.

The Regional Water Quality Control Board, Colorado River Region has designated a number of beneficial uses for the Salton Sea. These include aquaculture; water contact recreation; non-contact water recreation; warm freshwater habitat; wildlife habitat; and preservation of rare, threatened, or endangered species. Industrial service supply is designated as a potential beneficial use.

The continued rise in salinity and variable elevation threaten the region's environmental, recreational, and economic values associated with the Salton Sea. The Sea currently serves many important functions such as serving as a drainage basin for agricultural run-off of Coachella and Imperial valleys; providing important habitat for both resident and migratory wildlife species as well as several endangered species; providing recreational values such as fishing, hunting, boating, camping, nature study, bird-watching, and sightseeing; providing for growth of commercial resources and residential developments; and providing flood control measures by serving as a repository for stormwater run-off. The Salton Sea Authority is evaluating alternatives that have the ability to manage salinity and elevation of the Sea in order to protect the beneficial uses of the Sea.

In order to evaluate the efficacy of various potential management alternatives, salinity and elevation management goals or targets were established. Three quantitative criteria for screening potential management alternatives include, a target salinity range of 35 to 40 ppt, a target elevation range of -230 to -235 feet msl, and operation and maintenance cost that does not exceed $10,000,000 per year. Additionally, the Salton Sea Authority decided that the alternatives must make use of currently available, proven technologies. Any alternative that does not meet these criteria will be eliminated from consideration in further environmental reviews.

PROPOSED MANAGEMENT ALTERNATIVES

A wide variety of alternatives have been proposed over the years to manage the salinity and surface elevation of the Salton Sea. The various management alternatives have been grouped into six general categories: 1) diked impoundments within the Salton Sea; 2) pump-out of Salton Sea water to another area (e.g., dry lake beds, onshore evaporation ponds, the Gulf of California, or the Pacific Ocean); 3) a combination of alternatives consisting of diked impoundments, onshore evaporation ponds, and a pipeline/canal system to transport concentrated brine to Laguna Salada/Gulf of California, among others; 4) removal of salts from inflowing water before it enters the Sea (e.g., desalination plant, biological filters, or special pre-treatment reservoirs); 5) use of imported water to dilute the Sea; and 6) other proposed alternatives that do not specifically address the problem of stabilizing salinity or surface elevation.

Diked Impoundments

Managing salinity with diked impoundments is based on removing salts from the Sea and decreasing the volume of the lake, which results in greater dilution of the remaining Salton Sea water by inflowing fresh water. The diked impoundment acts as an evaporation basin, isolating and concentrating the brine by evaporating Salton Sea water within the impoundment (USDOI and RAC 1969, 1974; Aerospace Corporation 1971; CVWD pers.

comm. 1995). Although the effective volume of the lake would be reduced by the volume of the impoundment, which would result in a rising lake level given the same fresh water inflow, a volume of Salton Sea water equal to the freshwater inflow can be let into the impoundment to evaporate away, thereby controlling lake elevation. Eventually, the impoundment would fill with salts, and salt disposal would be necessary.

Numerous diked impoundment alternatives have been proposed over time. The major differences in these options include size of the impoundment, location of the impoundment, and the type of dike structure and design. Nine locations were first studied, with impoundment sizes ranging from 20 to 50 square miles. Since then, CVWD has updated the descriptions of various diked impoundment options and evaluated their efficacy in managing the Sea's salinity. Selected alternative configurations included in this discussion are: 1) a 50-square-mile diked impoundment at the southern end of the lake, 2) a 40-square-mile diked impoundment at the southern end of the lake, 3) two impoundments, one at the southwestern and on at the southeastern end of the lake, totaling 50 square miles, 4) diking off the northern third of the lake, 5) diking off the northern half of the lake, 6) parallel dikes forming 47-square miles of impoundment, and 7) a phased zoning concept. In general, the smaller diked impoundments have been placed in the southern portion of the Sea because the slope of the Sea's bottom and average depth of water is less in the southern end than the northern end. Larger impoundments that dike off one third to one half of the Sea would be located at the northern end of the Sea because the majority of fresher water inflows (New and Alamo rivers) are located in the southern end of the Sea. In addition to these configurations, many other sizes and locations are possible. In general, proposed sizes of the impoundment have ranged from approximately 8 to 50 percent of the surface area of the Salton Sea, and proposed impoundment locations have included all sectors of the lake.

The initial proposal for dike construction proposed an earthen dike be constructed with a conventional excavate and dredge, haul, and dump method. Since the time of this initial proposal, new technologies have made alternative dike structures feasible. A value engineering team formed by the U.S. Bureau of Reclamation (USBR) and the Salton Sea Authority Technical Advisory Committee (TAC) was formed to evaluate these alternative structures (USBR and Salton Sea Authority TAC 1994). The alternative structures evaluated included a plastic curtain, sheetpile, concrete wall, geotextile bags, pile and dredge, and dump and dredge. The value engineering team concluded that the excavation, haul, and dump dike was the most flexible, reliable, and cost effective separation structure and recommended this type of construction for the diked impoundments within the Salton Sea (USBR and Salton Sea Authority TAC 1994). This option does not include dredging of Salton Sea sediments, which eliminates the danger of resuspending large quantities of potential contaminants in Salton Sea sediments.

Pump-out Alternatives

The pump-out alternatives are based on the concept of removing Salton Sea water (and its associated salts) from the lake. This would provide, in effect, an outflow from the lake and change the system from a closed terminal lake to an open flowing system. Salts would be exported with the outflow rather than being retained in the lake when water evaporates. In addition to salts being exported from the Sea with a pump-out alternative, the lake's total volume is reduced as a result of pump-out (inflow no longer equal to outflow), which would result in a salinity decline from dilution with inflowing fresher water and a drop in the Sea's elevation. Surface elevation can only be maintained by importing water back to the Salton Sea. For example, water from the Gulf of California or the Colorado River could be used, in concept, to replace an amount of Salton Sea water that is pumped-out.

All of the pump-out alternatives are based on exporting saline water out of the Salton Sea. The major differences between different pump-out alternatives are the amount of water removed each year, the location to which Salton Sea water would be pumped, and whether water is pumped back to the Salton Sea to control elevation. The pump-out rate will be dependent upon the salinity of the Sea when initiation of pumping begins, the desired target salinity, the desired time to reach that target salinity, and cost considerations. The alternative pump-out locations proposed to date include pump-out to a dry lake bed (Palen Dry Lake will be used as an example, but other dry lakes such as Clark and Ford are considered options), evaporation ponds, Laguna Salada, the Gulf of California, the Pacific Ocean, or onshore treatment/filtration units.

The pump-out to onshore evaporation alternative involves pumping Salton Sea water into evaporation ponds located on the lake's shore, where the water evaporates leaving behind saline residue. Saline water would be removed from the lake at a predetermined rate until the desired salinity was reached. At this point, pump-out would continue at a rate such that salts removed by pump-out each year would equal the annual inflow of salts to the lake. Eventually, the evaporation ponds would fill with salts, and disposal would be necessary.

Areas on the southeastern shore, between Bombay Beach and Red Hill, have been suggested as a potential location for onshore evaporation ponds).

Most evaluations of evaporation ponds have concluded that evaporation ponds on land are not economical because of the high costs of acquiring sufficient land around the lake (USDOI and RAC 1969). However, developments in solar pond technology, such as an enhanced evaporation system (EES) (Ormat 1989), where salt water is pumped through an elevated spray system, producing increased evaporation rates, appear to require less land than standard evaporation ponds. The original volume of removed water is reduced by 90 percent with the enhanced evaporation system. The remaining saline water is pumped to conventional evaporation ponds for further evaporation. With the use of enhanced evaporation, Ormat anticipated the need for only 10 percent of the land area necessary for conventional evaporation ponds (Ormat 1989). The need for salt disposal still exists because the evaporation ponds would eventually fill with salt. Furthermore, there is more energy needed for the pumping and spray system associated with enhanced evaporation.

Evaporation ponds could be used for other purposes, such as using the saline residue in a solar plant for generation of electricity or using Sea water for aquaculture by first pumping the water to a series of aquaculture ponds and then to a series of evaporation ponds. In both cases, the principles for salt removal are essentially the same as described above for onshore evaporation ponds. These additional options represent a potential means to generate monies to offset construction, or operation and maintenance costs.

The pump-out of saline Salton Sea water to the Gulf of California alternative would transport Salton Sea water via a series of canals and pipelines to Laguna Salada and then to the Gulf of California. Canals would be used when transporting water downgradient, and pipelines would be used when pumping water uphill or for outfalls. Another option would be to carry water only to Laguna Salada and allow water to evaporate and the salts to remain. However, the consent of the Mexican government would be required for this option.

An additional option is to construct a return canal/pipeline to transport less saline Gulf of California water to the Salton Sea. Water from the Gulf of California would be pumped over the mountains to Laguna Salada and then gravity-fed to the Salton Sea. The amount of Gulf water pumped to the Sea would equal the amount pumped from the Sea to the Gulf, stabilizing the Sea's elevation.

Construction of an inland seaport at Laguna Salada has been discussed by both the Mexican and United States governments (Salton Sea Authority pers. comm. 1995). A canal would be constructed to carry sea water from the Gulf of California to Laguna Salada, which would replenish the dry lake. This canal would be large enough for both freight and pleasure ships to navigate. This proposal could benefit the Salton Sea area by providing for an outlet from the lake. If approval from the Mexican government were obtained, Salton Sea water could be pumped from the Salton Sea to the inland seaport. This alternative is essentially the same as a pump-out alternative to Laguna Salada or the Gulf of California, but the canal/pipe system would extend only to the northern terminus of the navigable waterway. It has also been suggested that a navigable waterway with a lock system could be constructed from Laguna Salada into the United States, providing for economic growth to both the United States and Mexico.

The pump-out to the Pacific Ocean alternative is similar to the pipeline/canal to the Gulf of California alternative, except a link between the Salton Sea and the Pacific Ocean would be established (Salton Sea Authority Public Comments 1995). The exact route has not yet been selected but would be dependent upon cost and engineering considerations. Ocean water would be carried to the Salton Sea, and Salton Sea water would be transported to the Pacific Ocean via the shortest and least expensive route. The distance between the two is estimated at about 100 miles. This exchange of water between the ocean and the Sea would eventually stabilize the salinity and elevation.

A number of proposed alternatives rely on treating or filtering Salton Sea water. Water would most likely be pumped to a filtering unit or plant to remove salts and other constituents. Many of these alternatives rely on developing or unproven and therefore could not be considered viable management alternatives.

Combinations of Impoundment and Pump-out Alternatives

The combination of alternatives use various combinations of the previously described alternatives and some enhancement options not yet mentioned (Salton Sea Authority Public Comments 1995; Dangermond and Associates, Inc. 1994). They may include all or some of the following options: diked impoundments, onshore evaporation ponds, shoreline enhancement areas, constructed wetlands, stabilizing dikes, solar pond and power generation plant, canal/pipeline with or without storage facilities. Some of the combined alternatives proposed thus far include:

- an in-Sea diked impoundment, on-shore evaporation ponds, and a pipeline to the Gulf of California;
- an in-Sea diked impoundment and a pipeline to the Gulf of California;
- on-shore evaporation ponds and a pipeline to the Gulf of California;
- a stabilizing dike, solar pond power generation, and constructed wetlands;
- a stabilizing dike, solar pond power generation, constructed wetlands, and pumped storage facility to the Gulf of California; and
- a joint USA/Mexico solar power generation and pumped storage to Laguna Salada.

These alternatives combine various options already discussed. A diked impoundment adjacent to the shoreline would serve to control elevation, allowing water in and out of the impoundment as needed, as well as manage the salinity. An onshore evaporation pond would serve to manage salinity and could potentially be used for solar pond power generation. A pipeline could be used to transport concentrated brine to another area (e.g., Laguna Salada, the Gulf of California, or the Yuma desalting plant discharge canal). The combined alternative offers the advantage of optimum control of salinity and elevation while also solving the problem of salt disposal. Any combination, such as a diked impoundment and pipeline; evaporation ponds and a pipeline; or a diked impoundment, evaporation ponds, and a pipeline, could be used to manage salinity and elevation.

Other options that could be coupled with these three options described above include, constructed wetlands and shoreline enhancement projects. This would serve to improve water quality and could potentially help to filter out contaminants as they enter the Sea. A stabilizing dike could be used to decrease the overall volume of the Sea and help to control elevation. This differs from the diked impoundment in that there is no enclosure and evaporation of water. Instead a dike is constructed at the southern end of the Sea to reduce the overall volume of the lake, helping to stabilize the surface elevation. A pumped storage facility could be constructed at the highest point of the canal/pipeline. This would allow for more control of the transportation of water, allowing pumping at night when electricity rates are the lowest.

Water Imports

Another proposed solution is to import fresh water to the Sea, diluting the Sea water to a desired salinity. It is unlikely sufficient fresh water is available to dilute the Sea to the desired salinity, nor does this solution address elevational control. However, many of the management alternatives discussed above, especially pump-out alternatives, call for the removal of Salton Sea water, which will lower the lake's elevation. The only way to stabilize surface elevation would be to add an equal amount of water to the lake to replace that which is removed. This would also help to decrease the Sea's salinity if the replacement water has low salinity relative to the Sea's water.

Identified sources of replacement water include Colorado River water and the Gulf of California water. Colorado River water could be delivered through existing canals or expanded canal systems only in years when surplus water is available. Gulf of California water could be delivered through constructed pipeline/canal systems. The latter option is more expensive, but potentially more reliable.

Other Proposed Options

Other proposed alternatives do not specifically address the problem of stabilizing salinity or surface elevation. Since these alternatives do not meet the purpose and need of the project, these alternatives can not be considered viable management alternatives.

ALTERNATIVES EVALUATION AND SCREENING

The primary objective of the management project is to stabilize the salinity and elevation of the Salton Sea at levels that maximize the economic, environmental, social, and cultural attributes of the region. To focus future studies and environmental analyses on those alternatives that are most likely to meet the objectives of the project, the Salton Sea Authority set management targets that were used to screen potential alternatives. These targets included the ability to maintain salinity in a range of 35 to 40 ppt, maintain surface elevation in range of -230 to -235 feet msl, have an annual O&M cost less than

$10,000,000, and rely on proven technologies. The ability of proposed management alternatives to meet these criteria are summarized below.

A number of alternatives, such as research or enhancement projects, did not address the problem of stabilizing salinity or surface elevation, and were not considered further as management alternatives. Alternatives that did not meet the established screening criteria include alternatives that propose to remove salts before water enters the Salton Sea. While many of the specifics of these alternatives were not available, it is unlikely that the various proposed alternatives could remove the 4,000,000 tons of salt that enter the Salton Sea each year, except at enormous cost, most likely exceeding the established annual O&M cost target. In addition, these alternatives do not manage surface elevation.

Alternatives that import water also do not appear to be an effective method to manage salinity of the Salton Sea. Sufficient volumes of water from the Colorado River do not appear to be available at a frequency to allow management of the Sea's salinity. Gulf of California water could be used to replenish water removed as part of a pump-out alternative, but pipeline/canal systems to the Gulf of California have been estimated to exceed the established annual O&M cost target.

Pump-out options, which do not incorporate water imports, do not manage surface elevation. Pump-out options which do incorporate water imports have the capability of managing salinity, elevation, and solve the problem of salt disposal. However, pipeline/canal alternatives are relatively expensive to operate and maintain, and are generally estimated to exceed the O&M target. In addition, the majority of pump-out options involve siting project components in Mexico, which would result in a loss of control over the project and greater uncertainty in the environmental process for the Salton Sea Authority. Similarly, combinations of alternatives that rely on pump-out or transport of Salton Sea water from the Salton Basin have the same problems as the pump-out alternatives; although the specifics of many of these combinations of alternatives are presently not available. Many of the remaining pump-out options rely on unproven technology or lack sufficient information to adequately evaluate their ability to meet screening targets. However, since the specifics of some of the pump-out and combinations of alternatives are not available, some of these alternatives were not eliminated by the screening process.

Diked impoundments appear to have the greatest potential for meeting the project objectives while satisfying the established Salton Sea Authority's screening criteria. In general, diked impoundments have the ability to manage both salinity and surface elevation and are relatively inexpensive to operate and maintain. However, the diked impoundment alternatives store the salts within the impoundment and salt disposal will be necessary at some point within the life of the project. A value engineering evaluation of alternative dike structures (USBR and Salton Sea Authority TAC 1994) concluded that excavation, haul, and dump dike construction is the most flexible, reliable, and cost-effective method. Combinations of alternatives that make use of diked impoundments and certain pump-out alternatives also appear to meet established screening criteria, except O&M costs of these alternatives have not been estimated. Based on the projected O&M costs for pipeline/canal systems, combinations of alternatives that utilize both diked impoundments and pipeline/canal systems are unlikely to meet the established O&M target; however, the O&M costs of many of these systems are uncertain at this time.

A number of environmental scoping issues, raised during the public review process, were identified for the project. All of the proposed alternatives will have potential environmental consequences that have not been addressed in this report. Potential impacts include construction or operational impacts to sensitive resources (e.g., wetlands, endangered species, and migratory birds); the potential for creating or exacerbating problems with toxic substances; and potential impacts to Mexican resources. Other issues include the need for and cost of land acquisition, right-of-way requirements, and environmental permitting requirements. Comments were also received regarding the need for refinement of the project's purpose and need, how management targets were established, the need for comprehensive water quality analyses, and making use of long-term inflow data and inflow variability (wet and dry cycles) for environmental analyses.

1.0 INTRODUCTION

The overall objectives of this report are to summarize the salinity and surface elevation management alternatives that have been proposed for the Salton Sea and to conduct a preliminary screening of these alternatives based on their ability to achieve identified salinity and surface elevation management targets, and operation and maintenance (O&M) costs. In addition, only those alternatives that are technologically feasible will be considered further in subsequent environmental analyses. This report is not intended to provide an analysis of environmental impacts but to narrow the list of potential management alternatives to those that meet the screening criteria discussed in Section 3.0.

This report represents the final product of the 1994 Clean Lakes Grant, and includes information presented in two previous submittals for this Clean Lakes Grant: Summary of Salinity and Elevation Management Alternatives (Ogden 1995a), and Economic Profile Study and a Discussion of Methodology for Economic Impact Analysis (Ogden 1995b, Appendix A).

1.1 BACKGROUND

This Salton Sea is the largest lake in California and is a regionally important feature from both environmental and economic standpoints. It is located in the southeastern corner of the state (Figure 1-1) within the geologic feature known as the Salton Basin (also Salton Sink or Trough), a natural basin located approximately 278 feet below mean sea level (-278 feet msl). The Salton Sea receives drainage from approximately 8,000 square miles of Riverside, Imperial, and San Diego counties and the Republic of Mexico. It is a closed basin; water only leaves the Sea via evaporation. Inflow to the Salton Sea consists of agricultural drainage, storm water, and wastewater and is generally in hydrologic balance with evaporative losses. The closed nature of the system has resulted in changes in the salinity and water surface elevation of the Salton Sea over time. The salinity of the Sea is currently 44 parts per thousand (ppt) and is expected to continue to rise. Elevation of the Sea varies as a result of changes in inflows and weather conditions that alter its hydrologic balance.

The continued rise in salinity and variable elevation threaten the region's environmental, recreational, and economic values associated with the Salton Sea. The Salton Sea supports many recreational activities, including a renowned sport fishery, and is an important habitat

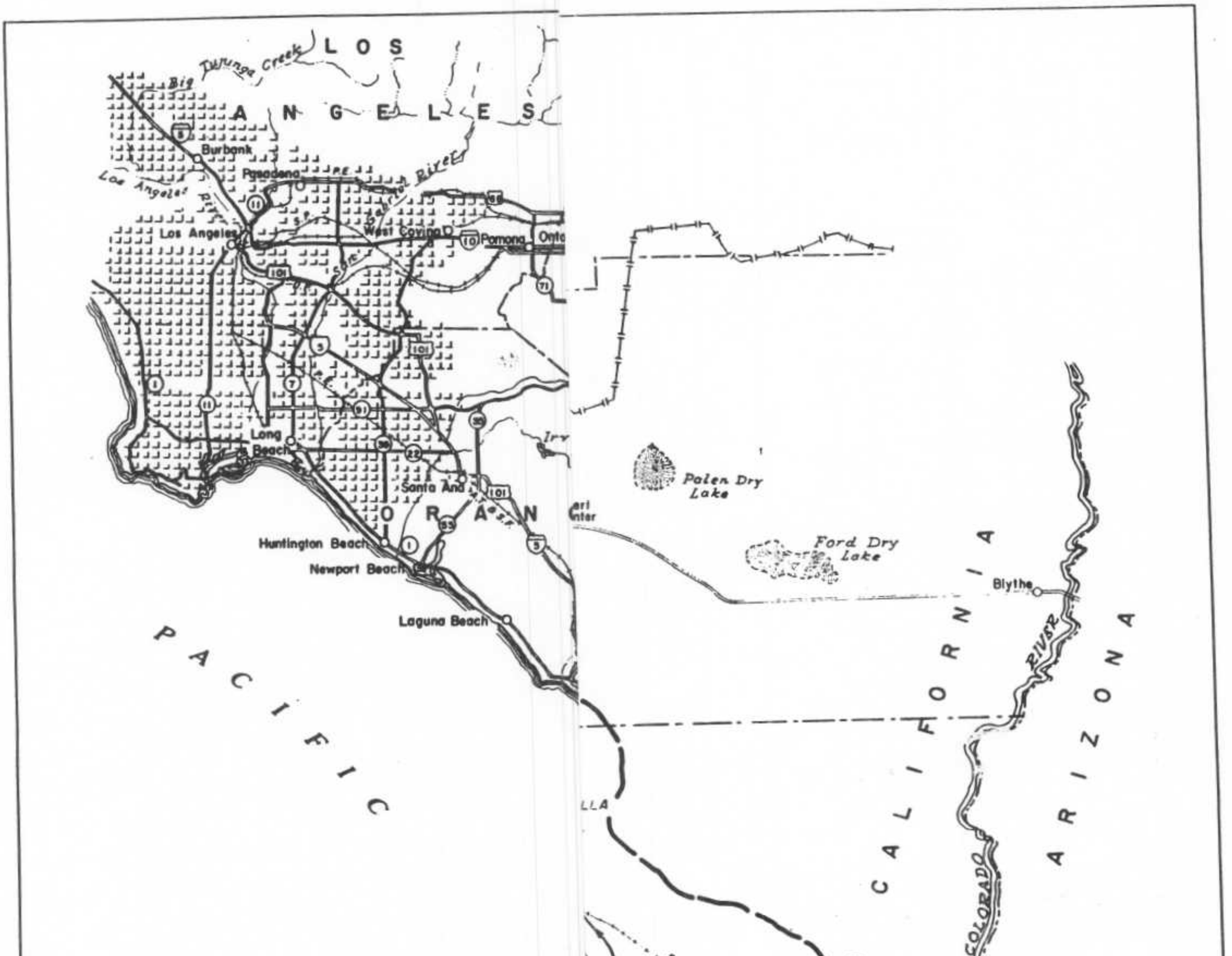

FIGURE 1-1

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for over two million migratory birds and several endangered species. The continued rise in salinity threatens the viability of populations of fish and fish-eating birds occurring at the Sea, as well as associated recreational activities. Lands surrounding the Salton Sea have been developed, creating an economy beneficial to Riverside and Imperial counties, the state, and the nation. Local agriculture is dependent on the Sea as a repository for agricultural drainage. Unstable Sea levels have adverse implications for the regional economy when events such as inundation of property and loss of tourism occur.

Over the years, a number of salinity and elevation management strategies have been proposed by various agencies. In 1993, the counties of Riverside and Imperial, the Imperial Irrigation District (IID), and the Coachella Valley Water District (CVWD) entered into a Joint Powers Agreement, creating a public agency known as the Salton Sea Authority. The Salton Sea Authority directs and coordinates actions relating to improvement of water quality, stabilization of water elevation, enhancement of recreational and economic development potential of the Salton Sea, and other beneficial uses, recognizing the importance of the Salton Sea to the dynamic agricultural economy in Imperial and Riverside counties. In 1994, the Salton Sea Authority received a grant from the U.S. Environmental Protection Agency's (USEPA) Clean Lakes Program to conduct environmental and economic analyses of salinity and elevation management options for the Salton Sea.

The purpose of this report, the final product of the 1994 Phase I Clean Lakes Grant, is to describe the environmental setting of the Salton Sea, the purpose and need for the project, the salinity and surface elevation management targets, the various salinity and elevation management alternatives under consideration by the Salton Sea Authority, and a preliminary screening of the management alternatives under consideration. It should be noted that the models used to evaluate changes in salinity and elevation under diked impoundment and pump-out alternatives have not been evaluated with respect to their sensitivity to model assumptions. Therefore, the quantitative predictions of these models should be interpreted with caution.

2.0 PROJECT SETTING

A description of the Salton Sea and surrounding areas is provided in this section. It is intended to provide a general overview of existing conditions and to identify sources of information for future environmental analyses.

2.1 HISTORY OF THE SALTON SEA

To understand how the Salton Sea was formed, a brief history is presented here. This is largely based on William Blake's expedition to the area in the 1850s and de Stanley's account of the history of the Salton Sea (Blake 1858; de Stanley 1966).

2.1.1 Lake Cahuilla

The Colorado River has historically flowed alternately into the Gulf of California and into the Salton Basin. During periodic, extreme flood stages, the river would flow north across the Colorado River delta and into the Salton Basin forming a large, temporary lake. Eventually, the Colorado River would return to its old course, south to the Gulf of California and, deprived of its water supply, the lake would ultimately dry up. The last in the series of these ancient lakes was Lake Cahuilla.

In the 1850s, William Blake, a geologist who was with an early exploration party searching for possible railroad routes in the southeastern desert area of California, studied the Colorado Desert region and found evidence of a historic lake that occupied much of the Imperial and Coachella valleys. Blake first identified the ancient lake in 1853 and named it Lake Cahuilla, after the Cahuilla Valley and the Cahuilla Indians who inhabited the area. He described the lake as 100 miles long and about 35 miles at its widest point. He speculated that the lake had been formed by the Colorado River flowing into the Salton Basin during flood stages. The influx of river water into the basin also deposited rich alluvial sediments, creating the rich agricultural environment of the Coachella and Imperial valleys. Buildup of sediments within the Colorado River Delta eventually blocked the river's flow into the Salton Basin and diverted it back to the Gulf of California. With the loss of the water supply, Lake Cahuilla dried up by evaporation, leaving behind the lacustrine (related to lakes) clay and alluvial surface of the Coachella and Imperial valleys. In 1853, Blake noted that if irrigation were possible, the valley would be capable of supporting luxuriant vegetation growth (Blake 1858).

This history of Lake Cahuilla is documented by the dating of shoreline features and also by local Indian folklore. About 40,000 years ago, early stages of the lake were at an elevation of 160 feet msl. More recently, about 15,000 years ago, the lake's elevation was about 40 feet msl. According to both Indian legends and carbon dating, the lake disappeared about 300 years ago (Littlefield 1966). The historic Lake Cahuilla shoreline can be seen today along the base of the Santa Rosa Mountains to the west and northwest of the Sea, and in the sand dunes on the southeast side near Niland (Setmire et al. 1990).

2.1.2 Salton Sea

Periodically during years of heavy rainfall, large river discharges would spread over the Colorado River Delta and drain into the Salton Basin. Floodwaters were reported in the Salton Basin in 1828, 1840, 1849, 1852, 1859, 1862, 1867, and 1891 (Littlefield 1966). The idea of constructing a canal from the Colorado River to the Salton Basin to reclaim the desert was first conceived in 1849. The canal would carry Colorado River water to the Imperial Valley for the purpose of agricultural development. It was not until 1901, however, that the main canal (Imperial Canal) was completed, and much of this canal was located in Mexico. By 1904, more than 12,000 people had moved to the area buying land at auctions for agricultural purposes.

The area prospered and towns such as Brawley, Holtville, Heber, and Calexico grew. Two important problems of the area had been ignored, however. These were the regular history of flooding in the area, and the tons of silt that were carried along with Colorado River water by the Imperial Canal. By 1904, the Imperial Canal was blocked by sediment, and the Imperial Valley was without water (de Stanley 1966).

To remedy this problem, a temporary diversion of the Colorado River on the Mexican side of the United States-Mexico border was constructed. On October 11, 1905, the temporary diversion failed during flood conditions, and the entire flow of the Colorado River rushed into the Salton Basin. It was not until February 1907, 16 months later, that the break in the dike was repaired, and the river was diverted back to its old course to the Gulf of California (de Stanley 1966).

At the time the break in the dike was repaired, the Salton Sea was -195 feet msl with a surface area of 520 square miles. By 1925, however, the lake's elevation had dropped to -250 feet msl due to evaporation and the low volume of agricultural wastewater draining to the Sea (Setmire et al. 1990). Since 1925, diversion of Colorado River water into the Imperial and Coachella valleys has raised the elevation of the lake to about -227 feet msl with a surface area of about 380 square miles (Ferrari and Weghorst 1995).

2.1.3 Agriculture

The California Development Company delivered water to the Imperial Valley in 1901. There were several mutual water companies that operated distribution canals for about 77,000 acres of land by 1904. The California Development Company, however, went bankrupt because of damage suits from the floods of 1905-1907. The Southern Pacific Company acquired its assets (United States Department of the Interior and the Resources Agency of California (USDOI and RAC) 1969).

The IID was officially formed in 1911 and by 1923 had acquired the California Development Company assets and the distribution canals from the mutual water companies. By 1928, irrigated land had expanded to 409,943 acres. Problems with silt buildup and potential flooding were still present, however. Congress passed the Boulder Canyon Project Act in 1928 authorizing the USBR to build the Hoover Dam, Imperial Dam, and the All-American Canal system. These facilities were completed in 1940, alleviating threats of flooding and silt buildup. The All-American Canal system included the construction of the Coachella Canal and its distribution system in 1954. This added 78,500 acres of irrigated land in the Coachella Valley. Today there are over 500,000 acres of irrigated land in the two valleys, approximately 460,000 acres in Imperial Valley, and 60,000 acres in Coachella Valley (Colorado River Board of California 1992). One of the major functions of the Sea is to serve as a sump for agricultural run-off for the Coachella and Imperial valleys. Executive Order of Withdrawal (Public Water Reserve No. 114, California No. 26), signed in 1928, designated lands within the Salton Sea below elevation -220 feet msl as storage for wastes and seepage water from irrigated lands in the Imperial Valley (RWQCB 1994).

2.1.4 Beneficial Uses

Water quality objectives for water bodies in California are established to protect or support the particular "beneficial uses" of the water body. Section 13050(f) of Division 7 of the California Water Code (Porter-Cologne Water Quality Control Act) describes beneficial uses as follows:

> "Beneficial uses of the waters of the State that may be protected against quality degradation include, but are not necessarily limited to, domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic

enjoyment; navigation; and preservation and enhancement of fish, wildlife, and other aquatic resources or preserves."

As described in Section 2.1.4, the primary purpose of the Salton Sea, as designated by Executive Order, is to store agricultural wastewater. Federal regulations, however, specify that waste transport or assimilation cannot be designated as a beneficial use for waters of the United States, per Clean Water Act, 40 CFR, Section 131.10(a) (RWQCB 1994). Beneficial uses that have been designated for the Salton Sea (RWQCB 1994) include:

- Aquaculture
- Contact Water Recreation
- Noncontact Water Recreation
- Warm Freshwater Habitat
- Wildlife Habitat
- Preservation of Rare, Threatened, or Endangered Species

Industrial Service Supply has been designated as a potential beneficial use.

The RWQCB, Colorado River Basin Region, considers some beneficial uses of the Salton Sea to be impaired due to low water quality (RWQCB 1996). Impaired beneficial uses are described below (from RWQCB 1996).

- Aquatic habitat is impaired by the currently elevated salinity level, the high level of nutrients, and the amount of selenium entering the food chain of the Sea. Lesser impairments are caused by pesticides and possibly boron.

- Wildlife are impaired by the rising salinity level and by selenium entering the food chain. Impacts from boron and nutrients are uncertain.

- Recreation is impaired by impacts to the Sea's fishery which are caused primarily by the salinity level. Selenium impairs recreation because there is a health advisory on eating Salton Sea fish. Fish kills and odor problems associated with the death of over abundant algae are caused by excessive nutrients and impair the aesthetic recreational use of the Sea. Elevated levels of bacteria in localized areas of the Sea (i.e., the extreme southern end) are of concern at times.

- Impacts to endangered species are uncertain but may be similar to the impacts to wildlife noted above.

2.2 Physical Description

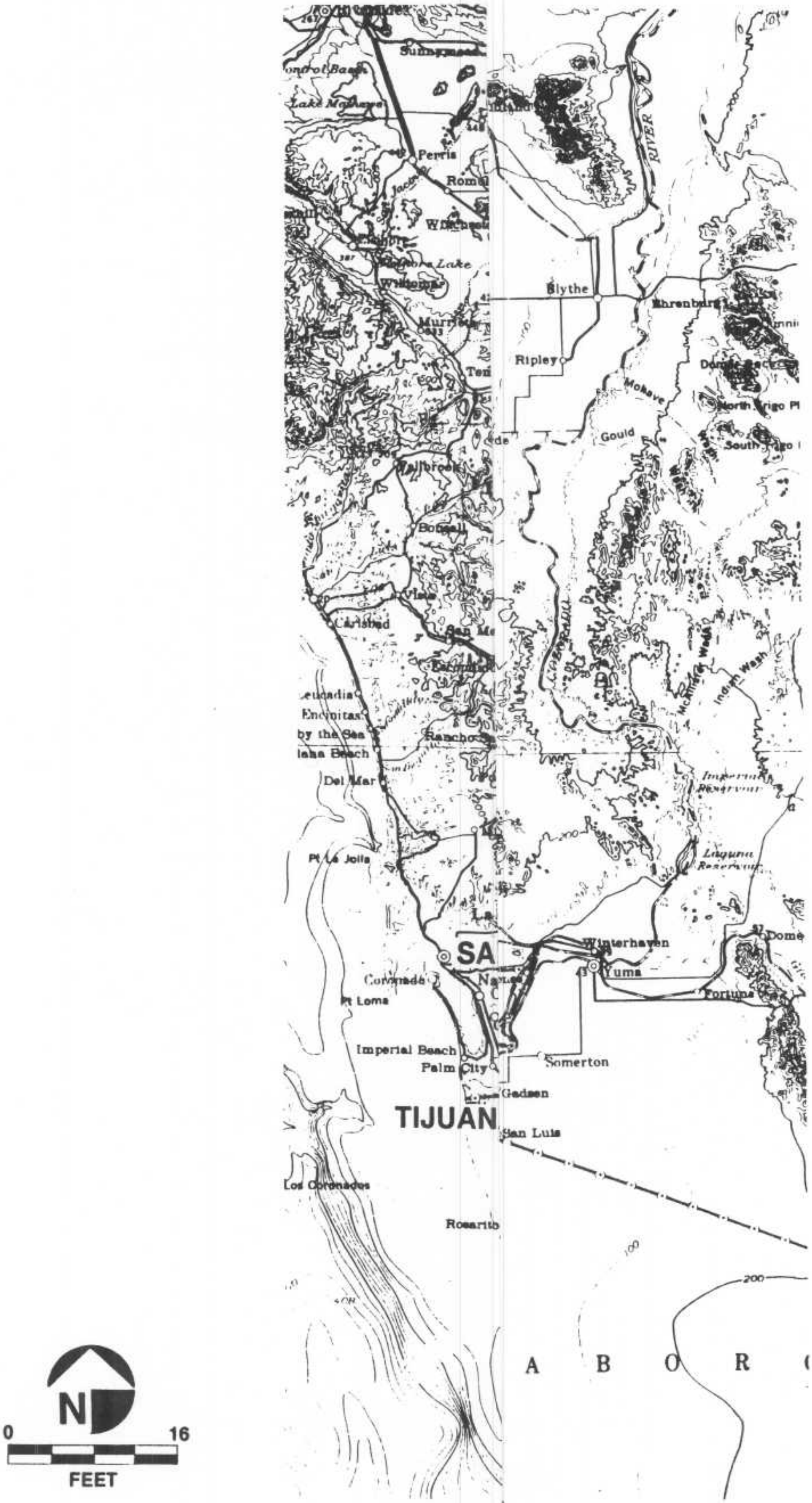
2.2.1 Geologic Setting

The Salton Sea is located in the northern part of the Salton Basin. The basin is at the north end of the actively spreading rift valley that runs along the bottom of the Gulf of California. In the geologic past, the Salton Basin was part of the Gulf of California. The Colorado River deposited its silt load at the mouth of the river, and eventually the Colorado River delta gradually extended to the southwest. Eventually, the Colorado River Delta separated the Salton Basin from the Gulf of California.

The Salton Basin (Figure 2-1) is bordered on the northwest by the San Gorgonio pass, on the west by the San Jacinto and Santa Rosa mountains, on the east by the Little San Bernadino and Chocolate mountains, and is contiguous with the Mexicali Valley in Mexico to the south (Setmire et al. 1990). The Salton Basin is 130 miles long and is 70 miles at its widest point.

2.2.2 Physical Characteristics

The Salton Sea currently has a surface elevation of about -227 to -228 feet msl with an estimated surface area of 242,049 acres (378 square miles) and 239,125 acres (374 square miles), respectively, at these surface elevations (Ferrari and Weghorst 1995). The lake is about 35 miles long and 15 miles wide at its widest point (Ferrari and Weghorst 1995). Recent data obtained by the USBR (Ferrari and Weghorst 1995) show that the Sea has a maximum depth of 51 feet with a volume of 7,654,585 acre-feet at surface elevation -227 feet msl and 7,413,997 acre-feet at elevation -228 feet msl. The inflow into the Sea is approximately 1,300,000 acre-feet per year, which carries about 4,000,000 tons of salt per year (California Regional Water Quality Control Board 1993).



SOURCE: Compiled in 1947 engraved and printed in 1952 by the

FIGURE

2-1

2.3 HYDROLOGY

2.3.1 Inflow

Inflow into the Salton Sea occurs through precipitation, surface-water inflow, and ground-water inflow. The Salton Sea watershed is approximately 8,360 square miles. A total average annual inflow of 1,322,000 acre-feet from the watershed has been estimated by IID. There is an additional 46,500 acre-feet contributed from rainfall onto the Sea each year. Table 2-1 breaks down the inflow into the Salton Sea by source, based on IID estimates. The total inflow of 1,262,000 acre-feet per year for rivers and agricultural drains is based on a 5-year average of the period 1982 to 1986. The inflow from ground water and intermittent washes is based on U.S. Geological Survey (USGS) estimates (Littlefield 1966; USDOI and RAC 1969).

Table 2-1

SALTON SEA INFLOW AND RELATIVE CONTRIBUTION FROM MAJOR SOURCES

Source of Inflow	Total Average Annual Inflow (Acre-feet)	Percent Contribution of Total Inflow
Alamo River	624,357	46.0
New River	438,379	32.0
Agricultural Drains	106,274	8.0
Whitewater River	92,990	7.0
Ground Water	50,000	4.0
Precipitation	46,478	3.0
San Felipe Creek	6,000	0.4
Salt Creek	4,000	0.3
Total	1,368,478	100.0

Precipitation

Approximately 3 percent of the total annual inflow into the lake is due to precipitation. The little precipitation that occurs in the Salton Sea drainage area is predominantly the result of winter storms and to a lesser extent summer storms. Most of the drainage area receives less than 3 inches of rain per year (Ormat 1989). A 38-year average of rainfall directly on the Sea surface, based on measurements from three evaporation stations, was estimated at 2.28 inches per year (0.19 feet/year) (Parsons Water Resources, Inc., 1985).

Surface Water Drainages

Geographically, surface-water inflow to the Salton Sea comes from three principal sources: 1) Imperial Valley, 2) Coachella Valley, and 3) the remaining tributary area. Inflow from the Imperial Valley includes drainage from both the Imperial Valley and the Mexicali Valley in Mexico. Approximately 80 percent of the total annual inflow into the Salton Sea is through the Alamo and New rivers located in the Imperial and Mexicali valleys. These rivers mainly carry agricultural drainage water and run-off water from Mexico, including human and industrial wastes to the Sea. The major source of inflow from the Coachella Valley is through the Whitewater River (Coachella Valley Stormwater Channel). The Whitewater River contributes approximately 7 percent of the total annual inflow into the lake. The principal surface-water input from the remaining tributary area is from San Felipe Creek, entering from the southwest end, and Salt Creek, entering from the northeast, as well as other minor washes contributing about 0.7 percent of the total annual input. Other input includes minor channels and agricultural drains that discharge directly into the lake and represent about 8 percent of the total annual inflow.

Ground-water Inflow

Ground water contributes very little to the total inflow to the Salton Sea. The Sea and its surrounding area are underlain by relatively impermeable lake deposits that overlie thick alluvial sediments. This is especially true of Imperial Valley sediments, which have low permeability. Coachella Valley sediments are more permeable and are associated with higher yields of both artesian and nonartesian wells (Colorado River Board of California 1992).

Annual ground-water inflow to the lake has been estimated at 50,000 acre-feet. Of this total, approximately 30,000 acre-feet are contributed by the Coachella Valley where surfacing artesian water is intercepted by tile drains, about 2,000 acre-feet is contributed by the Imperial Valley, about 10,000 acre-feet enters through the alluvium bordering San Felipe Creek, and 8,000 acre-feet enter through the alluvium in other peripheral areas (Colorado River Board of California 1992; Littlefield 1966).

2.3.2 Evaporation

The Salton Sea is a terminal lake located in an arid environment. The only way water leaves the lake is through evaporation. The average annual evaporation from the Salton Sea for the period of 1948 through 1962 was 5.78 feet (Hely et al. 1966), and the average annual evaporation rate for 1950 through 1987 was calculated to be 5.45 feet (Ormat 1989). Currently, the evaporation rate is estimated between 5.5 (Ormat 1989) and 6.0 feet/year (California Regional Water Quality Control Board, Colorado River Basin - Region 7 1991). The volume of water that evaporates in a given year is dependent upon the water surface area or water level of the lake and the salinity and ionic composition of the water. As the salinity increases, a decrease in the rate of evaporation can be expected. Currently, the volume of water that evaporates from the Sea each year is approximately equal to the volume of inflow each year.

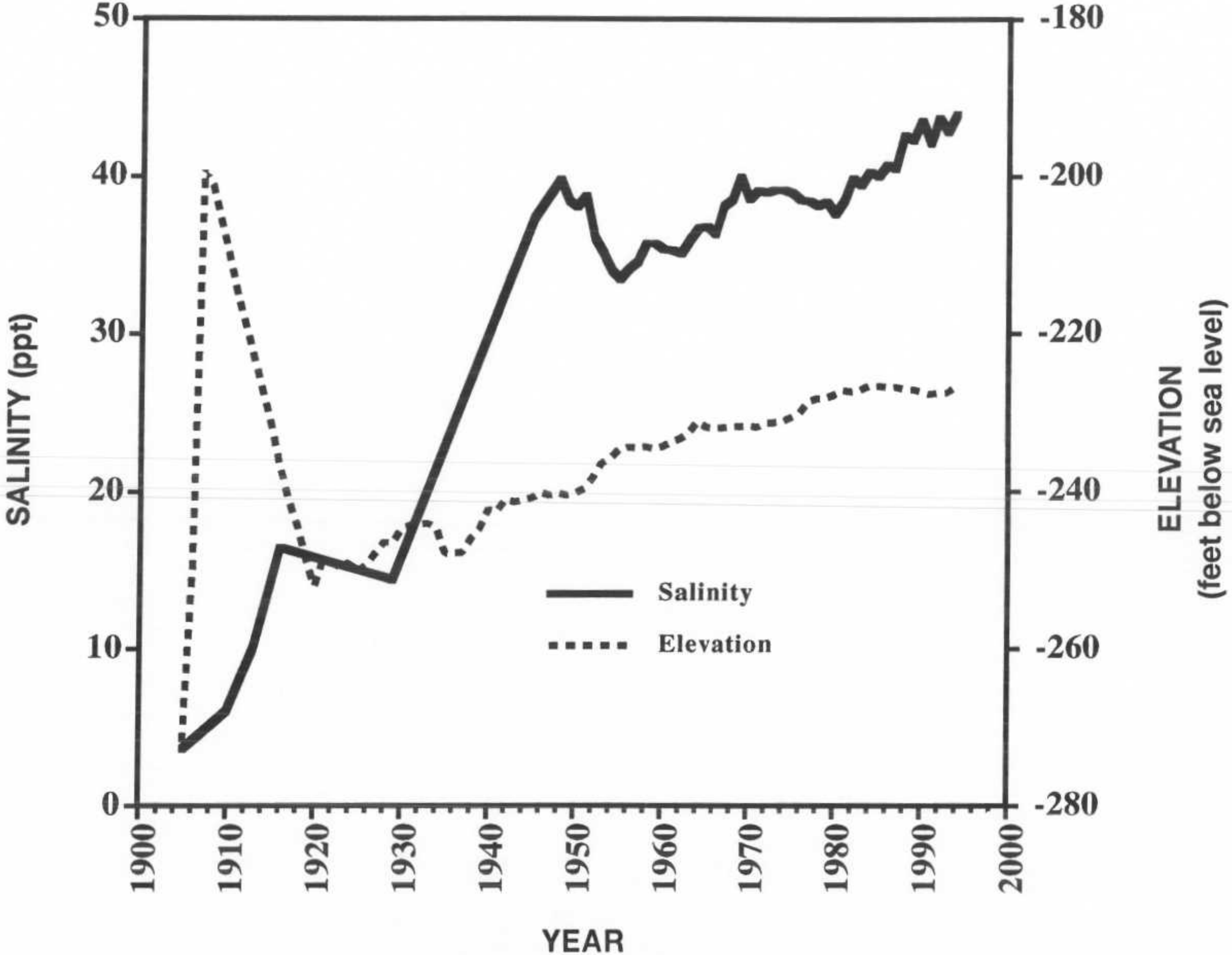
2.3.3 Surface Elevation

In 1907, when the Salton Sea was first formed, the surface elevation was about -195 feet msl. At that time, evaporation rates greatly exceeded inflow rates and the surface elevation dropped rapidly to about -250 feet msl in 1924. After 1924, increased irrigation and improvement of agricultural drainage systems and several major rain storms caused inflow to exceed evaporation, and resulted in a gradual increase in the lake's surface elevation. Although large fluctuations can still occur, surface elevation has stabilized somewhat, due in part to water conservation programs initiated by the irrigation districts after 1980. Figure 2-2 shows the historical water surface elevations. Currently, the water surface elevation is between -228 and -227 feet msl (Ferrari and Weghorst 1995). Recently, flood water damage to both public and private property caused by the rise of the Sea has resulted in multimillion dollar lawsuits (Ferrari and Weghorst 1995).

2.4 WATER QUALITY

2.4.1 Salinity

The salinity of the Salton Sea is a function of the total mass of dissolved salts present and the volume of the lake. The Colorado River water that entered the Salton Basin in 1907 had a salinity of 0.8 ppt; however, the salinity of the newly formed lake was 3.5 ppt. This was due to the dissolution of large quantities of salts that had accumulated in the lake bed



OGDEN

Historical Salinity and Elevation Through Time

FIGURE 2-2

from previous filling and drying cycles. Since the lake was first formed, there has been a trend toward increasing salinity, from the 3.5 ppt in 1907 to about 44 ppt in 1995 (Figure 2-2). The increasing salinity is due mainly to high evaporation rates, low rainfall, and the discharge of saline agricultural wastewaters into the lake.

The volume of water in the Salton Sea rapidly decreased after 1907 because of high evaporation rates and low rates of inflow. The reduced Sea volume, combined with gradual dissolution of salts from the sediments, caused a rapid increase in salinity. By 1920, the salinity had reached 38 ppt, and in 1936 it reached 43 ppt. From 1937 to 1962, the volume of the Salton Sea had greatly increased and, as a result, the salinity had decreased from 43 to 34 ppt by 1962 (Littlefield 1966). Because the volume of the Sea has stabilized somewhat, and evaporation and concentration of salts continue to occur, the salinity has slowly been increasing since 1980. The lake currently receives about 4,000,000 tons of salt per year dissolved in about 1,300,000 acre-feet of annual inflow. Presently, the salinity of the lake is approximately 44 ppt, and the rate of increase of salinity is about 0.8 ppt per year.

Salinity is a measure of the total salts present in water. The composition of these salts can influence evaporation rate, the lake's physical processes, and the biota present in the system. The major ions present in the Salton Sea are chloride, sodium, and sulphate. Recent analysis of the ionic composition of Salton Sea water was conducted by CVWD at eight sampling locations (CVWD 1994). The ionic composition of the Salton Sea differs from the ocean as shown in Table 2-2.

Ormat (1989) performed an analysis on Salton Sea water collected at five sampling stations by IID in 1981 to 1987, which allowed for some predictions on the sequence of precipitated salts. The analysis indicated that calcium carbonate ($CaCO_3$) and calcium sulphate ($CaSO_4$) are saturated in Salton Sea water. As Salton Sea water is concentrated, both $CaSO_4$ and Na_2SO_4 will precipitate out and become suspended solids. Ormat (1989) concluded that the high sulphate content and NaCl presence in the lake explained the additional precipitation of Na_2SO_4.

Table 2-2

THE IONIC COMPOSITION OF SALTON SEA WATER COMPARED TO OCEAN WATER

Constituent	Ion	Average of 8 Stations Located Throughout the Salton Sea (ppt)*	Average of 3 Stations Located in the Center of the Salton Sea* (ppt)	Normal Ocean (ppt)
Bicarbonate	HCO_3^-	0.25	0.24	0.15
Sulphate	SO_4^{-2}	9.85	9.63	2.69
Chloride	Cl^-	17.71	18.38	19.26
Calcium	Ca^+	1.13	1.18	0.41
Magnesium	Mg^{+2}	1.39	1.40	1.29
Potassium	K^+	0.18	0.20	0.39
Sodium	Na^+	12.33	12.43	10.71
Total Salts		42.83	43.47	34.90

*Samples collected by CVWD, April 1994.

2.4.2 Other Dissolved Solids

A reconnaissance study of water quality, bottom sediment, and biota associated with the irrigation drainage in the Salton Sea area was conducted in August 1986 by the USGS to determine the concentrations of certain trace elements and pesticides (Setmire et al. 1990). Samples were collected at 15 sites, including a composite site in the Salton Sea for bottom sediments and water quality and at 5 sites for biological samples (Setmire et al. 1990).

Selenium

Selenium was found to be the major element of concern in the Salton Sea area. Federal criteria for the protection of aquatic life is set at 5 micrograms per liter (µg/L) of selenium in water. The highest concentration of selenium for water samples was 300 µg/L collected in a tile agricultural drain. The average for the eight tile drains was 71 µg/L. The Alamo and New rivers at their outlets had concentrations of 9 and 4 µg/L, respectively. The minimum concentration was 1 µg/L for a composite sample collected in the Salton Sea. The

Colorado River is believed to be the source of the selenium in the Salton Sea watershed. Lower Colorado River water contains about 1-2 μg/L of selenium.

The highest concentration in a composite sample of Salton Sea bottom sediments was 3.3 milligrams per kilogram (mg/kg). Concentrations of selenium in sediments from adjacent rivers and drains ranged from 0.1 to 1.9 mg/kg, the lowest concentration was detected in the Whitewater River. The highest concentration of selenium in the composite Salton Sea sediment sample also had the lowest corresponding water concentration. This led Setmire et al. (1990) to conclude that selenium is removed from the water and concentrated in the bottom sediments allowing for incorporation and bioaccumulation of selenium into the food web.

Concentrations of selenium in fish tissues at the Salton Sea ranged from 3.5 to 20 micrograms per gram (μg/g) for tilapia and corvina, with a mean concentration of 10.5 μg/g, dry weight. The Health Advisory Board has set a level of 8 μg/g dry weight in fish for human consumption. Selenium concentrations were as high as 27 and 42 μg/g in black-necked stilts and cormorants. Although adverse effects from selenium at these concentrations in the Salton Sea area has not been documented, these levels have been shown to cause reproduction problems in other areas (Setmire et al. 1990).

Organochlorine Compounds

1,1-dichloro-2,2-bis(p-chlorophenyl)ethane (DDD), 1,1-dichloro-2,2-bis-(p-chlorophenyl) ethylene (DDE), and dieldrin were detected in a composite sediment sample from the Salton Sea, though at low levels (0.4, 2.2, and 0.2 μg/kg [wet weight], respectively; Setmire et al. 1990). The maximum concentrations detected in sediments for each of these compounds respectively, was 24 μg/kg of DDD in the New River, 64 μg/kg of DDE in the Alamo River outlet, and 2.2 μg/kg of dieldrin in the New River. Other organochlorine compounds detected in drainage and river sediments but not in the Salton Sea include polychlorinated biphenyls (PCBs), chlordane, methoxychlor, and toxaphene. As these compounds are strongly hydrophobic (do not dissolve readily in water), concentrations in water are usually low.

Organochlorine pesticide residues have been reported for fish and birds in the Salton Basin (Linn 1987; Mora 1984), and DDT metabolites may be bioaccumulating in certain waterfowl tissues (Setmire et al. 1990). Pesticides from agriculture in the Imperial, Coachella, and Mexicali valleys enter the Salton Sea via tributary drainages. Effects from organochlorine pesticides may be primarily chronic in nature. For example, eggshell thinning in birds has been linked to body burdens of DDT and its metabolites, and reduced reproductive success in reptiles and other species due to estrogenic mimicry from organochlorine compounds has been reported.

Nutrients and Salton Sea Productivity

The Salton Sea is a highly productive body of water. The Sea receives large amounts of nutrients such as nitrogen and phosphorus from the fertilizers used in agriculture in the area. Table 2-3 presents nutrient data on the Salton Sea sediments and some of its tributaries from samples taken in August 1986 (Setmire et al. 1990). The large amounts of nutrients in the Sea makes it highly productive which cause large phytoplankton (microscopic plants) blooms. If the blooms become too dense, decomposing phytoplankton can deplete dissolved oxygen from the water column. The decomposition of the plankton and the additional loss of oxygen in areas with already low oxygen, have been cited as contributing factors in fish kills in the Sea (California Regional Water Quality Board 1993).

2.5 Biological Resources

Although biological surveys were not conducted as part of this project, the following description of the biological resources associated with the Salton Sea is based on existing information for the area.

Information on biological resources was obtained, in part, from the following sources: *Final Environmental Impact Report for Modified East Lowline and Trifolium Interceptors, and Completion Projects* (IID 1994), *Biological Technical Report in Support of an Environmental Assessment for the Hazard Area Geothermal Exploration Project* (Ogden Environmental 1994a), and *Summary of Spring Biological Resources Surveys and Wetland Assessment for the Magma Power Company, Calipatria, California* (Ogden Environmental 1994b), and the California Natural Diversity Data Base (CNDDB). The vegetation community classification system follows Holland (1986), and modifications based on disturbance factors and/or exotic species are detailed in the text.

Table 2-3

CONCENTRATIONS OF SELECTED NUTRIENTS IN BOTTOM SEDIMENTS IN THE SALTON SEA AREA, AUGUST 1986

Site Name	Nitrogen, NH_4, total (mg/kg as N)	Nitrogen, NH_4 + org. (mg/kg as N)	Nitrogen, organic (mg/kg as N)	Nitrogen, $NO_2 + NO_3$ (mg/kg as N)	Phosphorus, total (mg/kg as P)	Carbon, organic (g/kg as C)	Carbon, inorganic (g/kg as C)
Salton Sea composite of four samples	28	1,500	1,500	10	890	10	20
East Highline Canal	37	--	--	6.0	--	4	15
Alamo River at international boundary	69	390	320	3.0	1,200	5	16
New River at international boundary	67	870	800	6.0	1,000	2	21
Alamo River at Imperial Wildlife Management Area	53	750	700	3.0	1,100	4	17
New River at midpoint	26	610	580	3.0	1,300	4	14
Alamo River at outlet	17	470	450	27	1,100	1	18
New River at outlet	23	540	520	3.0	1,600	3	14
Trifolium Drain 1	79	1,800	1,700	4.0	1,200	11	21
Vail Drain 4	93	960	870	3.0	1,100	1	23
T-Drain at Imperial Wildlife Management Area	39	250	210	3.0	870	1	20
Whitewater River upstream from Highway 111	7.1	30	23	4.0	600	0.3	0.7

Table 2-3 (Continued)

CONCENTRATIONS OF SELECTED NUTRIENTS IN BOTTOM SEDIMENTS IN THE SALTON SEA AREA, AUGUST 1986

Site Name	Nitrogen, NH_4, total (mg/kg as N)	Nitrogen, NH_4 + org. (mg/kg as N)	Nitrogen, organic (mg/kg as N)	Nitrogen, $NO_2 + NO_3$ (mg/kg as N)	Phosphorus, total (mg/kg as P)	Carbon, organic (g/kg as C)	Carbon, inorganic (g/kg as C)
Whitewater River at outlet	6.5	110	100	7.0	320	0.4	1.2
Avenue 64 Evacuation Channel at Highway 195	26	260	230	3.0	1,500	2	10

--, no data
Source: Setmire et al. 1990

2.5.1 Vegetation Communities

Typical vegetation communities expected to occur in the Salton Sea area include Sonoran creosote bush scrub, desert saltbush scrub, desert sink scrub, stabilized and partially stabilized desert dunes, tamarisk scrub, freshwater marsh, cismontane alkali marsh, Sonoran cottonwood-willow riparian forest/nonnative tamarisk scrub intermediate, open water, mud flats, ruderal, and agricultural lands.

Sonoran Creosote Bush Scrub

Sonoran creosote bush scrub, described as the basic creosote scrub of the Colorado Desert, is found on well-drained secondary soils of slopes, fans, and valleys (Holland 1986). This community is dominated by creosote bush (*Larrea divaricata*). Other subdominant species include burro weed (*Ambrosia dumosa*), brittle brush (*Encelia farinosa*), and ocotillo (*Fouquieria splendens*). Ephemeral herbs flower in late February and March when winter rains are sufficient (Holland 1986).

Desert Saltbush Scrub

Desert saltbush scrub occurs on poorly drained soils with high alkalinity and/or salinity (Holland 1986). In flat areas around the Sea, the dominant plant species in this vegetation type is allscale (*Atriplex polycarpa*) and other *Atriplex* spp. (IID 1994). Other plant associates include mesquite (*Prosopsis sp.*) and narrow-leaved wingscale (*Atriplex canescens*) found in areas with shallow water tables, and tamarisk (*Tamarix chinensis, T. ramosissima*) and quailbush (*Atriplex lentiformis*) found in the higher saline areas (IID 1994).

Desert Sink Scrub

The desert saltbush scrub transitions to desert sink scrub as ground-water elevation and salinity increase (IID 1994). The desert sink scrub is described by IID (1994) as reaching plant cover of 50 percent in areas with slightly higher water level and lower salinity. Typical plant species include iodine weed (*Suaeda torreyana* var. *ramosissima*) and seepweed (*Suaeda moquinif*). Iodine bush is considered a pioneer species. It colonizes playa-like situations that are periodically inundated and characterized by saline accumulations.

Stabilized and Partially Stabilized Desert Dunes

Stabilized and partially stabilized desert dunes are characterized by accumulations of dune sand in the desert. These areas are stabilized or partially stabilized by evergreen or deciduous shrubs, scattered low annuals, and/or perennial grasses (Holland 1986). Water is retained just below the sand surface, allowing perennial vegetation to survive periods of drought (Holland 1986). As the dune system stabilizes, the total vegetative cover increases. Dominant plant species include tamarisk and mesquite (IID 1994). Tamarisk covers the hummocks, while mesquite is found in the lower flats and is less tolerant of saline conditions. Other plant species found in this community include wingscale, goldenweed, and arrowweed (*Pluchea sericea*).

Tamarisk Scrub

Tamarisk scrub consists almost exclusively of tamarisk (*Tamarix chinensis*), a nonnative weedy shrub that often invades after native vegetation has been cleared. This scrub occurs on sandy or gravelly braided washes or along intermittent streams, often in saline areas. Tamarisk is a strong phreatophyte and a prolific seeder, and is therefore an aggressive competitor in disturbed riparian corridors (Holland 1986). Tamarisk scrub generally offers poor habitat for native wildlife except as nesting and roosting areas for birds.

Freshwater Marsh

Freshwater marsh consists of scattered stands dominated predominantly by weedy nonnative species such as common reed (*Phragmites australis*), cattail (*Typha* sp.), golden dock (*Rumex maritimus*), and rabbitfoot grass (*Polypogon monspeliensis*). Freshwater marsh is limited primarily to linear stands along unlined drainage canals and appears to have developed as a result of agricultural irrigation. Extensive man-created and managed freshwater marsh areas are found on the adjacent Imperial Waterfowl Management Area, Salton Sea National Wildlife Refuge, and private hunting clubs around the Sea. These support large numbers of waterfowl and a variety of sensitive species, particularly Yuma clapper rail and black rail.

Cismontane Alkali Marsh

Cismontane alkali marsh present in the area consists of excavated, low-lying areas supporting a dense cover of salt grass (*Distichlis spicata*) with scattered clumps of alkali bulrush (*Scirpus robustus*), cattail, common reedgrass, spreading alkali-weed (*Cressa truxillensis*), verrucose Sea-purslane (*Sessuvium verrucosum*), saltmarsh sand spurrey (*Spergularia marina*), and seaside heliotrope (*Heliotropium curassavicum*), among others. Cismontane alkali marsh occurs on alkaline soils in areas with a high water table. It is found primarily in disturbed sites such as borrow areas adjacent to dikes and along unlined drainage canals.

Sonoran Cottonwood-Willow Riparian Forest/Nonnative Tamarisk Scrub Intermediate

Sonoran cottonwood-willow riparian forest/nonnative tamarisk scrub intermediate (River Riparian) is found along rivers where historic willow and cottonwood stands have been intermixed or replaced by dense stands of tamarisk (IID 1994). Other plant species present include common reed (*Phragmites australis*), wingscale, and giant reed (*Arundo donax*). Tree species, such as willow (*Salix* spp.) cottonwood (*Populus fremontii*), palo verde (*Cercidium floridum*), mesquite, and California date palm (*Washingtonia filifera*) may occasionally be included in shrubby growth areas with low salinities (IID 1994).

Open Water and Mudflats Habitats

Interspersed throughout the Salton Sea are areas of open water and mudflats. Open water habitat is differentiated from mudflats in that it is more or less permanently flooded, and may support submerged and/or emergent vegetation. Mudflats are unvegetated areas that are periodically flooded and exposed.

Ruderal Habitat

Ruderal habitat characterizes landscaped or otherwise regularly maintained areas along roads, irrigation ditches, railroads, agricultural field borders, and buildings. These areas are regularly disturbed by mowing and vehicle traffic. Ruderal areas are vegetated by weedy and early successional species that can survive regular disturbance; e.g., pigweed (*Amaranthus blitoides*), cheeseweed (*Malva parviflora*), shepherd's purse (*Capsella bursa-*

pastoris), five-hook bassia (*Bassia hyssopifolia*), saltbush, tamarisk, bindweed (*Convolvulus arvensis*), Russian thistle (*Salsola tragus*), bermuda grass (*Cynodon dactylon*), Mexican sprangletop (*Leptochloa* sp.), as well as other common weedy species.

Agricultural Land

Agricultural land is found extensively throughout the Imperial and Coachella valleys and consists of actively cultivated, irrigated, and drained land. This habitat generally offers poor habitat for wildlife except as foraging areas for agricultural pest species and raptors, such as burrowing owls and red tailed hawks, which feed on insects and rodents attracted to crops. Flooded fields also offer foraging areas for wading birds and waterfowl, such as egrets and geese, particularly during winter.

2.5.2 Wildlife

It is probable that during the breakthrough of the Colorado River many organisms living in the river were introduced into the newly formed lake (Evermann 1916). With the increase in salinity, however, there have been major changes in the biotic community within the Sea. The following sections summarize the wildlife expected to occur in the Sea and in the surrounding desert habitats. This information is based on existing literature and databases as referenced.

Bacteria

The abundance and significance of bacteria in alkaline saline lakes are not well understood or studied in general. Bacteria probably have a dual functional role, acting as both primary producers and decomposers. As with most saline lakes, the Salton Sea bacterial assemblage is virtually unstudied. There are purple and green sulphur bacteria present, but there have been no real attempts to study the pelagic or benthic bacteria qualitatively or quantitatively. Elevated levels of bacteria are periodically present at the south end of the Salton Sea as a result of elevated bacterial levels in river discharge (RWQCB 1996).

Phytoplankton and Phytobenthos

The dominant primary producers in the lake are phytoplankton and phytobenthos. Phytoplankton and phytobenthos are microscopic plants that are found in the water column and benthic (bottom) habitats, respectively. The plant life in the Salton Sea is predominantly single-celled algae. Carpelan (1961) studied the lake between 1954 and 1956. The major groups of algae present were found to be diatoms (Chrysophyta), dinoflagellates (Pyrrophyta), and green algae (Chlorophyta). At this time, blue-green algae (Cyanophyta) was also found on the bottom of the lake in shallow water, and on buoys and pilings in the lake. In 1970, the USDOI reported that the major species present in the Salton Sea included diatoms (*Cyclotella caspia*, *Nitzchia longissima*, *Nitzschia sp.*, *Pleurosigma sp.*, *Thalassionema nitzschoides*), dinoflagellates (*Gyrodinium resplendens*, *Peridinium sp.*, *Cachonina niei*, *Exuviella sp.*), Euglenophyta (*Eutreptia sp.*), (*Westella botryoides*), and blue-green algae (*Oscillatoria sp.*, *Phomidium sp.*). Though no recent, in-depth studies of the current phytoplankton assemblage of the Sea have been conducted, samples collected by Gonzalez in 1991, indicated that many of these species are still present (Gonzalez, pers. comm. 1995). Dominant species in these collections included diatoms (*Cyclotella caspia*, *Nitzchia longissima*, *Nitzschia* sp., *Pleurosigma* sp., *Thalassionema nitzschoides*), dinoflagellates (*Oxyrrhis marina*, *Exuviella* sp., *Cachonina neii*, *Gymnodinium* sp., *Peridinium throchoideum*), and blue-green algae (*Oscillatoria* sp., *Phormidium* sp., *Spirulina* sp., *Calothrix* sp.).

Invertebrates

There are currently five phyla of invertebrates represented within the Salton Sea: Protozoa, Rotifera, Nematoda, Annelida (segmented worms), and Arthropoda (crustaceans and insects). Some of the common invertebrates found in the Sea include ciliate protozoans, *Brachionus plicatilis* (rotifer), *Apocyclops dengizicus* and *Cletocamptus dietersi* (copepods), *Balanus amphitrite* (barnacle), *Neanthes succinea* (pileworm), *Gammarus mucronatus* (amphipod), and *Trichocorixa reticulata* (corixid or water boatman). The major zooplankters (microscopic animals) in the Salton Sea include *Brachionus*, the two copepods, the egg and larval stages of the pile worm, and the nauplia and cypris of the barnacle. The remaining organisms and life history stages are considered to be primarily benthic. Most habitats in the lake are soft bottomed sand or silt, with only a few rocky areas present. This means all sessile organisms that need to attach to a hard substrate are limited to rocky areas, docks, discarded debris, or inundated brush along the shore.

Fish

Fishery resources in the Salton Sea area are present in canals, irrigation ditches, rivers, and the Sea itself. A list of fish present in the these water bodies is provided in Table 2-4. A brief history of fish introductions into the Sea is provided below.

History of Fish Introductions

Since the first introduction of fish to the Salton Sea in the early 1900s, the Sea has been characterized by changing fish communities. Initially freshwater species were introduced to the Salton Sea from the Colorado River during the Sea's initial formation. Though no published records exist, the fish were noted to be abundant in both numbers and numbers of species (Evermann 1961). As both the salinity and water level increased over time, however, the original freshwater fish fauna disappeared.

In 1929, a biological survey conducted by Coleman (1929) recommended the introduction of sportfish into the Salton Sea. Between 1929 and 1956, the California Department of Fish and Game (CDFG) made numerous transplants of both fish and invertebrates to develop a sport fishery in the Sea. Of the numerous species intentionally transplanted, only the pileworm (*Neathes*, introduced as fish forage), mudsucker, and three sportfish (orangemouth corvina, sargo, and bairdiella) survived. Two fish, threadfin shad (*Dorosoma petenense*) and tilapia, were accidentally introduced to the Salton Sea through tributary drainages. The threadfin shad was introduced into the Colorado River in 1954, entering the Salton Sea via irrigation canals in 1955 (Walker et al. 1961). This fish cannot reproduce in the Sea (Meyer Resources, Inc. 1988), and is probably only present in the tributaries. Both *Oreochromis mossambicus* and *Tilapia zilli* were seen in tributaries near the lake in 1964. The accounts vary as to which species exist in the lake, but is most likely *Oreochromis mossambicus* or some hybrid (Meyer Resources Inc. 1988; Black 1981).

The Salton Sea is currently reported to support eight species of fish, including desert pupfish (*Cyprinodon macularius*), sailfin molly (*Poecilia latipinna*), porthole livebearer (*Poeciliopsis gracilis*), longjaw mudsucker (*Gillichthys mirabilis*), tilapia, bairdiella (*Bairdiella icistia*), sargo (*Anisotremus davidsoni*), and orangemouth corvina (*Cynoscion xanthulus*). Bairdiella, sargo, and corvina are marine species, while the remaining species are estuarine or freshwater fish with extreme salinity tolerances. Each of these species is briefly described below.

Table 2-4

FISH SPECIES OCCURRING AT THE SALTON SEA

Scientific Name*	Common Name
Family Centrachidae	
Lepomis cyanellus	Green Sunfish
Micropterus salmoides	Largemouth Bass
Family Cichlidae	
Oreochromis mossambicus	Tilapia
Tilapia zilli	Tilapia
Family Cottidae	
Dorosoma petenense	Threadfin Shad
Family Cyprinidae	
Cyprinus carpio	Carp
Notropis lutrensis	Red Shiner
Pimephales promelas	Fathead Minnow
Family Cyprindontidae	
Cyprinodon macularius	Desert Pupfish
Fundulus parvipinnis	California Killifish
Family Gobiidae	
Gillichthys mirabilis	Longjaw Mudsucker
Family Haemulidae	
Anisotremus davidsoni	Sargo
Family Ictaluridae	
Ictalurus catus	White Catfish
Ictalurus natalis	Yellow Bullhead
Ictalurus punctatus	Channel Catfish

Table 2-4 (Continued)

FISH SPECIES OCCURRING AT THE SALTON SEA

Scientific Name*	Common Name
Family Poeciliidae	
Gambusia affinis	Mosquitofish
Poeciliopsis gracilis	Porthole Livebearer
Poecilia latipinna	Sailfin Molly
Poecilia mexicana	Shortfin Molly
Xiphophorus variatus	Variable Platyfish
Family Sciaenidae	
Cynoscion xanthulus	Orangemouth Corvina
Bairdiella icistia	Gulf Croaker (Bairdiella)

* Marine fish nomenclature follows Miller and Lea (1972), freshwater fish follows AFS (1991)

Desert Pupfish

Desert pupfish is the only native species in the Salton Sea. Historically, it was found in portions of Arizona, southeastern California, and northern Mexico (Lau and Boehm 1991). It is both a California endangered and a federally endangered species (Federal Register 51(61):10842-51). Desert pupfish is a small and chubby fish, with a thick body that measures up to 1.8 inches (in) in length. The females are pale with brownish blotches. The males are brightly colored during the spring and summer with blue backs and golden bellies, which may be important for visual stimulation during courtship (Liu 1969).

Desert pupfish have a high tolerance for extreme environmental conditions, including temperature, dissolved oxygen, and salinity (Barlow 1958). Barlow (1958) reported that the desert pupfish survived salinity as high as 90 ppt in the laboratory and reported finding them in pools near the Salton Sea with salinities of up to 65 ppt.

Desert pupfish are opportunistic feeders; their diet varies seasonally with food availability (Naiman 1979). Their diet consists of algae, minute organisms associated with detritus, insects, fish eggs, and small crustaceans (Cox 1972; Naiman 1979). They are not considered important food for wading birds and other fish because of their low numbers (Walker et al. 1961; Barlow 1961).

Historically, desert pupfish were abundant along the shore of the Salton Sea through the 1950s (Barlow 1961). During the 1960s, the numbers declined and by 1978, they were noted as scarce and sporadic (Black 1980). The decline in abundance is due primarily to the introduction of exotic species and habitat alteration (Lau and Boehm 1991). Surveys conducted by the U.S. Fish and Wildlife Service (USFWS) to determine their distribution around the Salton Sea indicated that desert pupfish were present in a majority of the drains and shoreline pools around the Salton Sea, at the mouth of Salt Creek, and in lower San Felipe Creek with varying densities (Lau and Boehm 1991).

Sailfin Molly

Sailfin molly has a native range along the east coast of North America from North Carolina to the Yucatan Peninsula. The population in the Salton Sea is believed to have stemmed from escapees/releases from tropical fish farms in the 1960s (St. Amant 1966). Sailfin mollies inhabit saltwater marshes, ponds, and ditches, as well as freshwater pools, ponds, and ditches (Herbert et al. 1987). They are an oblong fish, reaching over 4.7 inches in length. They differ from most other freshwater species in that they are livebearers, the females carry the developing eggs until they hatch internally, and the young emerge from the female alive (Eddy and Underhill 1978). They feed on plants, small organisms associated with detritus, and opportunistically on insects and their larvae (Eddy and Underhill 1978; Herbert et al. 1987). They are extremely tolerant of wide ranges of salinity (Herbert et al. 1987) and adults are reported to withstand salinities greater than 80 ppt (Nordlie et al. 1992; Herre 1929).

Porthole Livebearer

Porthole livebearer native range includes Central America and southern Mexico (Lee et al. 1980). It was also probably introduced through escapes/releases from tropical fish farms in the 1960s (Mearns 1975).

Longjaw Mudsucker

Longjaw mudsucker has a native range from central California to the Gulf of California. The Salton Sea population stems from 500 fish planted in 1930 by CDFG (Walker et al. 1961). They are found mostly inshore around cover and quiet water (Walker et al. 1961). The longjaw mudsucker reaches a length of 5.5 in. They have a long upper jaw reaching to the posterior part of the head. They are able to withstand high salinities and have been collected in the field with salinities of 83 ppt (Barlow 1963).

Their diet consists of harpacticoid copepods, larvae, and nematodes for juveniles and *Neanthes*, barnacles, and juvenile pupfish, mudsuckers, and tilapia for the adults. They have value as baitfish for corvina and historically were numerous enough to support a small bait fishery. During certain seasons they may be an important food item for corvina (Walker et al. 1961).

Tilapia

Tilapia is an introduced cichlid from Africa used in mosquito control, weed control, and as an aquarium fish. They are a robust fish reaching up to 3.53 pounds (lbs) in weight and a length of 15.8 in. The males are larger than the females, which may be related to the fact that they are mouthbreeders (females carry the eggs and young fry in their mouths). Tilapia is a warm freshwater species that is also able to withstand high salinities. Spawning may occur 5 to 8 times per year. They are limited by high water temperatures and low dissolved oxygen concentrations in the spring and summer and by low winter water temperatures in the Sea which can cause large die offs (Meyer Resources Inc. 1988; USFWS 1996a).

Tilapia are omnivorous feeding on plankton, insects, larvae, crustaceans, and plant material. They are currently the major food source for corvina, and are also an important sportfish (Black 1981; Meyer Resources Inc. 1988). Their salinity range is thought not to exceed 70 ppt, and their reproductive capabilities may be lost at 60 ppt (Pullin et al. 1982). Popper and Lichatowich (1975) reported reproduction at salinities as high as 49 ppt.

Bairdiella

Bairdiella is native to the Gulf of California. They are common in shallow and moderate depths. The Salton Sea population stems from 67 fish introduced in 1950 to 1951 by CDFG (Walker et al. 1961). By 1952, sampling in the Sea indicated a sizable population (Walker et al. 1961). Bairdiella are small silvery fish, and average about 5.6 ounces in weight and 9.8 inches in length.

The diet of the young of the year consists of copepods and their larvae, barnacle larvae, fish eggs, and smaller larvae of their own. The adults feed primarily on pileworms (Quast 1961) and probably other invertebrates. Bairdiella are an important source of food for corvina. Salinity and temperature effects on bairdiella reproduction studied by May (1975, 1976) indicate diminished reproductive success at 40 ppt and above. Ichthyoplankton field data collected between 1987 and 1989, with salinities ranging from 38 to 44 ppt respectively, showed a significant increase in the number of late larval stages but a decrease in the number of eggs and early larvae with each progressive year (Matsui et al. 1991a).

Sargo

Sargo have a native range from Point Conception, California to southern Baja California and the upper Gulf of California. The population in the lake stems from the 65 fish planted in 1951. Initially, they did not show an explosive increase. Evidence of spawning occurred in 1957 and by 1960 a large population existed, supporting a sportfishery (Walker et al. 1961).

Sargo has been reported to exceed a length of 17 in. In the Salton Sea they have been reported to reach 2.2 lbs in weight and 13.8 inches in length. They have a deep body, a strong spinous first dorsal fin, and have three strong spines in the anal fin. A black bar extends below the 5th and 7th dorsal spine. With their increase in numbers, the sargo became an important gamefish and forage fish in the Sea (Walker et al. 1961; Meyer Resources Inc. 1988). Their numbers, however, have greatly declined and their present status is unclear. Results of laboratory salinity tolerance tests indicated that although sargo acclimated to treatment salinities of 45 ppt, significant larval mortality occurred in salinities above 40 ppt (Matsui et al. 1991b). Field data collected between 1987 and 1989 with salinities of 38 and 44 ppt, respectively, showed a decrease in both the number of late egg and early larval stages for sargo (Matsui et al. 1991a).

Orangemouth Corvina

Orangemouth corvina has a native range within the Gulf of California. They were planted in the Salton Sea at various times between 1950 and 1955. They increased substantially to form the sportfishery in the Salton Sea (Walker et al. 1961), and are considered the chief gamefish in the Sea. They are a long fish with a tan back and silvery sides that reach over 26.5 lbs in weight and 42.5 inches in length. They have two almost separated dorsal fins and two anal spines. It was introduced at the same time as short fin corvina, which showed initial signs of acclimation, but was not able to spawn in the Sea.

The diet of young of the year corvina consists of barnacle nauplii and other plankters. When they are 1.2 to 2.4 inches, they feed primarily on pileworms or other invertebrates. The adults feed on the fry and young of the year of tilapia, bairdiella, and other fish of appropriate size. Corvina were acclimated to laboratory test salinities up to 55 ppt, but oocytes failed to mature in salinities greater than 50 ppt (Matsui et al. 1991c). Natural spawning occurred in test salinities of 35 and 40 ppt, but no spawning occurred in test salinities of 45 or 50 ppt (Matsui et al. 1991c). Field data collected between 1987 and 1989 with salinities of 38 and 44 ppt respectively, showed a decrease in number of ichthyoplankton (larval fish) as a result of significant decline in both the late egg and early larval stages for corvina (Matsui et al. 1991a).

Aquatic Birds

The Salton Sea is important to numerous migrating, wintering, and breeding bird species, particularly waterbirds. The Sea and adjacent wetlands, river systems, natural habitats, and agricultural fields provide foraging and roosting opportunities for large numbers of birds. Table 2-5 lists over one hundred waterbird species found at the Salton Sea and presents information on their residency status, federal and/or state sensitivity status, and foraging habits. Information for Table 2-5 was obtained from a review of selected ornithological literature for the area (Rosenberg et al. 1991; Garret and Dunn 1981), from recent surveys of the Sea (Ogden unpub. data 1995c), from environmental documents (IID 1994), and from federal and state agencies (CDFG 1992; USFWS 1993a, 1994a, 1994b).

Waterbirds represent the higher trophic levels of food webs in the Salton Sea and surrounding areas. The primary food resources in the Salton Sea are fish and aquatic invertebrates; but aquatic plants, terrestrial invertebrates, amphibians, and reptiles found along shorelines and in adjacent fresh/brackish water wetlands and agricultural drainage systems are also utilized. Some species roost on the Sea but forage for grains, plants, terrestrial invertebrates, amphibians, reptiles, birds, and small mammals in surrounding agricultural fields and natural habitats. Certain species of raptors hunt for avian prey at the Sea or in neighboring habitats. Waterbirds can be categorized into guilds based on their primary methods of foraging. Table 2-5 lists the foraging guild classification for each waterbird species at the Salton Sea but does not include other foraging methods that may be used in nearby agricultural or natural terrestrial habitats. Following is a description of waterbird foraging guilds found in the waters and along the shorelines of the Salton Sea and in adjacent fresh/brackish water ponds, marshes, agricultural drainage ditches, and riparian habitats.

The *wader/shallow* foraging guild includes birds that use shallow waters, often along the edge of the Sea or in adjacent wetlands to forage for invertebrates, fish, other small vertebrates, or submerged aquatic vegetation. This guild is largely made up of herons, egrets, geese, and dabbling ducks.

The *prober* foraging guild is characterized by birds (includes many shorebirds) that probe for invertebrates with their bills in the shoreline substrate (e.g., exposed sandy beaches, mudflats, and submerged shoreline).

Table 2-5

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Family Podicipedidae					
Podilymbus podiceps	Pied-billed Grebe	RB	WC	AI, F	
Podiceps nigricollis	Eared Grebe	W, OB	WC	AI, F	
Aechmophorus occidentalis	Western Grebe	RB	WC	F, AI	CSA
Aechmophorus clarkii	Clark's Grebe	RB	WC	F, AI	CSA
Family Pelecanidae					
Pelecanus erythrorhynchos	American White Pelican	M, PB	SF	F	SSC
Pelecanus occidentalis californicus	California Brown Pelican	PV	PD	F	FE, SE
Family Phalacrocoracidae					
Phalacrocorax auritus	Double-crested Cormorant	RB	WC	F, AI	SSC
Family Ardeidae					
Botaurus lentiginosus	American Bittern	W	WS	F, AI, TI, SV	
Ixobrychus exilis	Western Least Bittern	SB	WS	F, AI, TI, SV	FC2, SSC
Ardea herodias	Great Blue Heron	RB	WS	F, AI, SV	CSA
Casmerodius albus	Great Egret	RB	WS	F, SV, AI, TI	CSA
Egretta thula	Snowy Egret	RB	WS	AI, F, TI	CSA
Bubulcus ibis	Cattle Egret	RB	GG	TI, SV, AI	
Butorides striatus	Green Heron	RB	WS	F, TI, AI	
Nycticorax nycticorax	Black-Crowned Night-Heron	RB	WS	F, AI, SV	CSA
Family Threskiornithidae					
Plegadis chihi	White-faced Ibis	W	PR	AI, TI, SV, SE	FC2, SSC
Family Ciconiidae					
Mycteria americana	Wood Stork	PV	WS	F, SV, AI	SSC

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Family Anatidae					
Dendrocygna bicolor	Fulvous Whistling-duck	SV, OB	WS	SE, GR	FC2, SSC
Anser albifrons	Greater White-fronted Goose	W	WS	SE, GR	
Chen caerulescens	Snow Goose	W	WS	GR, SE	
Chen rossii	Ross' Goose	W	WS	SE, GR	
Branta bernicla	Brant	M	WS	GR	
Branta canadensis	Canada Goose	W	WS	SE, GR	
Anas crecca	Green-winged Teal	W	WS	SE, TI, AI, GR	
Anas platyrhynchos	Mallard	W, OB	WS	SE, GR, AI	
Anas acuta	Northern Pintail	W	WS	SE, TI, AI, GR	
Anas discors	Blue-winged Teal	M	WS	GR, AI, TI, SE	
Anas cyanoptera	Cinnamon Teal	M	WS	SE, GR, TI, AI	
Anas clypeata	Northern Shoveler	W	WS	PL, AI, SE, GR	
Anas strepera	Gadwall	W	WS	GR, SE, AI	
Anas americana	American Wigeon	W	WS	GR, SE	
Aythya valisineria	Canvasback	W	BF	GR, SE, AI,	
Aythya americana	Redhead	RB	BF	GR, SE, AI	
Aythya collaris	Ring-necked Duck	W	BF	SE, GR, AI	
Aythya marila	Greater Scaup	W	BF	AI, GR, SE	
Aythya affinis	Lesser Scaup	W	BF	AI, GR, SE	
Melanitta perspicillata	Surf Scoter	M	BF	AI, GR	
Bucephala clangula	Common Goldeneye	W	BF	AI, GR, SE, F	
Bucephala albeola	Bufflehead	W	BF	AI, F, GR, SE	
Mergus merganser	Common Merganser	W	WC	F	
Mergus serrator	Red-breasted Merganser	W	WC	F, AI	
Oxyura jamaicensis	Ruddy Duck	RB	BF	GR, AI, SE	
Family Accipitridae					
Pandion haliaetus	Osprey	NB	PD	F, SV	SSC
Circus cyaneus	Northern Harrier	W	PT	SV, B	SSC

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Family Falconidae					
Falco peregrinus anatum	American Peregrine Falcon	W	PT	B	FE, SE
Falco mexicanus	Prairie Falcon	W	PT	B, SV	SSC
Family Rallidae					
Laterallus jamaicaensis	California Black Rail	RB	GG	AI, TI, SE	FC2, ST
Rallus longirostris yumanensis	Yuma Clapper Rail	RB	PR	AI, TI, F, SV	FE, ST
Rallus limicola	Virginia Rail	RB	GE	TI, AI, SE, F	
Porzana carolina	Sora	W	GG	SE, TI, AI	
Gallinula chloropus	Common Moorhen	RB	GE	GR, AI, TI, SE	
Fulica americana	American Coot	RB	GE	GR, F, AI, TI	
Family Gruidae					
Grus canadensis tabida	Greater Sandhill Crane	W	PR	AI, TI, SV, SE, GR	ST
Family Charadriidae					
Pluvialis squatarola	Black-bellied Plover	W	GG	TI, AI	
Charadrius alexandrinus nivosus	Western Snowy Plover	RB	GG	TI, AI, F	FT, SSC
Charadrius semipalmatus	Semipalmated Plover	M	GG	AI, TI, SE	
Charadrius vociferus	Killdeer	RB	GG	TI, AI	
Charadrius montanus	Mountain Plover	W	GG	TI	FC2, SSC

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Family Recurvirostridae					
Himantopus mexicanus	Black-necked Stilt	RB	PR	AI, TI, F	
Recurvirostra americana	American Avocet	RB	PR	AI, TI, GR, SE	
Family Scolopacidae					
Tringa melanoleuca	Greater Yellowlegs	W	PR	F, AI, TI	
Tringa flavipes	Lesser Yellowlegs	W	PR	TI, AI, F	
Catoptrophorus semipalmatus	Willet	W	PR	AI, F	
Actitis macularia	Spotted Sandpiper	W	PR	TI, AI	
Numenius phaeopus	Whimbrel	M	GG	TI, AI, GR	
Numenius americanus	Long-billed Curlew	W	PR	TI, AI, SV	FC3, SSC
Limosa fedoa	Marbled Godwit	M	PR	AI, TI	
Arenaria interpres	Ruddy Turnstone	M	GG	TI, AI	
Calidris canutus	Red Knot	M	GG	TI, SE, AI	
Calidris alba	Sanderling	M	PR	TI, AI, GR	
Calidris mauri	Western Sandpiper	W	GG	TI, AI	
Calidris minutilla	Least Sandpiper	W	GG	TI, AI, SE	
Calidris bairdii	Baird's Sandpiper	M	GG	TI	
Calidris alpina	Dunlin	M	GG	TI, AI, SE	
Micropalama himantopus	Stilt Sandpiper	M	PR	AI, GR, SE	
Limnodromus griseus	Short-billed Dowitcher	M	PR	AI, TI, SE	
Limnodromus scolopaceus	Long-billed Dowitcher	W	PR	AI, TI, SE	
Gallinago gallinago	Common Snipe	W	PR	TI, AI	
Phalaropus tricolor	Wilson's Phalarope	M	SF	AI, SE	
Phalaropus lobatus	Red-necked Phalarope	M	SF	AI, SE, PL	

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Family Laridae					
Larus atricilla	Laughing Gull	PV, OB	GE	AI, TI, SC, F	SSC
Larus pipixcan	Franklin's Gull	M	GE	TI, F	
Larus philadelphia	Bonaparte's Gull	M	GE	TI, AI, F	
Larus delawarensis	Ring-billed Gull	W	GE	SC, F, TI, SV	
Larus californicus	California Gull	M	GE	SC, TI, SV, F	SSC
Larus argentatus	Herring Gull	W	GE	SC, SV, F, AI, TI	
Larus thayeri	Thayer's Gull	W	GE	SC, F, SV	
Larus livens	Yellow-footed Gull	PV	GE	SC, F, AI	
Larus glaucescens	Glaucous-winged Gull	W	GE	SC, F, AI	
Sterna nilotica	Gull-billed Tern	SB	HA	TI, AI	FC2, SSC
Sterna caspia	Caspian Tern	SV, OB	PD	F, AI	CSA
Sterna hirundo	Common Tern	SV	PD	F, AI	
Sterna forsteri	Forster's Tern	SB	PD	F, AI, TI	CSA
Chlidonias niger	Black Tern	SV	HA	TI, AI, F	FC2, SSC
Rynchops niger	Black Skimmer	SB	SF	F, AI	SSC
Family Alcedinidae					
Ceryle alcyon	Belted Kingfisher	M	PD	F, AI, SV	
Troglodytidae					
Cistothorus palustris	Marsh Wren	RB	GG	TI, AI	
Subfamily Emberizinae					
Ammodramus sandwichensis rostratus	Large-billed Savannah Sparrow	W	GG	TI, SE	

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

Scientific Name**	Common Name	Residency Status***	Foraging Guild****	Food Types*****	Sensitivity Status******
Subfamily Icterinae					
Agelaius phoeniceus	Red-winged Blackbird	RB	GG	TI, SE	
Xanthocephalus xanthocephalus	Yellow-headed Blackbird	SB	GG	TI, SE	

* This list includes birds using the waters and shorelines of the Salton Sea or immediately adjacent freshwater habitats. This list excludes species that USFWS (1993) has determined are occasional (<5 individuals/season) or accidental (< 10 records for entire area, not to be expected).

** Nomenclature follows American Ornithologist's Union 1983, 1984, 1985, 1987, and 1989.

*** Residency status codes list the predominant status of the species at the sea along with breeding status if it differs. Residency status are based on USFWS (1993) and are defined as follows:

OB = species has bred in the area and may continue to breed sporadically but is not expected to become a regular nester.
RB = occurs year round at the sea with regular breeding in the area.
M = species is most abundant during fall and/or spring migration.
NB = species occurs year-round but does not breed.
PB = species has bred in the area in the past but no recent breeding records.
PV = post-breeding visitor that occurs primarily in the late summer and early fall.
SB = species occurs in spring and summer primarily as a breeding visitor.
SV = species occurs in spring and summer primarily as a non-breeding visitor
W = species occurs primarily as a winter visitor.

**** Foraging guild codes (see text for descriptions of foraging guild behavior):

BF = bottom feeder
GE = generalist
GG = ground gleaner
HA = hawking
PD = plunge diver
PR = prober
PT = predator
SF = surface feeder
WC = water column diver
WS = wader/shallow water

***** Food type codes list the most common categories of food in each species diet based on Ehrlich et. al. 1988. Diets of ducks and geese are specific to winter and are from Belrose 1980. Food types are defined as:

Table 2-5 (Continued)

AQUATIC HABITAT DEPENDENT BIRDS OCCURRING AT THE SALTON SEA*

AI = aquatic invertebrates includes; insects, crustaceans, molluscs, etc...
B = birds
F = fish
GR = vegetative parts of aquatic or terrestrial plants
PL = plankton (phyto- or zooplankton)
SC = scavenged foods such as garbage and dead organisms.
SE = seeds includes grains and aquatic plant seeds
SV = small vertebrates (excluding birds) such as amphibians, reptiles, and small mammals
TI = terrestrial invertebrates such as insects, spiders, worms, mites, snails,

***** Sensitivity status codes are based on USFWS (1994a, 1994b) and CDFG (1992) and are defined as follows:

CSA = CDFG Special Animal
FC2 = Federal Category 2 Candidate Species
FC3 = Federal Category 3 Candidate Species
FE = Federally listed as Endangered
FT = Federally listed as Threatened
SE = Listed as Endangered by the State of California
ST = Listed as Threatened by the State of California
SSC = CDFG Species of Special Concern

Bottom feeders dive underwater and forage on the bottom of the Sea and in neighboring freshwater ponds for invertebrates and submerged vegetation. Typically, this guild forages in deeper waters than the wader/shallow water guild. The bottom feeding guild includes diving and Sea duck species such as canvasback (*Aythya valisineria*), scaup species, goldeneye, bufflehead (*Bucephala albeola*), and ruddy duck (*Oxyura jamaicensis*).

The *water column diver* guild is composed of cormorants, grebes, and mergansers that dive under the surface of the water to various depths and forage for fish.

Members of the *plunge diver* guild search for fish while flying, then dive to just below the surface to capture their prey. The plunge diving guild includes California brown pelican (*Pelecanus occidentalis californicus*), osprey (*Pandion haliaetus*), and tern species.

The *surface feeder* guild includes birds such as the American white pelican (*Pelecanus erythrorhynchos*) that swim or float on the surface of the water and submerge their head to catch fish near the surface. This guild also includes the black skimmer (*Rhynops niger*) which flies low over the water scooping up aquatic invertebrate and small fish from the surface.

The *predator* guild is represented by raptors that hunt for other avian prey species over the waters of the Sea (e.g., American peregrine falcon [*Falco peregrinus anatum*]) or along shorelines and adjacent wetlands (e.g., northern harrier [*Circus cyaneus*], sharp-shinned hawk [*Accipiter striatus*], and Cooper's hawk [*Accipiter cooperii*]).

Ground gleaners pick up mostly invertebrates and some seeds from the sand and other shoreline substrates along the Sea. This guild also scavenges for dead aquatic organisms along the shoreline. Typical ground gleaners are cattle egret (*Bubulcus ibis*), plovers, and some other shorebirds.

Hawkers capture insects while in flight, often taking short flights from a perch or hovering. Examples in this foraging guild include gull-billed tern (*Sterna nilotica*) and common tern (*Sterna hirundo*).

The *generalist* foraging guild includes gull species, American coots (*Fulica americana*), common moorhen (*Gallinula chloropus*), and other species that use a wide variety of food sources and employ various foraging techniques on shore and in the water.

Over 50 percent of waterbird species at the Salton Sea belong to guilds that forage in shallow water of the Sea and adjacent wetlands, or probe and glean for food along shorelines, mudflats, and in agricultural fields. About 20 percent of species specialize on feeding for fish in deeper waters. The wader/shallow water foraging guild has the highest number of species occurring at the Salton Sea and in adjacent wetlands (21.8 percent of 101 species; Table 2-5). Ground gleaners are second in number of species (17.8 percent), followed by probers (15.8 percent), generalists (11.9 percent), bottom feeders (8.9 percent), water column divers (6.9 percent), plunge divers (5.9 percent), predators (5.0 percent), surface feeders (4.0 percent), and hawkers (2.0 percent). A number of these species roost on the Salton Sea but forage primarily in adjacent agricultural lands (e.g., cattle egret, geese, white-faced ibis (*Plegadis chihi*), long-billed curlews (*Numenius americanus*), and blackbirds).

The most numerous waterbird species at the Salton Sea is eared grebe (*Podiceps nigricollis*) with 65,000 to 700,000 individuals annually (USFWS 1996). This is followed by black-necked stilt (*Himantopus mexicanus*), American avocet (*Recurvirostra americana*), and ring-billed gull (*Larus delawarensis*), each with an estimated 100,000 individuals. Northern shoveler (*Anas clypeata*) is fifth in abundance (60,000 individuals), followed by long-billed dowitcher (*Limnodromus scolopaceus*) with a population of 50,000 and ruddy duck (*Oxyura jamaicensis*) with 42,000 individuals.

The Salton Sea provides important food sources, especially fish and invertebrates, for many foraging waterbirds. Other birds rest on the Sea and along shorelines, foraging on plants and invertebrates in agricultural fields and natural habitats in the Imperial and Coachella valleys. Of those species typically occurring at the Salton Sea and in adjacent wetlands, primary food sources were categorized and ranked for each species using dietary information from Ehrlich et al. (1988), Bellrose (1980), and IID (1994). This information is general to each species and is not an actual reflection of specific food resources used at the Salton Sea. Using this categorization, aquatic invertebrates comprised 29.5 percent of the first or second highest ranked food sources used by the 101 waterbird species (Table 2-5). The second highest ranked food resource was terrestrial invertebrates (21.2 percent), followed by fish (16.7 percent), vegetative material (includes aquatic and terrestrial plant parts except for seeds; 11.4 percent), and seeds (10.9 percent). Other food sources included small vertebrates (amphibians, reptiles, and small mammals; 4.1 percent), scavenged foods (garbage, carrion; 3.1 percent), avian prey (2.6 percent), and plankton (0.5 percent).

The majority of the 101 species that are dependent upon the Salton Sea and adjacent wetlands are winter visitors (44.6 percent) or migrants (19.8 percent; Table 2-5). About 27 percent of waterbird species regularly breed at the Salton Sea. Over 80 percent of the breeding species occur as year-round residents, while the remainder are summer visitors. The breeding population is augmented by a small proportion (4.0 percent) of winter or spring visitors that sporadically breed at the Salton Sea. Four percent of species are post-breeding visitors and only one species occurs year round as a nonbreeder.

Terrestrial Fauna

There are numerous amphibians, reptiles, birds, and mammals that are found in terrestrial habitats adjacent to the Sea and in the surrounding Imperial and Coachella valleys. A list of terrestrial vertebrate species found or expected to occur in habitat adjacent to the Sea (USFWS 1993a, Zeiner et al. 1988, 1990a, and 1990b) is provided in Table 2-6.

2.5.3 Sensitive Resources

Sensitive resources include those that are regulated by resource or regulatory agencies, are rare or declining in the region, or support sensitive species. There are numerous sensitive biological resources associated with the Salton Sea or in upland habitats adjacent to the Sea. Sensitive resources observed or expected to occur at the Salton Sea area are discussed in Appendix B.

2.6 SOCIOECONOMICS

A detailed socioeconomic profile for the Salton Sea area has previously been prepared for this project (Ogden 1995b) and is provided as Appendix A.

3.0 SALTON SEA MANAGEMENT TARGETS

To evaluate the efficacy of various potential management alternatives, it is necessary to first establish salinity, elevation, and cost management goals or targets. Management target ranges were established by consensus of members of the Salton Sea Authority with input

Table 2-6

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
REPTILES AND AMPHIBIANS**	
Order Salientia	**Frogs and Toads**
Family Bufonidae	
Bufo punctatus	Red-spotted Toad
Bufo woodhousei	Woodhouse's Toad
Bufo cognatus	Great Plains Toad
Family Ranidae	
Rana catesbeiana	Bullfrog
Rana yavapaiensis	Lowland Leopard Frog
Order Testudines	**Turtles**
Family Testudinidae	
Gopherus agassizii	Desert Tortoise
Family Trionychidae	
Trionyx spiniferus	Spiny Softshell
Order Squamata	**Lizards and Snakes**
Family Gekkonidae	
Coleonyx variegatus	Western Banded Gecko
Family Iguanidae	
Dipsosaurus dorsalis	Desert Iguana
Callisaurus draconoides	Zebra-tailed Lizard
Uma notata	Colorado Desert Fringe-toed Lizard
Crotaphytus insularis	Desert Collared Lizard
Gambelia wislizennii	Long-nosed Leopard Lizard
Sceloporus magister	Desert Spiny Lizard
Uta stansburiana	Side-blotched Lizard
Urosaurus graciosus	Long-tailed Brush Lizard
Phrynosoma platyrhinos	Desert Horned Lizard
Phrynosoma mcallii	Flat-tailed Horned Lizard

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Family Teiidae	
Cnemidophorus tigris	Western Whiptail
Family Leptotyphlopidae	
Leptotyphlops humilus	Western Blind Snake
Family Colubridae	
Phyllorhynchus decurtatus	Spotted Leaf-nosed Snake
Masticophis flagellum	Coachwhip
Salvadora hexalepsis	Western Patch-nosed Snake
Arizona elegans	Glossy Snake
Pituophis melanoleucus	Gopher Snake
Lampropeltus getulus	Common Kingsnake
Rhynocheilus lecontei	Long-nosed Snake
Thamnophis marcianus	Checkered Garter Snake
Sonora semiannulata	Western Ground Snake
Chionactis occipitalis	Western Shovel-nosed Snake
Hypsiglena torquata	Night Snake
Family Viperidae	
Crotalus atrox	Western Diamondback Rattlesnake
Crotalus cerastes	Sidewinder
Crotalus viridis	Western Rattlesnake

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES
OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
BIRDS**	
Order Falconiformes	**Vultures, Hawks, and Falcons**
Family Cathartidae	
Cathartes aura	Turkey Vulture
Family Accipitridae	
Elanus leucurus majusculus	White-tailed Kite
Circus cyaneus	Northern Harrier
Accipiter striatus	Sharp-shinned Hawk
Accipiter cooperii	Cooper's Hawk
Buteo lineatus	Red-shouldered Hawk
Buteo jamaicensis	Red-tailed Hawk
Buteo regalis	Ferruginous Hawk
Aquila chrysaetos	Golden Eagle
Family Falconidae	
Falco peregrinus anatum	American Peregrine Falcon
Falco sparverius	American Kestrel
Falco columbarius	Merlin
Falco mexicanus	Prairie Falcon
Order Galliformes	**Megapodes, Curassows, Pheasants, and Relatives**
Family Phasianidae	
Phasianus colchicus	Ring-necked Pheasant
Callipepla gambelii	Gambel's Quail
Order Columbiformes	**Pigeons and Doves**
Family Columbidae	
Columba livia	Rock Dove
Zenaida asiatica	White-winged Dove
Zenaida macroura	Mourning Dove
Columbina inca	Inca Dove
Columbina passerina	Common Ground Dove

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES
OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Order Cuculiformes	**Cuckoos and Relatives**
Family Cuculidae	
Geococcyx californianus	Greater Roadrunner
Order Strigiformes	**Owls**
Family Tytonidae	
Tyto alba	Common Barn Owl
Family Strigidae	
Otus kennicottii	Western Screech Owl
Bubo virginianus	Great Horned Owl
Speotyto cunicularia	Burrowing Owl
Asio flammeus	Short-eared Owl
Order Caprimulgiformes	**Goatsuckers and Relatives**
Family Caprimulgidae	
Chordeiles acutipennis	Lesser Nighthawk
Phalaenoptilus nuttallii	Common Poorwill
Order Apodiformes	**Swifts and Hummingbirds**
Family Apodidae	
Chaetura vauxi	Vaux's Swift
Aeronautes saxatalis	White-throated Swift
Family Trochilidae	
Archilochus alexandri	Black-chinned Hummingbird
Calypte anna	Anna's Hummingbird
Calypte costae	Costa's Hummingbird
Selasphorus rufus	Rufous Hummingbird
Selasphorus sasin	Allen's Hummingbird

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Order Coraciiformes	**Kingfishers and Relatives**
Family Alcedinidae	
Ceryle alcyon	Belted Kingfisher
Order Piciformes	**Woodpeckers and Relatives**
Family Picidae	
Melanerpes uropygialis	Gila Woodpecker
Sphyrapicus nuchalis	Red-naped Sapsucker
Picoides scalaris	Ladder-backed Woodpecker
Colaptes auratus	Northern Flicker
Order Passeriformes	**Perching Birds**
Family Tyrannidae	
Contopus borealis	Olive-sided Flycatcher
Contopus sordidulus	Western Wood-pewee
Empidonax traillii extimus	Southwestern Willow Flycatcher
Empidonax hammondii	Hammond's Flycatcher
Empidonax oberholseri	Dusky Flycatcher
Empidonax wrightii	Gray Flycatcher
Empidonax difficilis	Pacific Slope Flycatcher
Sayornis nigricans	Black Phoebe
Sayornis saya	Say's Phoebe
Pyrocephalus rubinus	Vermilion Flycatcher
Myiarchus cinerascens	Ash-throated Flycatcher
Tyrannus verticalis	Western Kingbird
Family Alaudidae	
Eremophila alpestris actia	California Horned Lark
Family Hirundinidae	
Tachycineta bicolor	Tree Swallow
Tachycineta thalassina	Violet-green Swallow
Stelgidopteryx serripennis	Northern Rough-winged Swallow
Riparia riparia	Bank Swallow
Hirundo pyrrhonota	Cliff Swallow
Hirundo rustica	Barn Swallow

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Family Corvidae	
Aphelocoma coerulescens	Scrub Jay
Corvus brachyrhynchos	American Crow
Corvus corax	Common Raven
Family Remizidae	
Auriparus flaviceps	Verdin
Family Aegithalidae	
Psaltriparus minimus	Bushtit
Family Sittidae	
Sitta canadensis	Red-breasted Nuthatch
Family Troglodytidae	
Campylorhynchus brunneicapillus	Cactus Wren
Salpinctes obsoletus	Rock Wren
Thryomanes bewickii	Bewick's Wren
Troglodytes aedon	House Wren
Cistothorus palustris	Marsh Wren
Family Muscicapidae	
Regulus calendula	Ruby-crowned Kinglet
Polioptila caerulea	Blue-gray Gnatcatcher
Polioptila melanura	Black-tailed Gnatcatcher
Sialia currucoides	Mountain Bluebird
Catharus ustulatus	Swainson's Thrush
Catharus guttatus	Hermit Thrush
Turdus migratorius	American Robin
Family Mimidae	
Mimus polyglottos	Northern Mockingbird
Oreoscoptes montanus	Sage Thrasher
Toxostoma crissale	Crissal Thrasher

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Family Motacillidae	
Anthus spinoletta	Water Pipit
Family Bombycillidae	
Bombycilla cedrorum	Cedar Waxwing
Family Ptilogonatidae	
Phainopepla nitens	Phainopepla
Family Laniidae	
Lanius ludovicianus	Loggerhead Shrike
Family Sturnidae	
Sturnus vulgaris	European Starling
Family Vireonidae	
Vireo solitarius	Solitary Vireo
Vireo gilvus	Warbling Vireo
Family Emberizidae	
Vermivora celata	Orange-crowned Warbler
Vermivora ruficapilla	Nashville Warbler
Dendroica petechia	Yellow Warbler
Dendroica coronata	Yellow-rumped Warbler
Dendroica nigrescens	Black-throated Gray Warbler
Dendroica townsendi	Townsend's Warbler
Dendroica occidentalis	Hermit Warbler
Setophaga ruticilla	American Redstart
Geothlypis tolmiei	MacGillivray's Warbler
Geothlypis trichas	Common Yellowthroat
Wilsonia pusilla	Wilson's Warbler
Icteria virens	Yellow-breasted Chat
Piranga ludoviciana	Western Tanager
Pheucticus melanocephalus	Black-headed Grosbeak
Guiraca caerulea	Blue Grosbeak
Passerina amoena	Lazuli Bunting
Pipilo chlorurus	Green-tailed Towhee

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Pipilo erythrophthalmus	Rufous-sided Towhee
Pipilo crissalis	California Towhee
Pipilo aberti	Abert's Towhee
Spizella passerina	Chipping Sparrow
Spizella breweri	Brewer's Sparrow
Pooecetes gramineus	Vesper Sparrow
Chondestes grammacus	Lark Sparrow
Amphispiza belli	Sage Sparrow
Ammodramus sandwichensis	Savannah Sparrow
Melospiza melodia	Song Sparrow
Melospiza lincolnii	Lincoln's Sparrow
Zonotrichia leucophrys	White-crowned Sparrow
Junco hyemalis	Dark-eyed Junco
Agelaius phoeniceus	Red-winged Blackbird
Sturnella neglecta	Western Meadowlark
Xanthocephalus xanthocephalus	Yellow-headed Blackbird
Euphagus cyanocephalus	Brewer's Blackbird
Quiscalus mexicanus	Great-tailed Grackle
Molothrus aeneus	Bronzed Cowbird
Molothrus ater	Brown-headed Cowbird
Icterus cucullatus	Hooded Oriole
Icterus galbula	Northern Oriole
Carpodacus mexicanus	House Finch
Carduelis pinus	Pine Siskin
Carduelis psaltria	Lesser Goldfinch
Carduelis lawrencei	Lawrence's Goldfinch
Carduelis tristis	American Goldfinch
Family Passeridae	
Passer domesticus	House Sparrow

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
MAMMALS**	
Order Insectivora	**Insectivores**
Family Soricidae	
Notiosorex crawfordi	Desert Shrew
Order Chiroptera	**Bats**
Family Phyllostomidae	
Macrotus californicus	California Leaf-nosed Bat
Choeronycteris mexicana	Mexican Long-tongued Bat
Family Vespertilionidae	
Myotis californicus	California Myotis
Pipistrellus hesperus	Western Pipistrelle
Eptesicus fuscus	Big Brown Bat
Lasiurus cinereus	Hoary Bat
Lasiurus xanthinus	Southern Yellow Bat
Euderma maculatum	Spotted Bat
Plecotus townsendii	Townsend's Big-eared Bat
Antrozous pallidus	Pallid Bat
Family Molossidae	
Tadarida brasiliensis	Brazilian Free-tailed Bat
Nyctinomops femorosacca	Pocketed Free-tailed Bat
Nyctinomops macrotus	Big Free-tailed Bat
Order Lagomorpha	**Rabbits, Hares, and Pikas**
Family Leporidae	
Sylvilagus audubonii	Desert Cottontail
Lepus californicus	Black-tailed Jackrabbit

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Order Rodentia	**Squirrels, Rats, Mice, and Relatives**
Family Sciuridae	
Ammospermophilus leucurus	White-tailed Antelope Squirrel
Spermophilus tereticaudus	Round-tailed Ground Squirrel
Family Geomyidae	
Thomomys bottae	Botta's Pocket Gopher
Family Heteromyidae	
Perognathus longimembris	Little Pocket Mouse
Chaetodipus formosus	Long-tailed Pocket Mouse
Chaetodipus penicillatus	Desert Pocket Mouse
Chaetodipus spinatus	Spiny Pocket Mouse
Dipodomys deserti	Desert Kangaroo Rat
Dipodomys merriami	Merriam's Kangaroo Rat
Family Cricetidae	
Reithrodontomys megalotis	Western Harvest Mouse
Peromyscus eremicus	Cactus Mouse
Peromyscus maniculatus	Deer Mouse
Peromyscus crinitus	Canyon Mouse
Onychomys torridus	Southern Grasshopper Mouse
Sigmodon hispidus	Hispid Cotton Rat
Neotoma albigula	White-throated Woodrat
Neotoma lepida	Desert Woodrat
Ondatra zibethicus	Muskrat
Family Muridae	
Rattus rattus	Black Rat
Ratus norvegicus	Norway Rat
Mus musculus	House Mouse

Table 2-6 (Continued)

TERRESTRIAL WILDLIFE SPECIES OCCURRING AT THE SALTON SEA*

Scientific Name	Common Name
Order Carnivora	**Carnivores**
Family Canidae	
Canis latrans	Coyote
Vulpes macrotis	Kit Fox
Urocyon cinereoargenteus	Gray Fox
Family Procyonidae	
Procyon lotor	Raccoon
Family Mustelidae	
Taxidea taxus	Badger
Spilogale gracilis	Western Spotted Skunk
Mephitis mephitis	Striped Skunk
Family Felidae	
Felis rufus	Bobcat

* Species occurrence information obtained from IID (1994), USFWS (1993a), and Zeiner et al. (1988, 1990a, and 1990b). This list excludes most bird species considered by the USFWS (1993a) to be occasional (<5 individuals/season) or accidental (<10 records, not expected).

** Amphibian, reptile, bird, and mammal nomenclature follows Laudenslayer et al. 1991.

from members of their various committees, including the Technical Advisory Committee (TAC), Steering Committee, and Citizen's Advisory Committee (CAC). Quantitative studies were not utilized to establish management targets. This section discusses the project's management goals, and the salinity, elevation, and cost targets to be used for evaluation of management alternatives.

3.1 Project Purpose and Need

The statement of purpose and need for the project establishes the project's objectives and what minimum requirements it must attain to meet these objectives. The statement of purpose and need is the basis for preparing an analysis of project alternatives under the National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA). It also helps to focus the selection of project alternatives so that emphasis can be placed on the most viable alternatives. Alternatives that do not meet the project's objectives can be eliminated from further consideration, so that technical studies and engineering efforts can be focused on the remaining viable alternatives.

At this stage of the project, a definitive statement of purpose and need has not yet been developed. In general, however, it would be desirable to maintain or enhance existing functions of the lake, while improving the local economy. The lake currently serves many potentially conflicting functions (Dangermond and Associates, Inc. 1994), including

- serving as a drainage basin for agricultural run-off of Coachella and Imperial valleys
- providing important habitat for both resident and migratory wildlife species
- providing recreational values such as fishing, hunting, boating, camping, nature study, bird-watching, and sightseeing
- providing for growth of commercial resources and residential developments
- providing flood control measures by serving as a repository for stormwater run-off

The general goal or purpose of the management project, therefore, is to stabilize the salinity and elevation of the Salton Sea at levels that maximize the economic, environmental, social, and cultural attributes of the region. A more definitive statement of project purpose and need will be developed in subsequent phases of the environmental review process.

3.2 Management Targets

The Salton Sea Authority has decided to use three quantitative criteria for screening potential management alternatives for this project. These criteria include ability to achieve target salinities, ability to achieve target elevations, and expected operation and maintenance (O&M) costs. They are described below. In addition, the Salton Sea Authority has decided that the alternatives must make use of currently available, proven technologies.

3.2.1 Target Salinity

Salinity management targets have been established at levels that are protective of the existing fishery in the Salton Sea. The Salton Sea currently supports a fishery of marine species (i.e., corvina, sargo, and bairdiella) transplanted to the Sea when the salinities rose too high to support freshwater species. The Salton Sea's fishery is important to the region from both environmental and economic viewpoints. For example, fish are important biologically to fish-eating birds and other animals found around the shore of the Salton Sea, and the wildlife in the region attracts fisherman, hunters, and naturalists providing economic growth to the area. Furthermore, the Water Quality Control Plan (Basin Plan) for the Colorado River Basin (California Regional Water Quality Control Board - Region 7 1994) designates warm water aquatic habitat as a beneficial use, and the water quality objective for salinity relates to sustenance of aquatic life. The dynamics of the fishery are not well understood, however. While it is logical to assume that elevated salinities are partially responsible for the decline of the fishery, it is not clear what ultimate effect lowering salinity would have on the fishery.

Recent research (Matsui 1991a, 1991b, 1991c) suggests that populations of the primary game fishes in the Salton Sea will begin to decrease as the Sea's salinity increases above 40 ppt. This research showed that, although corvina acclimated to salinities of 45 and 50 ppt, no spawning occurred at these salinities in the laboratory. Although some spawning may occur in areas of the lake where salinities remain below 45 ppt, rapid decreases in fish populations are likely through attrition (Matsui 1991a, 1991b, 1991c).

For the existing fishery to be maintained, a target salinity range of 35 to 40 ppt has been established. These salinities would allow fish species currently found in the lake to spawn, thereby complying with some Basin Plan requirements for protecting beneficial uses of the Sea. However, comments received from the U.S. Fish and Wildlife Service (USFWS), Ecological Services Division, questioned the desirability of maintaining the existing fish species assemblage (USFWS 1996b).

3.2.2 Target Elevation

There are many considerations when determining a target water surface elevation of the Salton Sea. Private and commercial property owners are concerned with lake elevation as it will affect property values and determine the elevation of future construction projects. As the Sea is a repository for agricultural drainage, the lake's elevation is important to agricultural interests. The Salton Sea's elevation is also important to the biota of the area. Birds, such as the endangered Yuma clapper rail, are dependent on wetland habitats around the margins of the Sea for breeding, and many hundreds of acres of wildlife refuge have been inundated by rising Sea levels. State and federal agencies must also plan for potential flood conditions. History has shown that rapid flooding occurs regularly in the area, and the Sea is a repository for storm run-off. Finally, the Sea's target elevation is closely connected to its target salinity. The removal of water from the Sea as a means of removing salt can result in dramatic changes in elevation. The elevation management target and ability to regulate elevation may ultimately determine the salinity management option selected for implementation.

The surface elevation of the lake is currently about -227 feet msl. The lake's elevation fluctuates about 1 foot per year based on IID elevation data for the past 9 years. In 1994, for example, the Salton Sea's elevation ranged between -227.75 to -226.75 feet msl and between -227.8 to -227.2 from November 1994 to February 1995. A target elevation range of -230 to -235 feet msl will be used for this project.

3.2.3 Threshold Operation and Maintenance (O&M) Costs

It is anticipated that the ultimate capital costs of any selected management project will be shared among federal, state, and local governments. The long-term O&M costs of the project will most likely be paid for at the local level. To ensure the affordability of the project in the long-term, O&M cost will be used to screen management alternatives during this phase of the project. An annual threshold of $10,000,000, not including debt servicing, will be considered the maximum feasible for the project. Therefore, management alternatives that exceed this threshold will be eliminated from further consideration.

3.2.4 Technological Feasibility

Only alternatives that are technologically feasible will be considered in subsequent environmental studies. Management alternatives that rely on unproven technologies or require substantial research and development will be excluded from further consideration.

4.0 DESCRIPTION OF PROPOSED OF MANAGEMENT ALTERNATIVES

Management alternatives for stabilizing salinity and elevation of the Salton Sea were first discussed in 1965 in a Reconnaissance Study and Preliminary Report on a Water Quality Control Plan for the Salton Sea (Pomeroy and Cruse 1965). Since then, many new management alternatives have been proposed, including proposals made by members of the public at two workshops held on August 31 and September 14, 1995 by the Salton Sea Authority TAC. As many of the proposed alternatives rely on the same basic principles, the various management alternatives have been grouped into six general categories: 1) diked impoundments within the Salton Sea; 2) pump-out Salton Sea water to another area (e.g., dry lake beds, onshore evaporation ponds, the Gulf of California, the Pacific Ocean, or onshore treatment/filtration units); 3) a combination of alternatives consisting of diked impoundments, onshore evaporation ponds, a pipeline/canal system to transport concentrated brine to Laguna Salada/Gulf of California, among others; 4) removal of salts from inflowing water before it enters the Sea (e.g., desalination plant, biological filters, or special pretreatment reservoirs); 5) use of imported water to dilute the Sea; and 6) other proposed alternatives that do not address the problem of stabilizing salinity or surface elevation. These management alternatives are listed in Table 4-1 and are described in the sections below. Detailed descriptions of individual alternatives have been prepared by USBR (in progress). It should be noted that the descriptions of the various alternatives were often incomplete and the details of the alternatives presented here rely on information presented to the Salton Sea Authority in their public workshops.

Table 4-1

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[5]	Controls Salinity?[5]	Controls Elevation?[5]	Proven Technology?
I Diked Impoundment									
50 square miles (S end)	1994	CVWD	Equivalent Inflow = 190,000	188.0	4.0	50 ppt to 40 ppt in 18 yrs	Yes	Yes	Yes
	1974	USDOI/RAC		65.0	0.416	42 ppt to 35 ppt in 12 yrs			
	1971	Aerospace Corp		130.0	?	42 ppt to 38 ppt in 7 yrs			
	1969	USDOI/RAC		110.0	0.173	40 ppt to 35 ppt in 10 yrs			
50 square miles (N end)	1969	USDOI/RAC		183.0	0.023	40 ppt to 35 ppt in 10 yrs			
40 square miles (S end)	1994	USBR	Equivalent Inflow = 150,000	110-154		50 ppt to 40 ppt in 31 yrs	Yes	Yes	Yes
	1988	CVWD		188.0	?	50 ppt to 40 ppt in 31 yrs			
	1974	USDOI/RAC		58.0	0.251	42 ppt to 35 ppt in 18 yrs			
	1969	USDOI/RAC		?	?	40 ppt to 35 ppt in 19 yrs			
20 & 30 square miles (S end only)	1994	CVWD	Equivalent Inflow = 190,000	?		50 ppt to 40 ppt in 18 yrs	Yes	Yes	Yes
20 square miles (N) & 30 square miles (S)	1969	USDOI/RAC		168.0	0.025	40 ppt to 35 ppt in 10 yrs			
One third of the Sea (127 sq. miles, N end)	1994	CVWD	?	?	?	50 ppt to 40 ppt in 9 yrs	Yes	Yes	Yes
One half of the Sea (use polyethylene curtain to divide Sea in half)	1995	Martin	?	7.0	5 yrs. of O&M included in Cost	50 ppt to 40 ppt in 3 yrs	Yes	Yes	No?
One half of the Sea (190 sq. miles, N end)	1994	CVWD				50 ppt to 40 ppt in 3 yrs	Yes	Yes	Yes
Construction of lake(s) within the Sea (use polyethylene curtains)	1995	Martin	?	28.0	5 yrs. of O&M included in Cost	50 ppt to 35 ppt in 2 yrs	Yes	Yes	No?
Phased Zoning Concept - 3 diked portions	1994	USBR	?	70.0-90.0	?	1 yr for smaller diked portion	Yes	Yes	Yes
In-Sea evaporation basins (parallel dikes)	?	CVWD	180,000	188.0	?	?	Yes	Yes	Yes
II Pump-out									Yes
Pump-out offsite (unidentified)	1971	Aerospace Corp	350,000 to 142,000	?	?	42 ppt to 39 ppt in 16 yrs	Yes	>6' drop	Yes
Offsite evaporation (Palen, Clark, or Ford)	1969	USDOI/RAC	200,000	?	?	?	Yes	No	
Canal/dam system that transports Sea water to the base of Chocolate Mountains	1995	Arnold	?	?	?	?	Yes?	No	Yes
Solar pond/diked	1995	McCracken	60,000	250.0	1.0	?	Yes?	No	Yes
Evaporation ponds outside lake	1969	USDOI/RAC	200,000	?	?	40 ppt to 35 ppt in 10 yrs	Yes?	No	Yes
Enhanced evaporation ponds/Solar energy	1989	Ormat	100,000	132.0	?	?	Yes?	No	Yes
	1989	Ormat	225,000	297.0	?	45 ppt to 35 ppt in 15 yrs	Yes?	No	Yes
Fish ponds/(enhanced) evaporation ponds	1995	Aquafarms Int.	150,000	140 0	?	?	Yes?	No	Yes

Table 4-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[5]	Controls Salinity?[5]	Controls Elevation?[5]	Proven Technology?
Pump-out to filtration/treatment units									
Solar heated membrane distillation plant	1995	NWRI	?	?	?	?	?	?	No
Waste-water disposal units to remove salt	1993	FAE	?	?	?	?	?	?	?
Cogeneration of electrical power/thermal distillation	1992	CPA	60.0	?	?	?	?	?	Yes?
Enzyme-activated cellulose filtering technology	1992	TET	?	?	?	?	?	?	No?
Reverse osmosis filtration slow sand pre-treatment	1992	WRI &	0.087-	?	?	?	?	?	Yes
	1991	Cluff	0.121						
Enhanced solar still desalination/replenishment from Colorado River	1991	Free	?	?	?	?	?	?	Yes?
	1990	EET							
	1977	Bechtel Corp.							
Pulsed plasma discharge wasterwater treatement	1990	AURIX, Inc.	?	?	?	?	?	?	No?
Filtration of Sea water with processing modules	?	Zitelli Trust	?	?	?	?	No?	?	No?
Queen resort hydropower and filtration system	?	Queen	?	?	?	?	?	?	No?
SNAP technology/evaporation tower	1992	Technion, IIT	400,000	?	?	?	?	?	No
Canal/pipeline to Laguna Salada									
Pumpout only	1994	IID	400,000	270.0	32.9	44 ppt to 40 ppt in 10 yrs	Yes	13'drop/inc	Yes
Pumpout/replenish from Colorado River	1994	IID	150,000[2]	113.0	12.6	44 ppt to 40 ppt in 10 yrs	Yes	Yes	Yes
Pumpout only	1994	IID	200,000	157.0	16.7	44 ppt to 40 ppt in 20 yrs	Yes	10' drop	Yes
Pumpout only	1991	USBR	415,000	270.0	?	?	Yes	No	Yes
Pumpout/replenish from Gulf of California	1991	USBR	415,000	875.0	?	?	Yes	Yes	Yes
Pipeline to Laguna Salada									
Pumpout only	1991	USBR	415,000	532.0	?	?	Yes	No	Yes
Pumpout/replenish from Gulf of California	1991	USBR	415,000	1,496.0	?	?	Yes	Yes	Yes
Canal/pipeline to Gulf of California									
Pumpout only	1994	IID	400,000	385.0	33.4	44 ppt to 40 ppt in 10 yrs	Yes	13' drop/inc	Yes
Pumpout/replenish from Colorado River	1994	IID	150,000	177.0	13.1	44 ppt to 40 ppt in 10 yrs	Yes	Yes	Yes
Pumpout only	1994	IID	200,000	240.0	17.2	44 ppt to 40 ppt in 20 yrs	Yes	10' drop	Yes
Pumpout storage/replenish from Gulf of California	1994	Dangermond	?	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
One-way pumping to Gulf of California	1974	USDOI/RAC	250,000	?	?	?	Yes	No	Yes
Pipeline/lined Canal to Gulf of California	1971	Aerospace Corp	120,000	30.0	?	?	Yes	No	Yes
Two-way pumping to Gulf of California	1969	USDOI/RAC	250,000	?	?	?	Yes	Yes	Yes
Pipeline to the Pacific Ocean (Camp Pendleton area)	1995	Munro	?	?	?	?	Yes?	Yes?	Yes
Navigable waterway/locks system	1994	Dangermond	?	?	?	Stabilize at 35 ppt	Yes	Yes	Yes
	1988	Meyer Res.	?	350.0	?				
	?	CVWD	?	?	?				
Canal/pipeline to Yuma Delating Plant discharge drain	1988	Meyer Res.	?	?	?	?	No	No	Yes

Table 4-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[5]	Controls Salinity?[5]	Controls Elevation?[5]	Proven Technology?
III Combination									
Diked impoundment/evaporation pond/pipeline-canal to Gulf of California	1995	Salton Sea Authority TAC, and Dangermond	?	?	?	?	Yes	No	Yes
Diked impoundment/evaportaion pond/pipeline-canal to Yuma Desalting Plant	1995	Salton Sea Authority TAC, and Dangermond	?	?	?	?	Yes	No	Yes
Diked impoundment/solar pond and power generation/constructed wetlands	1994	Dangermond	250,000	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
Freshwater shoreline/pumped storage	1994	Dangermond	250,000	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
Joint USA/Mexico solar power generation/pumped storage Laguna Salada salt disposal	1994	Dangermond	210,000	?	?	45 ppt to 35 ppt in 15 yrs	Yes	Yes	Yes
Diked impoundment/pumping out/replenish from Imperial East Mesa Well Field									Yes
30 square miles/pump Palen Lake $95 ft^3/s$	1974	USDOI/RAC	65,000	105.0	0.104+2.5[3]	42 ppt to 35 ppt in 14 yrs	Yes?	Yes?	
30 square miles/pump Palen Lake $195 ft^3/s$	1974	USDOI/RAC	135,000	141.0	0.104+4.7[4]	42 ppt to 35 ppt in 8 yrs			
IV Removal of Salt Before Water Enters the Sea[6]									
Move Yuma Desalting Plant to the Sea	1995	Michaels Co. & Watkins	-	?	?	?	No	No	Yes
Desalting inflow (electrodialysis)	1969	USDOI/RAC	-	820.0	?	?	No	No	Yes
Desalination plant	1969	USDOI/RAC	-	?	?	?	No	No	Yes
Filtration technology used at the New River	?	Gill/USFCT	-	?	?	?	No	No	Yes
Poplar trees used as filters	1995	Maxwell	-	?	?	?	No	No	Yes
Special pre-treatment reservoirs	1995	Bloom/DST	-	50.0-100.0	?	?	No	No	No?
V Water Imports									
Replenish with Gulf of California water (canal/pipeline)	1991	USBR	400,000	605.0	?	-	-	Yes	Yes
Replenish with Gulf of California (pipeline)	1991	USBR	400,000	964.0	?	-	-	Yes	Yes

Table 4-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[5]	Controls Salinity?[5]	Controls Elevation?[5]	Proven Technology?
Replenish with Colorado River	1988 1971	Meyer Res. Aerospace Corp	? 100,000 350,000	? $10–58/ acre-foot	? ?	- -	- -	Yes? Yes?	Yes Yes
Pump non-river water at Calexico and combine with Salton Sea water	1995	Graves	?	?	?	?	?	?	Yes
VI Other									
Metal Ion Extraction	?	Brown	-	?	?	?	?	No	No
Siphon air pump oxygenation (Canal/conveyor screen to remove debris and oxygenate the Sea water)	1995	Hensley	-	?	?	-	No	No	Yes
Selenium management with groundwater pumping	1993	HCI	?	?	?	-	No	No	?
Foraminifera studies on Sea (3 year study)	1995	Casey	-	0.105	-	?	No	No	Yes
Partioning off sections of Sea with plastic pond liners for potenial use studies	1995	Casey	?	0.073	?	Some areas allowed to become saline, others mixed with potable water for a variety of salinities	No	No	Yes
Dispose of salts with injection wells	1995 1971	Duffey Aerospace Corp	- -	? 8.0 17.0 44.0	? 3.8 4.8 6.0	- -	No No	No No	Yes Yes
Land Speed Racetrack	1995	SCTA	-	?	?	-	No	No	Yes
Mexican cleanup of the New River	1991	Gunaji	-	100.0	?	-	No	No	?
Air diffusion and UV ozone systems to improve water quality Aeration fountains for surface aeration	1995 1991	ADS/ Thompson Free	- -	0.250 ?	0.012 ?	- -	No No	No No	Yes Yes
Water Conservation Programs Intercepting and reuse of irrigation drainage water	1992 1989 1991	CRBC and IID/MWD Rhoades	- -	? ?	? ?	- -	No No	No No	Yes Yes
Gravel berms	1995	Garcia	-	?	?	-	No	No	Yes

- Not applicable
? Data not available
Yes? Proposal indicates the ability to control salinity or elevation, however, analysis indicates that this is uncertain.

Table 4-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

[1]**The Following Sources were used to Compile this Table.**

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Table 4-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION

[1]**The Following Sources were used to Compile this Table (Continued).**

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[2]After 10 years, reduce to 80,000 acre-feet/yr.
[3]Initially the cost will be 2.5 million dollars a year for first 14 years and then reduced to $104,000 per year.
[4]Initially the cost will be 4.7 million dollars a year for first 8 years and then reduced to $104,000 per year.
[5]This information is discussed in Section 5.0.
[6]Removal of salt before water enters the Sea will result in maintaining salinity at project initiation point. Pumping of Sea water through the plants, filters, or reservoirs in addition to the inflow would be required to reduce the salinity.

4.1 Diked Impoundments

A diked impoundment, as a means of reducing salinity, was first formally proposed in 1969 (USDOI and RAC 1969, 1974). The impoundment would receive water from the main body of the lake through inlets, concentrate it through evaporation, and store the removed solids from the lake for an indefinite period of time. Eventually, the impoundment would fill with salts, and salt disposal would be necessary. Nine locations were first studied, with impoundment sizes ranging from 20 to 50 square miles. Since then, CVWD has updated the descriptions of various diked impoundment options and evaluated their efficacy in managing the Sea's salinity. Based on the diked impoundment options evaluated by CVWD and proposals received from the public and USBR, seven different impoundment configurations proposed include: 1) a 50-square-mile diked impoundment, 2) a 40-square-mile diked impoundment, 3) two diked impoundments totaling 50 square miles (2 configurations), 4) a 127-square-mile impoundment formed by diking off one-third of the surface area of the lake, 5) an approximately 190-square mile impoundment formed by diking the Sea in half, 6) parallel dikes forming 47-square miles of impoundment, and 7) a phased zoning concept.

Managing salinity with diked impoundments is based on removing salts from the Sea and decreasing the volume of the lake, which results in greater dilution of the remaining Salton Sea water by inflowing fresh water. The diked impoundment acts as an evaporation basin, isolating and concentrating the brine by evaporating Salton Sea water within the impoundment (USDOI and RAC 1969, 1974; Aerospace Corporation 1971; CVWD pers. comm.). Although the effective volume of the lake would be reduced by the volume of the impoundment, which would result in a rising lake level given the same fresh water inflow, a volume of salty Salton Sea water equal to the freshwater inflow can be let into the impoundment to evaporate away, thereby controlling lake elevation. Some change in elevation may occur because evaporation rates in the impoundment and the Sea will likely be affected by the salinity and temperature changes that will occur as the Sea becomes fresher and the impoundment becomes saltier (saltier water absorbs more heat, thus reaches a higher temperature before evaporating than fresher water).

4.1.1 Alternative Dike Structures and Design

The 1974 proposal for dike construction proposed an earthen dike be constructed with a conventional excavate and dredge, haul, and dump method. Since the time of this initial proposal, new technologies have made alternative dike structures feasible. A value engineering team formed by the USBR and the Salton Sea Authority TAC was formed to evaluate these alternative structures (USBR and Salton Sea Authority TAC 1994). The alternative structures evaluated included a plastic curtain, sheetpile, concrete wall, geotextile bags, pile and dredge, and dump and dredge. Their findings are summarized in Table 4-2. The value engineering team concluded that the excavation, haul, and dump dike was the most flexible, reliable, and cost effective separation structure and recommended this type of construction for the diked impoundments within the Salton Sea (USBR and Salton Sea Authority TAC 1994). This option does not include dredging of Salton Sea sediments, which eliminates the danger of resuspending large quantities of potential contaminants in Salton Sea sediments.

The original impoundment proposal (USDOI and RAC 1969, 1974) suggested a trapezoidal dike, reaching a width of up to 225 feet at the base and 40 feet at the top (Figure 4-1). The dikes that form the impoundment were to be created from sediment dredged from the bottom of the Salton Sea on the offshore side and imported fill material on the shore side. A two-way road would be constructed on top of the dike to permit access for fishing and other recreation such as bird watching. The impoundment inlet structures consist of two or more parallel open channels that are 10 feet wide and 100 feet long (Figure 4-2). Control of the water flow would be through radial gates that close and open. The dike crest would widen to 100 to 120 feet at inlet structures to provide a foundation for the channels.

The value engineering team assessed this original design and modified it based on considerations of cost, changing Sea levels, and slope of the dike. The estimated costs in 1974 were indexed to reflect 1994 dollars for a 40-square-mile diked impoundment (the preferred alternative of the 1974 study). Since the surface elevation of the Salton Sea has increased since 1974, so has the volume of material necessary for the dike construction. A crest elevation of -220 msl instead of -225 msl is presently required. Finally, the value engineering team recommended that a slope of 10:1 instead of 4:1 would produce a more stable dike (USBR and Salton Sea Authority TAC 1994). The value engineering team proposed an additional option, decreasing the crest from 40 feet to 20 feet wide. This would reduce the amount of fill material and save money as shown in Table 4-3. However, this would not allow for two-way traffic with parking.

Table 4-2

SUMMARIZATION OF VALUE ENGINEERING TEAM'S RECOMMENDATION FOR ALTERNATIVE DIKE STRUCTURES

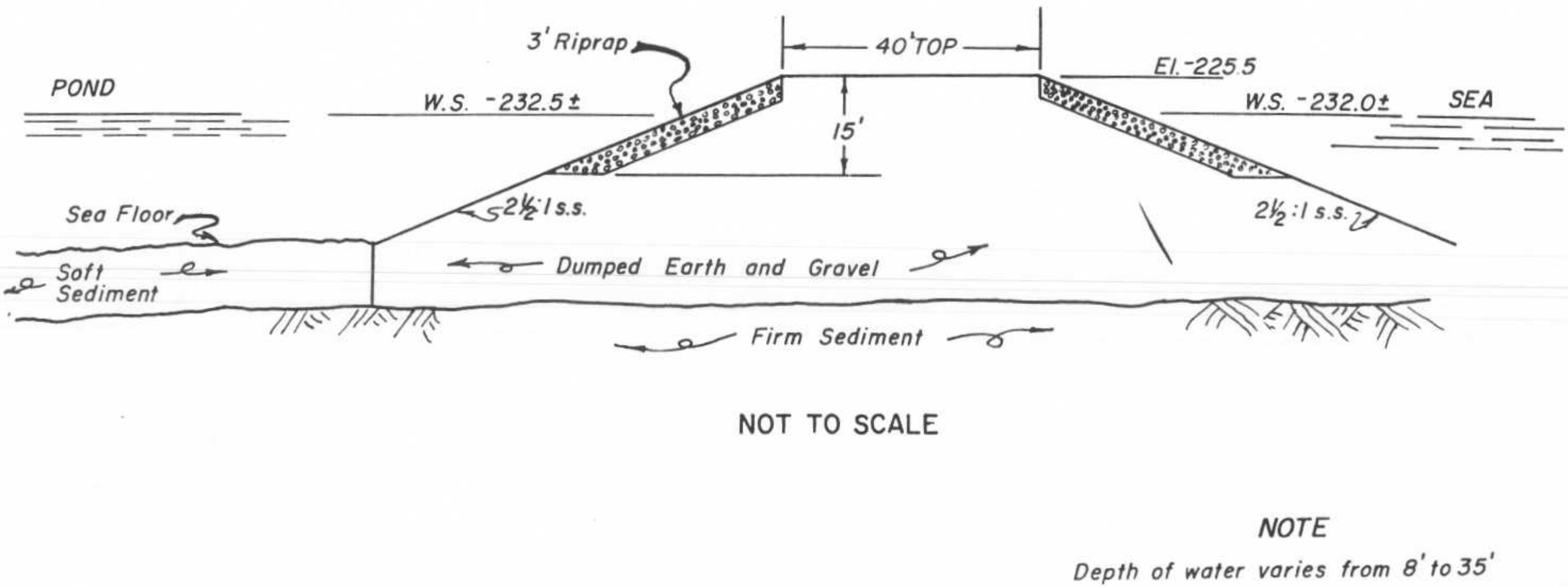
Option	Recommendation	Preliminary Cost in Million of $
Excavate, haul, & dump	This option has a high static and dynamic stability, seepage resistance, and uses a denser fill than the dredge fill. The disadvantages include environmental impacts to the borrow area & noise and dust impact on residents. Recommend this option as the preferred option alternative.	132.00 (40 ft crest) 140.00 (20 ft crest)
Dredge & fill dike	Though this option would confine all environmental effects to the Sea, there is low resistance to earth quake loading, and less resistance to seepage than the haul and dump option. Disturbance of Sea sediments will likely resusupend contaminants. Viable option, could be considered as alternative to preferred option.	145.00 (40 ft crest) 137.40 (20 ft crest)
Plastic curtain	Although the concept appears attractive theoretically, the team had no confidence in the option proving successful in a practical application at the Salton Sea. No further evaluation of this option is warranted.	115.50
Sheetpile	The lack of durability and high cost of the option were serious drawbacks. No further evaluation of this option is warranted.	126.50
Concrete wall	Serious disadvantages of this option include: the known lack of durability of concrete in the high salt environment, concerns over sealing of joints, high initial cost, and construction feasibility. These concerns make this option not viable. No further evaluation of this option is warranted.	221.80

Table 4-2 (Continued)

SUMMARIZATION OF VALUE ENGINEERING TEAM'S RECOMMENDATION FOR ALTERNATIVE DIKE STRUCTURES

Option	Recommendation	Preliminary Cost in Million of $
Geotextile Bags	It was pointed out to the team that the Corps of Engineers has had little success in using dredged material to fill the bags because the fines plug the fabric and inhibit water drainage from the material inside the bags. No further evaluation of this option is warranted.	161.60
Sheetpile and Dredge	The high cost of sheetpile and rockpile are seen as drawbacks to this option. The resulting structure is more expensive than an earthen dike and does not provide any additional benefits. No further evaluation of this option is warranted.	276.00
Haul, dump, and dredge coarser material	Logistical and construction difficulties are the major disadvantages. No further evaluation of this option is warranted.	161.00

Note: USBR and Salton Sea Authority TAC 1994

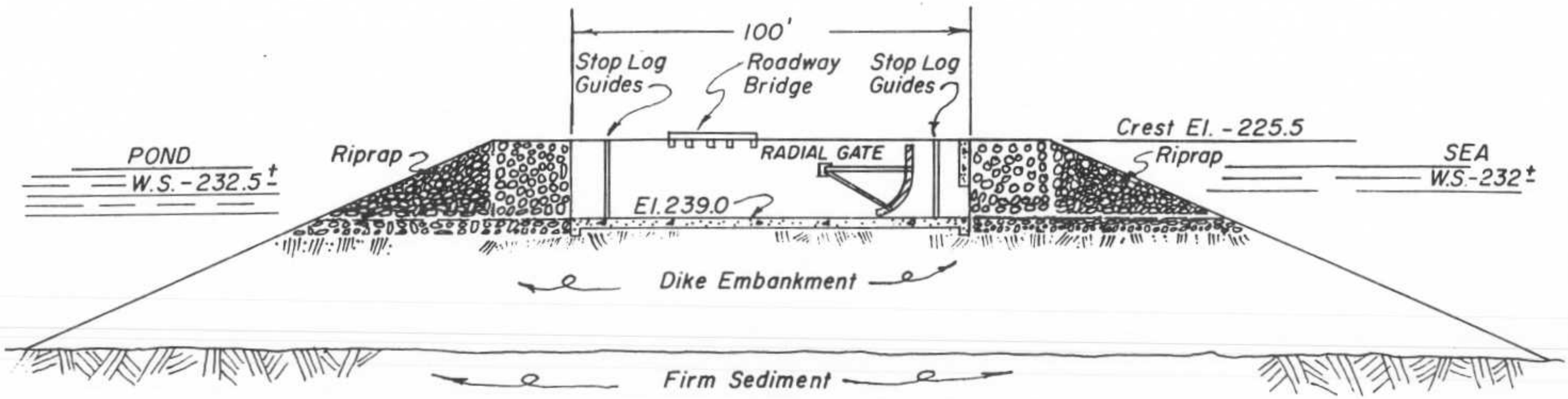


NOTE: Source from USDOI and The Resources Agency of California, Drawing No.1169-326-55.

OGDEN

Cross-section of Typical Dike (Dumped Embankment)
Salton Sea, California

FIGURE 4-1



NOT TO SCALE

NOTE

Crest elevation to be increased from 40 feet wide to 120 feet wide at inlet structure

NOTE: Source from USDOI and The Resources Agency of California, Drawing No. 1169-326-54.

OGDEN

Cross-section Through Inlet Structure
Salton Sea, California

FIGURE **4-2**

Table 4-3

CORRECTED COSTS FOR SELECTED DIKE DESIGNS

Option	Cost (Million of $)
Original proposal	48.00 (40 ft crest)
Original corrected proposal (1994 Cost, -220 msl, 10:1 dredge slope)	153.80 (40 ft crest) 140.00 (20 ft crest)
All dredge material	145.00 (40 ft crest) 137.40 (20 ft crest)
All dump material	132.00 (40 ft crest) 109.90 (20 ft crest)

Source: Ferrari and Weghorst 1995

4.1.2 Diked Impoundment Alternative Configurations

Aside from the construction material used for the dike, the remaining major difference between proposed diked impoundment alternatives are size and location in the Salton Sea. Most of the diked impoundment alternatives are located at the southern end of the lake, where the lake bottom is flattest. The alternative configurations discussed below are: 1) a 50-square-mile impoundment at the southern end of the lake, 2) a 40-square-mile impoundment at the southern end of the lake, 3) two impoundments, one at the southwestern and one at the southeastern end of the lake, totaling 50 square miles, 4) diking off the northern third of the lake, 5) diking off the northern half of the lake, 6) parallel dikes forming 47-square miles of impoundment, and 7) a phased zoning concept. Of course, many more sizes and locations for the dike are possible, some of those proposed are listed in Table 4-1. Proposed sizes of the impoundment have ranged from approximately 8 to 50 percent of the surface area of the Salton Sea, and proposed impoundment locations have included all sectors of the lake.

Fifty-square-mile Impoundment at the Southern End of the Lake

An earthen dike would be constructed at the southern end of the lake (Figure 4-3) (CVWD pers. comm.). The 37-mile dike would enclose 50 square miles or 14 percent of the lake's surface area. The dike would be 0.5 to 1 mile from the shore on the shoreside. A freshwater channel would be formed between the shoreside dike and the shore of the Salton Sea, where inflow from the New and Alamo rivers would be directed. Two causeways, each with a bridge, would be constructed between the dike and the shore to allow for vehicle traffic. The impoundment would hold water at a depth of about 10 feet.

The following is a list of some specifications necessary to construct a 50-square-mile diked impoundment, as described above (USDOI and RAC 1974).

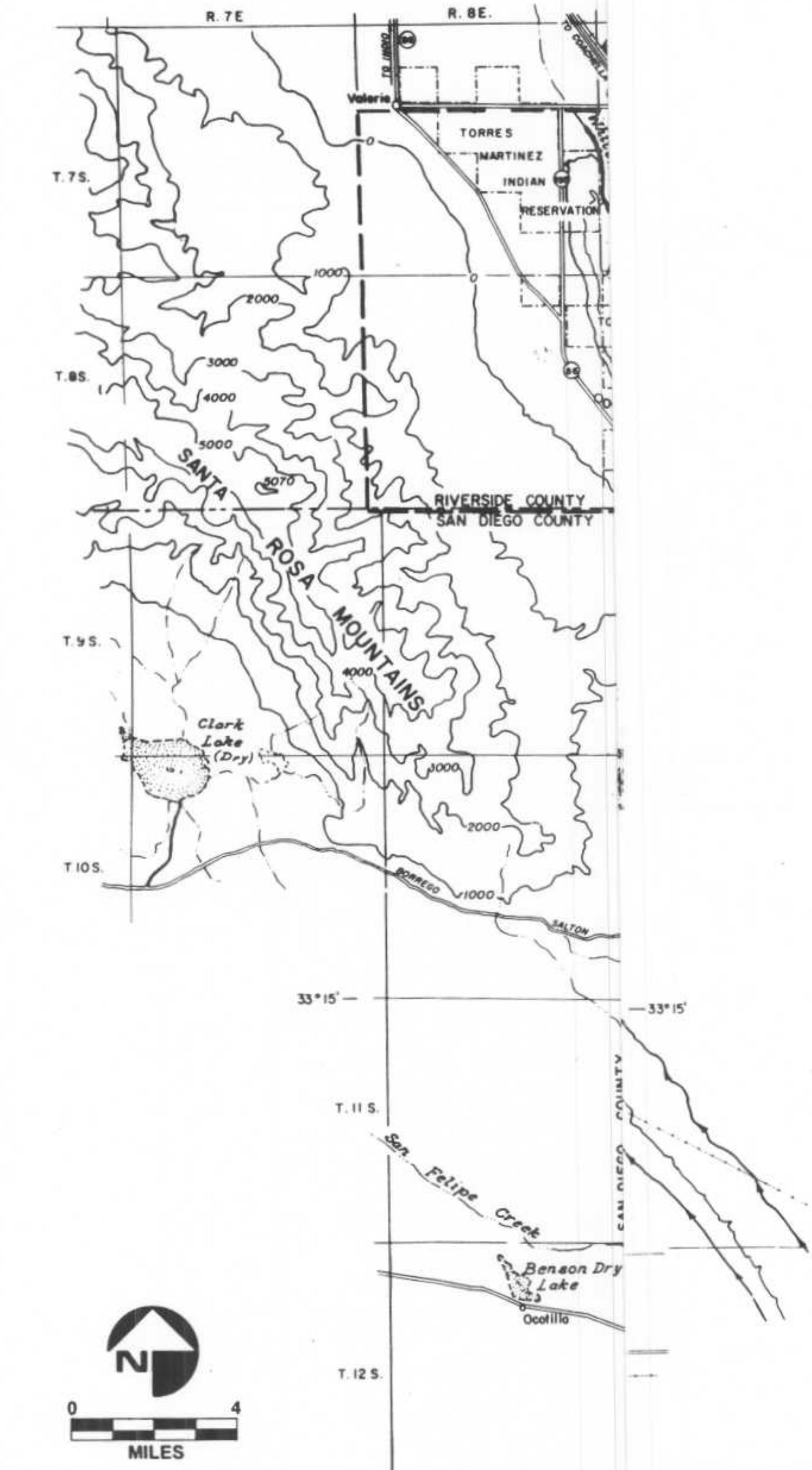
- 37 miles of dike and access road
- 7.5 feet of freeboard
- inlet structures consisting of two or more parallel open channels with radial gates
- monitoring equipment for operation
- a means for eventually removing salt from impoundment

Forty-square-mile Impoundment at the Southern End of the Lake

This alternative would control the salinity in the same manner as the 50-square-mile impoundment. The 27-mile dike would enclose 40 square miles or 11 percent of the lake's surface area (Figure 4-4). The remaining features of the dike would be essentially the same as the 50-square-mile impoundment, with the exception of the location and certain construction modifications dictated by the location. The list of components necessary to construct a 40-square-mile diked impoundment is essentially as described above, except the length of the dike is 27 miles rather than 37 miles.

Two Diked Impoundments Totaling 50 Square Miles

Under this option, two diked impoundments would be constructed on the southeastern and southwestern sides of the lake (Figure 4-5), utilizing sections of shoreline rather than shore-side dikes in the lake. Their combined surface area would equal approximately 50 square miles with a length of about 22 to 28 miles each. This alternative would



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

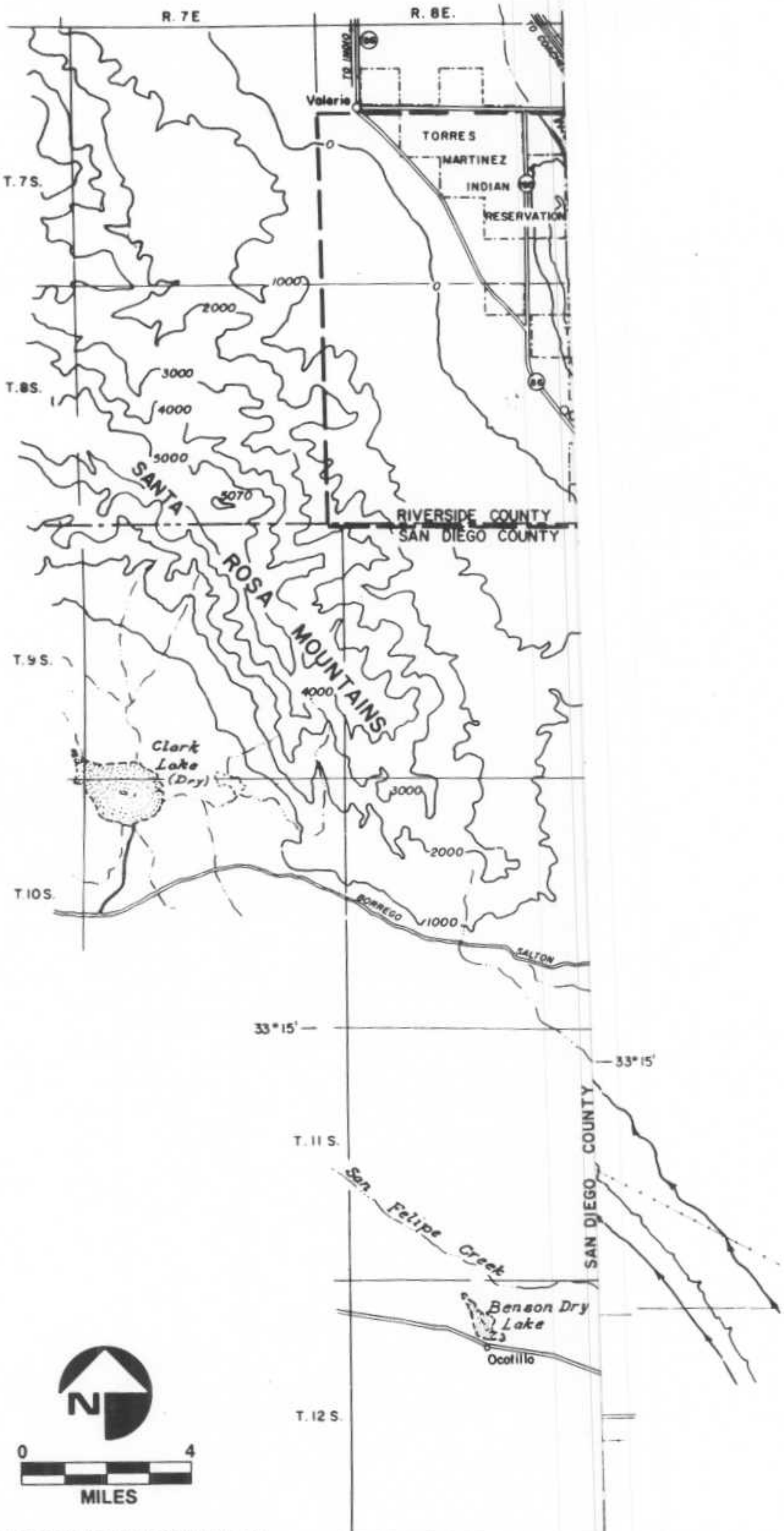
SOURCE: Interior - Reclamation, B C., Nev. 4-74

NOTE: Source of Impoundment and location from USDOI and The Resources Agency of California Drawing No. 1169-326-23.

OGDEN

FIGURE

4-3



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

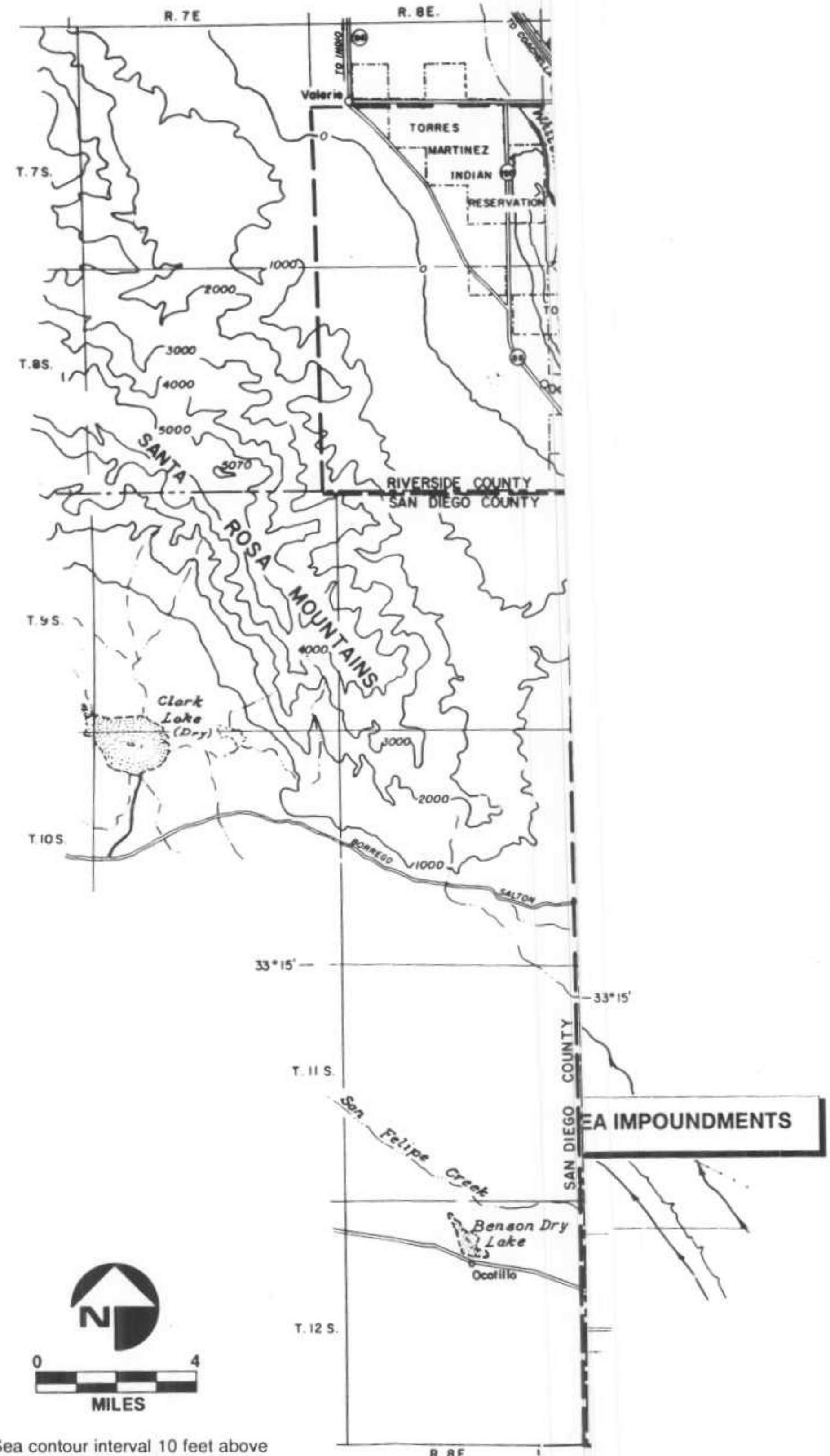
SOURCE: Interior - Reclamation, B C., Nev. 4-74

NOTE: Source of Impoundment and location from USDOI and The Resources Agency of California Drawing No. 1169-326-23.

OGDEN

FIGURE

4-4



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

SOURCE: Interior - Reclamation, B.C., Nev. 4-74

NOTE: Source of Impoundments and locations from Dangermond & Associates, Inc., 5-94.

OGDEN

FIGURE

4-5

function in the same manner as the single 50-square-mile impoundment, but salts would remain in two impoundments rather than one. A potential advantage of the two-impoundment configuration is that the dikes could be placed in areas that may cause less interference with inflow from the New and Alamo rivers.

Dike Off Northern Third of the Lake

This alternative would control the salinity in the same manner as both the 50- and 40-square-mile impoundments; however, this alternative essentially cuts the lake into two unequal portions. An earthen dike would be constructed across the northern end of the lake, enclosing approximately one-third of the lake or 127 square miles (Figure 4-6). As the majority of freshwater enters the lake at the south end, under this scenario the northern third of the Salton Sea will serve as the impoundment or evaporation basin. This effectively reduces the total volume of the lake by one-third, allowing dilution of the remaining two-thirds of the Sea with freshwater inflow and a corresponding reduction in salinity. However, the elevation of the lake would change very little because the evaporation basin will support the remaining surface area of the lake.

Dike Off Northern Half of the Lake

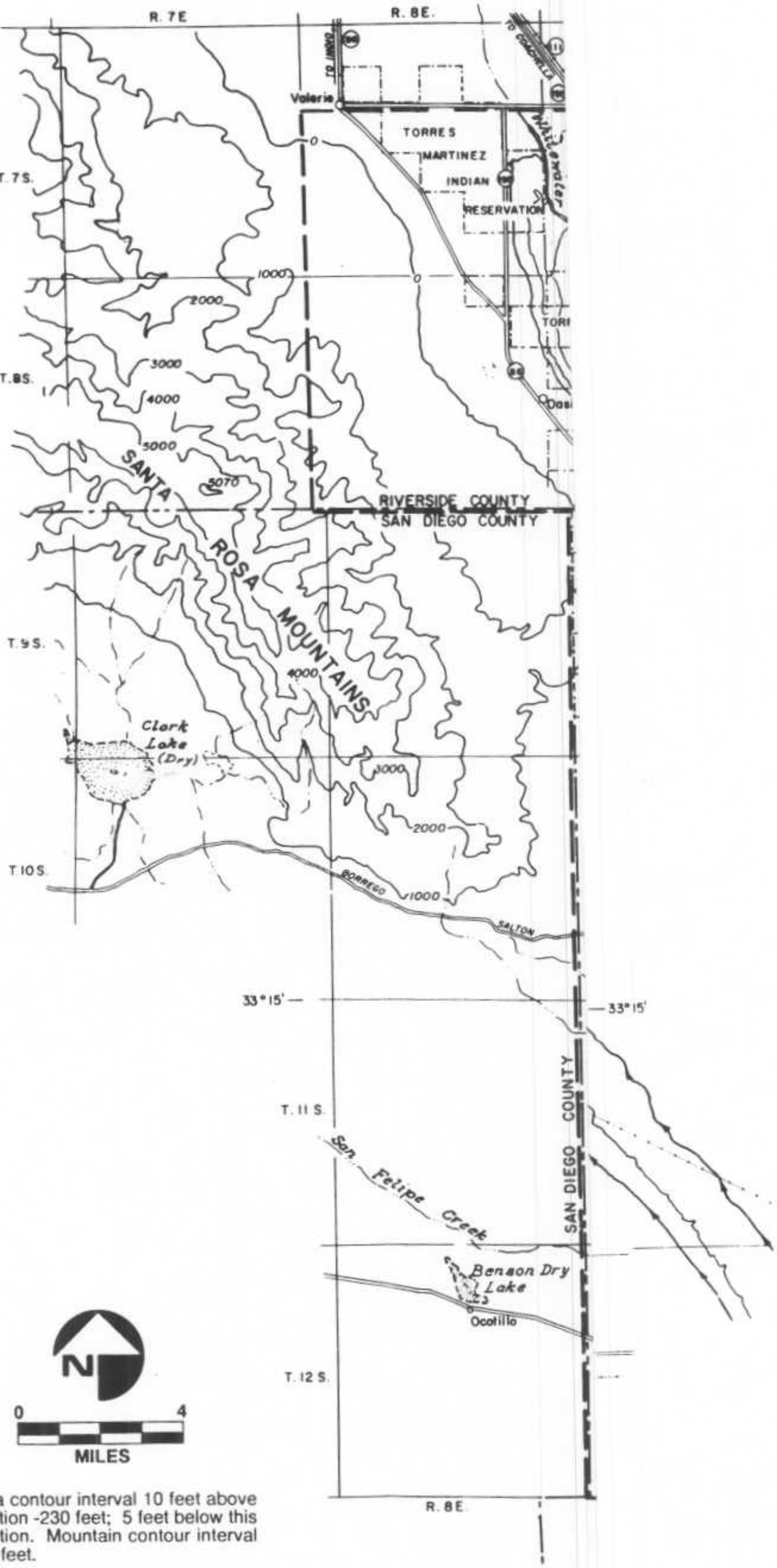
This alternative follows the concepts for the one-third option, except it essentially divides the lake in half. The dike would be constructed across the narrowest point of the lake and would form an impoundment approximately 190 square miles in area.

Parallel Dikes

This alternative is similar to other diked impoundment alternatives but the evaporation basins would be formed by a series of parallel dikes within the Sea. The total surface area of the evaporation basins is about 47 square miles.

Phased Zoning Concept

This plan, proposed by USBR (1994), would create three zones of varying salinities. The first zone would consist of a 25-square mile impoundment at the southeast shore of the Salton Sea. The Alamo River would flow into this impoundment resulting in the rapid formation of a brackish water body with a projected salinity of 8 ppt. The second and



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

SOURCE: Interior - Reclamation, B C., Nev. 4-74

OGDEN

FIGURE

4-6

third zones would be formed by constructing a dike bisecting the northern third of the Sea. The second zone would eventually reach a projected salinity of 35 ppt, while the third zone would become an evaporation basin where salinities would rise to very high levels.

4.2 PUMP-OUT

All of the pump-out alternatives are based on the concept of removing Salton Sea water (and its associated salts) from the lake. This would provide, in effect, an outflow from the lake and change the system from a closed terminal lake to an open flowing system. Salts would be exported with the outflow rather than being retained in the lake when water evaporates. In addition to salts being exported from the Sea with a pump-out alternative, the lake's total volume is reduced as a result of pump-out, which would result in a salinity decline from dilution with inflowing fresh water.

The lake's elevation is dependent on the relationship between inflow and outflow. At present, the lake's elevation is relatively stable; that is, inflow/precipitation is equal to evaporation, the only outlet for water at present. The removal of water from the Salton Sea via a pump-out alternative would alter the hydrologic balance of the Sea, resulting in total outflow exceeding total inflow and a drop in the lake's elevation. Surface elevation can only be maintained by importing water back to the Salton Sea. For example, water from the Gulf of California or the Colorado River could be used, in concept, to replace the amount of Salton Sea water that is pumped-out.

There are infinite possibilities for the pump-out rates. Formal proposed pump-out rates have ranged from 65,000 acre-feet to 400,000 acre-feet per year. The major differences between these rates being the amount of time it would take to reach the target salinity and the construction costs associated with different pipe sizes. Two alternative rates of pump-out have received the most attention and study. These are 200,000 acre-feet per year and 400,000 acre-feet per year. Therefore, while the number of options for pump-out rates are large, this study will emphasize these two so that other options can be gauged against them. Pump-out alternatives also vary with respect to the location to which Salton Sea water is pumped (e.g., a dry lake bed, onshore evaporation ponds, Laguna Salada/Gulf of California or the Pacific Ocean) using either of the two annual pump-out rates.

4.2.1 Pump-out Alternatives

All of the pump-out alternatives are based on exporting saline water out of the Salton Sea. Aside from the amount of water removed each year, the major difference between pump-out alternatives is the location to which Salton Sea water will be pumped. The alternatives proposed to date include pump-out to a dry lake bed (Palen Dry Lake will be used as an example, but other dry lakes such as Clark and Ford are considered options), evaporation ponds, Laguna Salada/Gulf of California, the Pacific Ocean, or onshore treatment/filtration units. These alternatives are described below.

Pump-out to Palen Dry Lake

Salton Sea water would be pumped from the Salton Sea through a pipeline to Palen Dry Lake northeast of the Salton Sea (Figure 4-7; USDOI and RAC 1974). There is a difference of 1,800 feet in elevation between the two lakes (USDOI and RAC 1974). An earthen dam would be constructed around Palen Dry Lake to form a sump to retain Salton Sea water and its associated salt, thereby essentially acting as an evaporation pond and storage area for the salts removed from the Salton Sea.

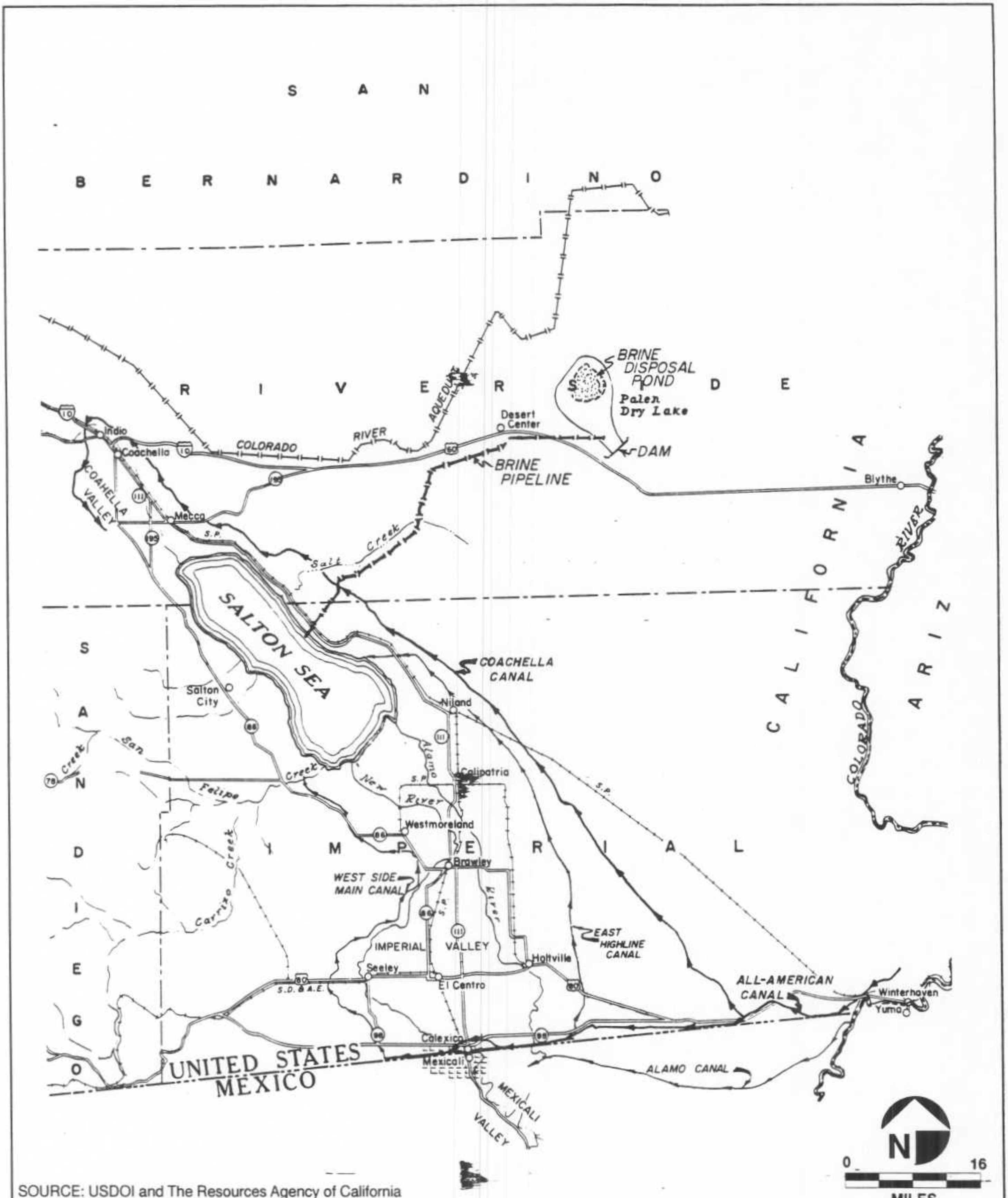
The following is a list of some of the major components or specifications of this alternative:

- four pumping plants (lift water 1,800 feet)
- 46.7 miles of pipeline
- earthen dam around Palen Lake (undescribed)
- maintenance facilities (undescribed)

Other suggested options include pumping Salton Sea water to other lakes, such as Clark Dry Lake, which is located in the Anza-Borrego Desert State Park or to the base of the Chocolate Mountains.

Pump-out to Onshore Evaporation Ponds

This alternative involves pumping Salton Sea water into evaporation ponds located on the lake's shore, where the water evaporates leaving behind saline residue. Saline water would be removed from the lake at one of the pump-out rates discussed above until the desired salinity was reached. At this point, pump-out would continue at a rate such that salts



SOURCE: USDOI and The Resources Agency of California Drawing No. 1169-326-73, April 1974.

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Potential Location of Pipeline to Palen Dry lake

FIGURE 4-7

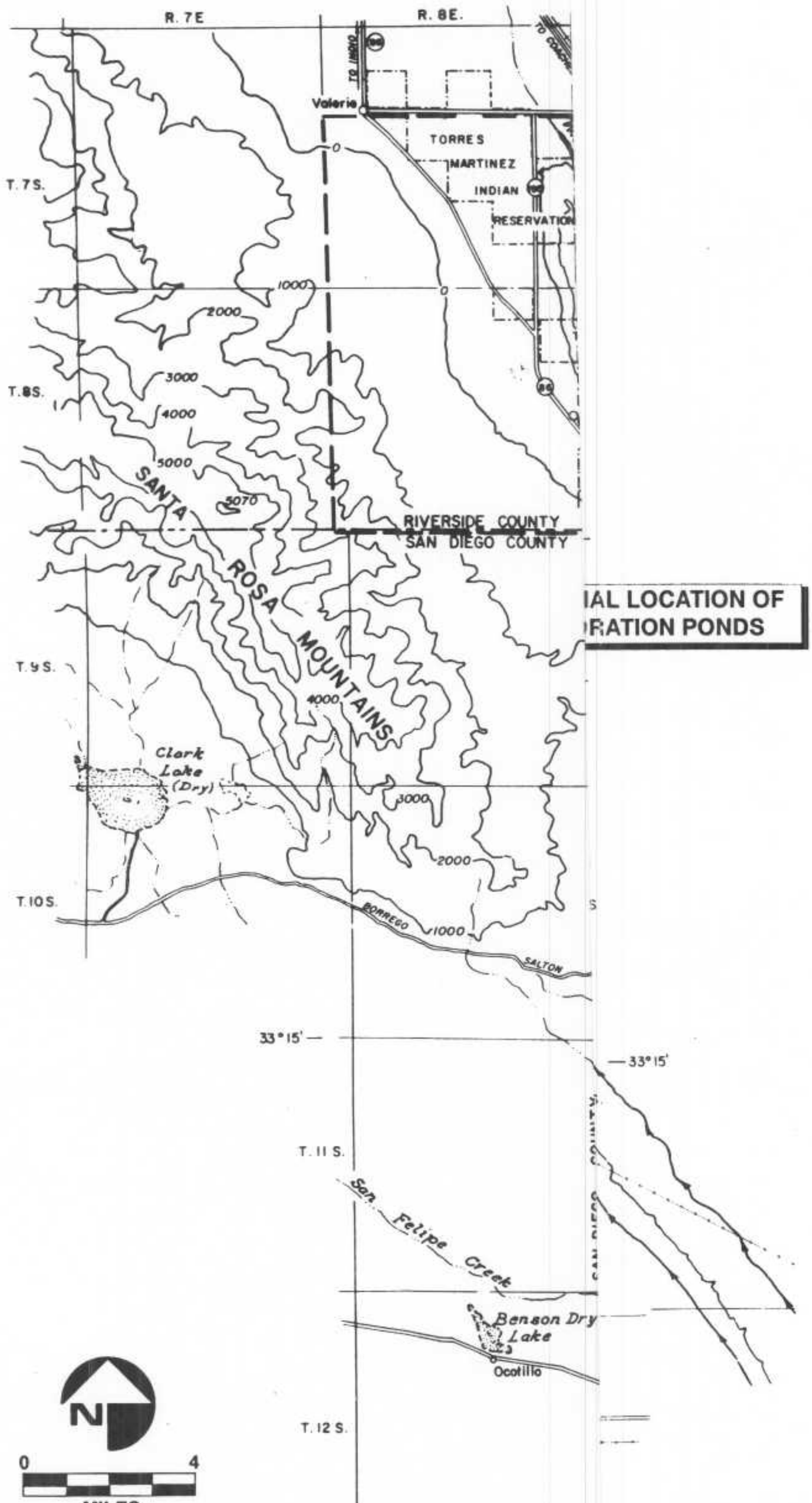
removed by pump-out each year would equal the annual inflow of salts to the lake. Eventually, the evaporation ponds would fill with salts, and disposal would be necessary. Areas on the southeastern shore, between Bombay Beach and Red Hill, have been suggested as a potential location for onshore evaporation ponds (Figure 4-8).

Most evaluations of evaporation ponds have concluded that evaporation ponds on land are not economical because of the high costs of acquiring sufficient land around the lake (USDOI and RAC 1969). However, developments in solar pond technology, such as an enhanced evaporation system (enhanced evaporation system) (Ormat 1989), where salt water is pumped through an elevated spray system, producing increased evaporation rates, appear to require less land than standard evaporation ponds. The original volume of removed water is reduced by 90 percent with the enhanced evaporation system. The remaining saline water is pumped to conventional evaporation ponds for further evaporation. With the use of enhanced evaporation, Ormat anticipated the need for only 10 percent of the land area necessary for conventional evaporation ponds (Ormat 1989). The need for salt disposal still exists because the evaporation ponds would eventually fill with salt. Furthermore, there is more energy needed for the pumping associated with enhanced evaporation (CVWD pers. comm.).

Evaporation ponds could be used for other purposes, such as using the saline residue in a solar plant for generation of electricity or using Sea water for aquaculture by first pumping the water to a series of aquaculture ponds and then to a series of evaporation ponds. In both cases, the principles for salt removal are essentially the same as described above for onshore evaporation ponds. These additional options represent a potential means to generate funds for operation or construction costs. Further research is necessary to determine if these options would, in fact, generate funds. These options are described below.

<u>Solar Ponds</u>

This technology uses highly saline water to trap the sun's energy for the production of electricity. Highly saline water would be obtained by pumping water from the Salton Sea to an enhanced evaporation system (Ormat 1989). Salton Sea water would be pumped through an elevated spray system, which concentrates the brine, and reduces (through evaporation) the fluid volume by 90 percent (Ormat 1989). The concentrated brine would then be pumped into multiple solar ponds.



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

SOURCE: Interior - Reclamation, B.C., Nev. 4-74

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FIGURE

4-8

The highly saline water in the solar ponds becomes stratified with dense saline water sinking to the bottom and the fresher water floating to the surface. Solar energy is absorbed by the highly saline water at the bottom of the pond. Special diffusers and a proprietary gradient control system are used to prevent mixing of the stratified layers (Ormat 1989). The hot water at the bottom of the pond, or the storage zone, is extracted and passed on through heat exchangers, called evaporators (boilers), which vaporize a working organic fluid. This produces a pressurized vapor that is transported to turbines where the vapor expands and powers turbine generators producing electric power (Ormat 1989).

Ormat designed the project to have several "Basic Modules," each consisting of smaller duplicated subsystems. The modules could be constructed in one area or in several locations around the lake. The basic module would evaporate 25,000 acre-feet per year and would occupy a maximum area of 2.0 x 1.2 miles or 2.4 square miles. Four of the basic modules would evaporate 100,000 acre-feet per year, and nine of the basic modules would evaporate 225,000 acre-feet per year. These would produce a total electrical generation capacity of 36 megawatts (MW) (144,000 MWhr/yr) and 72 MW (288,000 MWhr/yr), respectively. Nine basic modules would occupy a maximum of 21.6 square miles.

Ormat (1989) described a basic module as having the following components:

- 612 acres of enhanced evaporation system (70 subsystems)
- four (and up to 8) 1.0 MW Ormat Energy Converter power generation modules
- four (and up to 8) 40-acre solar ponds
- 75 acres of crystallization ponds
- one deep injection well or another unspecified means of removing excess brine

More salt would be produced than could be used in the solar power generation; therefore, salt disposal would be necessary.

Fish Ponds

In this option, proposed by Aquafarms International, salts are removed through evaporation ponds, using both enhanced and conventional evaporation pond technologies. In addition, the evaporation ponds are coupled with aquaculture ponds to provide for fish production. This option calls for 70 salt water aquaculture facilities around the perimeter of the lake. Each facility would require 1 square mile (640 acres); thus, a total of 70 square miles (44,800 acres) would be necessary for the entire project. Each aquaculture facility would be composed of 200 acres of fish ponds; 400 acres of evaporation ponds; and 40 acres of surface roads, utilities, and maintenance structures. The entire project would include

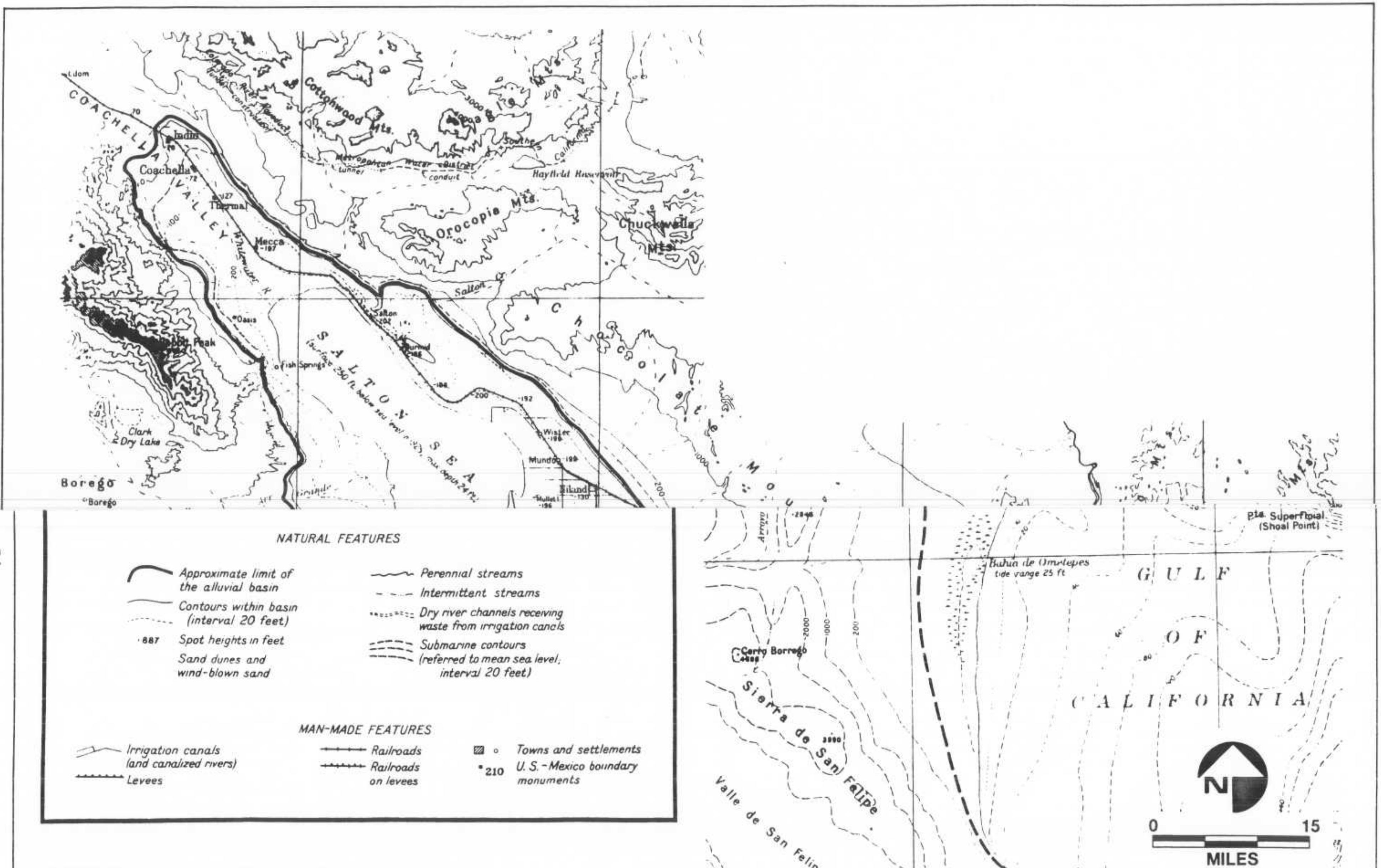
- 22 square miles (14,000 acres) of aquaculture ponds
- 44 square miles (28,000 acres) of evaporation ponds
- 4.4 square miles (2,800 acres) for supporting structures

With an evaporation pond surface area of 28,000 acres and an evaporation rate of 5 to 6 feet per year, this option is estimated to remove between 140,000 and 168,000 acre-feet of water per year. Salts would accumulate in the evaporation ponds and disposal would be necessary.

Pump-out to Laguna Salada or Gulf of California

Pump-out of saline Salton Sea water to the Gulf of California was first proposed in 1969 by the USDOI and RAC. This alternative was later revised in 1971 by the Aerospace Corporation, in 1991 by the USBR (1991), and in 1994 by IID (pers. comm.). This alternative would transport 200,000 to 400,000 acre-feet of Salton Sea water per year to Laguna Salada or to the Gulf of California.

The USBR proposed a route for the pipeline/canal shown in Figure 4-9. Canals would be used when transporting water downgradient, and pipelines would be used when pumping water uphill or for outfalls. An intake channel would carry water from the Salton Sea to the Salton Sea Pumping Plant. Section 1 of the pipeline carries water 25,000 feet from the Salton Sea Pumping Plant to the canal. Section 2 of the pipeline carries water 12,000 feet around the southern tip of the Naval Reservation. Section 3 of the pipeline carries water 12,000 feet from La Rosita Pumping Plant to the saddle of Laguna Salada. The outfall pipeline/canal has two components that carry water from the saddle of Laguna Salada to the Laguna Salada basin. An 84-inch pipe would carry water 8,000 feet downward until Sea level is reached, and a 3,000-foot canal (identical to the intake channel with side slopes of 1:1) would carry the water to Laguna Salada.



SOURCE: Carnegie Instn. of Washington Publ. No. 460 -
American Geographical Society, Special Publication No. 19, Pl. I, 1937.

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Approximate Location of Canal/Pipeline to the Gulf of California and Return Route to the Salton Sea

FIGURE **4-9**

A 76-mile concrete-lined channel to the Gulf of California would be constructed to carry water from Laguna Salada to the Gulf of California. Another option would be to carry water only to Laguna Salada and allow water to evaporate and the salts to remain. However, the consent of the Mexican government would be required for this option, which may be difficult to obtain. If the water is carried to the Gulf of California, this opens up both the Salton Sea and Laguna Salada which may be a more attractive concept to the Mexican government.

The following is a list of some of the components and specifications necessary for this alternative (USBR 1991):

- three pumping plants
  - Salton Sea pump station (southern tip of Salton Sea, 16,400 kilowatt [Kw])
  - Canal Pumping Plant (2 miles south of the southern tip of the Naval Reservation, 4,100 Kw)
  - La Rosita Pumping Plant (1 mile south of La Rosita, Mexico 13,000 Kw plant)
- 11 miles of pipeline (five sections)
  - Sections 1-4 use two 96-inch pipes
  - Section 5 outfall pipe uses an 84-inch pipe
- 44.5 miles of concrete lined canal
  - Bottom width of 10 feet
  - 8.5 feet deep
- 0.5 mile of intake channel
  - 12 feet deep
  - bottom width of 60 feet
  - 3:1 slope
- 76 miles of concrete-lined channel to the Gulf of California

USBR (1991) further proposed an option for the above alternative that would control the Sea's elevation. A canal/pipeline would be constructed to transport less saline Gulf of California water to the Salton Sea. Between 200,000 to 400,000 acre-feet of water from the Gulf of California would be pumped over the mountains to Laguna Salada and then gravity-fed to the Salton Sea.

An intake pipeline would pump water from the Gulf of California to the Las Amajas Pumping Plant. A 35-mile-long pipeline would carry water from the Gulf of California to Cerro Prieto, Mexico. A canal from Cerro Prieto carries gravity-fed water to the Salton Sea. An 11,000-foot-double-inverted siphon would be necessary to carry water around the southern tip of the Naval Reservation. A 0.5-mile-long outlet channel at the lake would feed the Gulf of California water into the Salton Sea (USBR 1991).

A power plant could be located at Cerro Prieto to generate energy as the Gulf of California water flowed down from the mountains and into the Sea. The 6,000 Kw power plant would generate 53,000,000 Kwhr/yr. The energy generated would partially offset pumping requirements. The return pipeline would include

- Intake pipeline (located at Las Amajas, Mexico)
- One pumping Plant (located at Las Amajas, Mexico)
- 35-mile pipeline (Gulf of Mexico to Cerro Prieto)
- Canal
  - 8.5 feet deep
  - bottom width of 10 feet
- Siphon (11,000 foot long double inverted siphon, 78 inch diameter)
- Small power plant
- Outlet channel at the Salton Sea
  - 12 feet deep
  - 60 feet wide
  - 3:1 side slopes

Dangermond and Associates, Inc. (1994) proposed a similar alternative. A two-way canal/pipeline system would be constructed between the Salton Sea and the Gulf of California as described above. A storage facility for water and a power generation plant would be built at the highest point between the two water bodies. This would allow for pumping to occur at night when electricity rates are the lowest and for water to flow downhill during the day to generate hydroelectric power when rates are highest.

Pump-out to Pacific Ocean

This alternative is similar to the pipeline/canal to the Gulf of California alternative, except a link between the Salton Sea and the Pacific Ocean would be established (Salton Sea

Authority Public Comments 1995). The exact route has not yet been selected but would be dependent upon cost and engineering considerations. Ocean water would be carried to the Salton Sea, and Salton Sea water would be transported to the Pacific Ocean via the shortest and least expensive route. The distance between the two is estimated at about 100 miles. This exchange of water between the ocean and the Sea would eventually stabilize the salinity and elevation. The proposal suggests potential business ventures around the Salton Sea and along the pipeline such as saltwater farms (lobster, abalone, kelp, pearls, research, fishing, etc.) theme parks, and oceanographic research centers could be supported by such an alternative.

Pump-out to Navigable Waterway/Locks System

Construction of an inland seaport at Laguna Salada has been discussed by both the Mexican and United States governments (Salton Sea Authority pers. comm.). A canal would be constructed to carry seawater from the Gulf of California to Laguna Salada, which would replenish the dry lake. This canal would be large enough for both freight and pleasure ships to navigate. It has also been suggested that a navigable waterway with a lock system could be constructed from Laguna Salada into the United States. More research is needed to determine the feasibility and cost of this option.

This proposal could benefit the Salton Sea area by providing for an outlet from the lake. If approval from the Mexican government were obtained, Salton Sea water could be pumped from the Salton Sea to the inland seaport and from there into the Gulf of California. This alternative is essentially the same as a pump-out alternative to Laguna Salada or the Gulf of California, but the canal/pipe system would extend only to the northern terminus of the navigable waterway.

Pump-out to Treatment/Filtration Units

A number of alternatives have been proposed that rely on treating or filtering Salton Sea water to remove salts and other constituents. These alternatives are presented in Table 4-1 and are described in more detail in USBR (in progress). Many of these alternatives rely on developing technologies or have little detailed information available regarding specifications or performance.

4.3 Combinations of Impoundment and Pump-out Alternatives

The following alternatives use various combinations of the previously described alternatives and some enhancement options not yet mentioned. They may include all or some of the following options: diked impoundments, shoreline enhancement areas, constructed wetlands, onshore evaporation ponds, solar pond and power generation plant, canal/pipeline with or without storage facilities. These combinations are described further below.

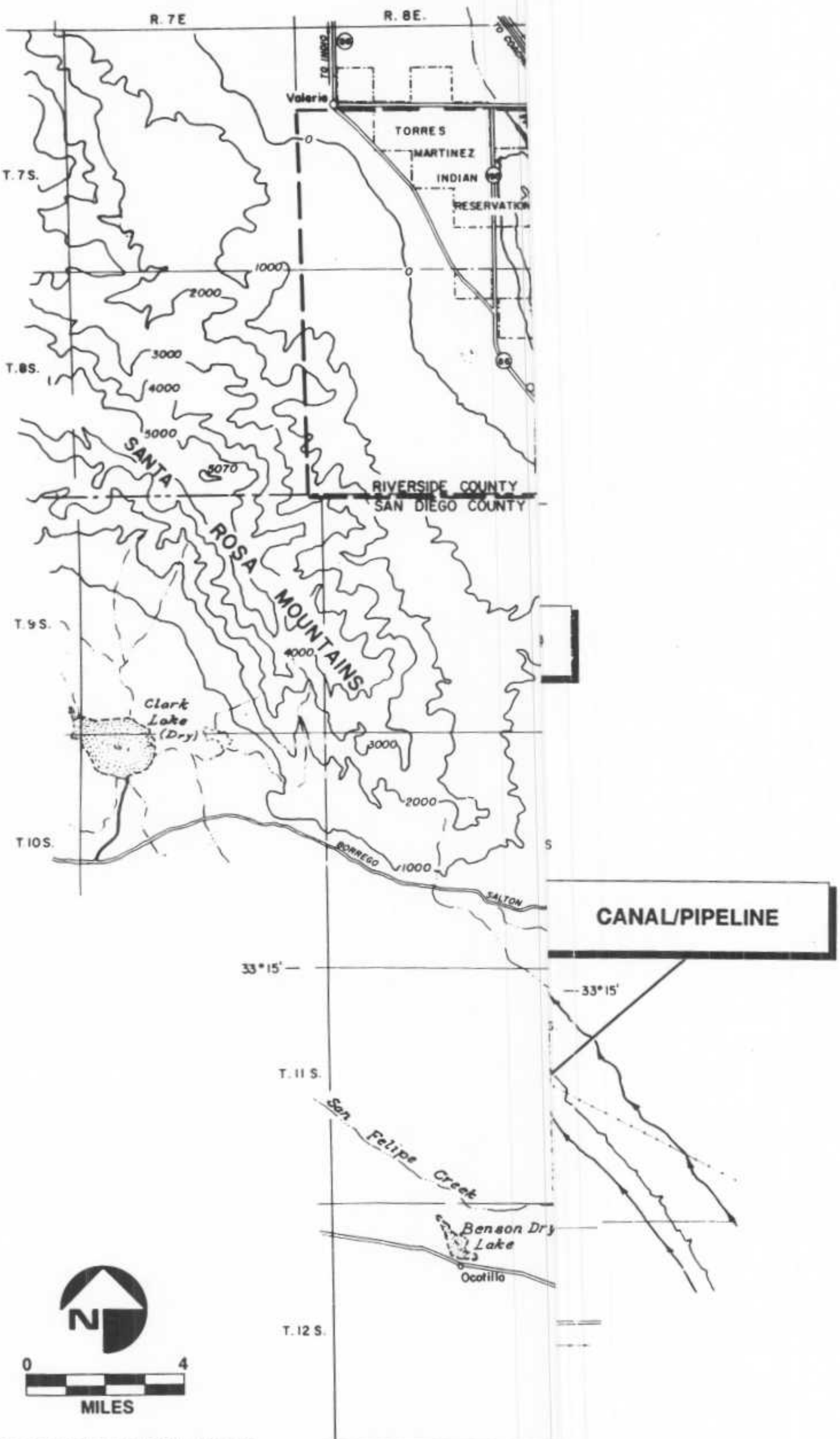
4.3.1 Diked Impoundment/Evaporation Pond/Pipeline Alternative

This alternative combines a diked impoundment adjacent to the shore, an onshore evaporation pond, and a pipeline to transport concentrated brine to another area (e.g., the Gulf of California or the Yuma desalting plant discharge canal). A 24-square-mile diked impoundment in the southwestern end of the lake would be constructed (Figure 4-10). The dike's specifications would be similar to those described for the diked impoundment alternatives, with the dike utilizing portions of shoreline rather than a shoreside dike within the lake. Pumping facilities would remove concentrated Salton Sea water from the diked impoundment and pump it to a 22-square-mile evaporation pond located in the same area onshore. A pipeline would be constructed to transport the concentrated brine from the evaporation pond to another area (Figure 4-10).

Two options have been proposed for the discharge of the concentrated brine. One option is to transport and release the concentrated brine into the Gulf of California (CVWD and IID, pers. comm.). A second option is to transport the concentrated brine to the Yuma desalting plant and release the brine into the plant's discharge canal, which dumps into the Santa Clara slough and ultimately into the Gulf of California (CVWD and IID pers. comm.). The alignment of either pipeline has not yet been determined.

The following components would be necessary for this alternative:

- 24 miles of dike and access road
- inlet structures consisting of two or more parallel open channels with radial gates
- monitoring equipment for operation



Sea contour interval 10 feet above elevation -230 feet; 5 feet below this elevation. Mountain contour interval 1000 feet.

SOURCE: Interior - Reclamation, B C., Nev. 4-74

OGDEN

FIGURE

4-10

- 22 square miles of evaporation ponds on the southwestern shore
- pipeline to Gulf of California or the Yuma desalting plant discharge canal

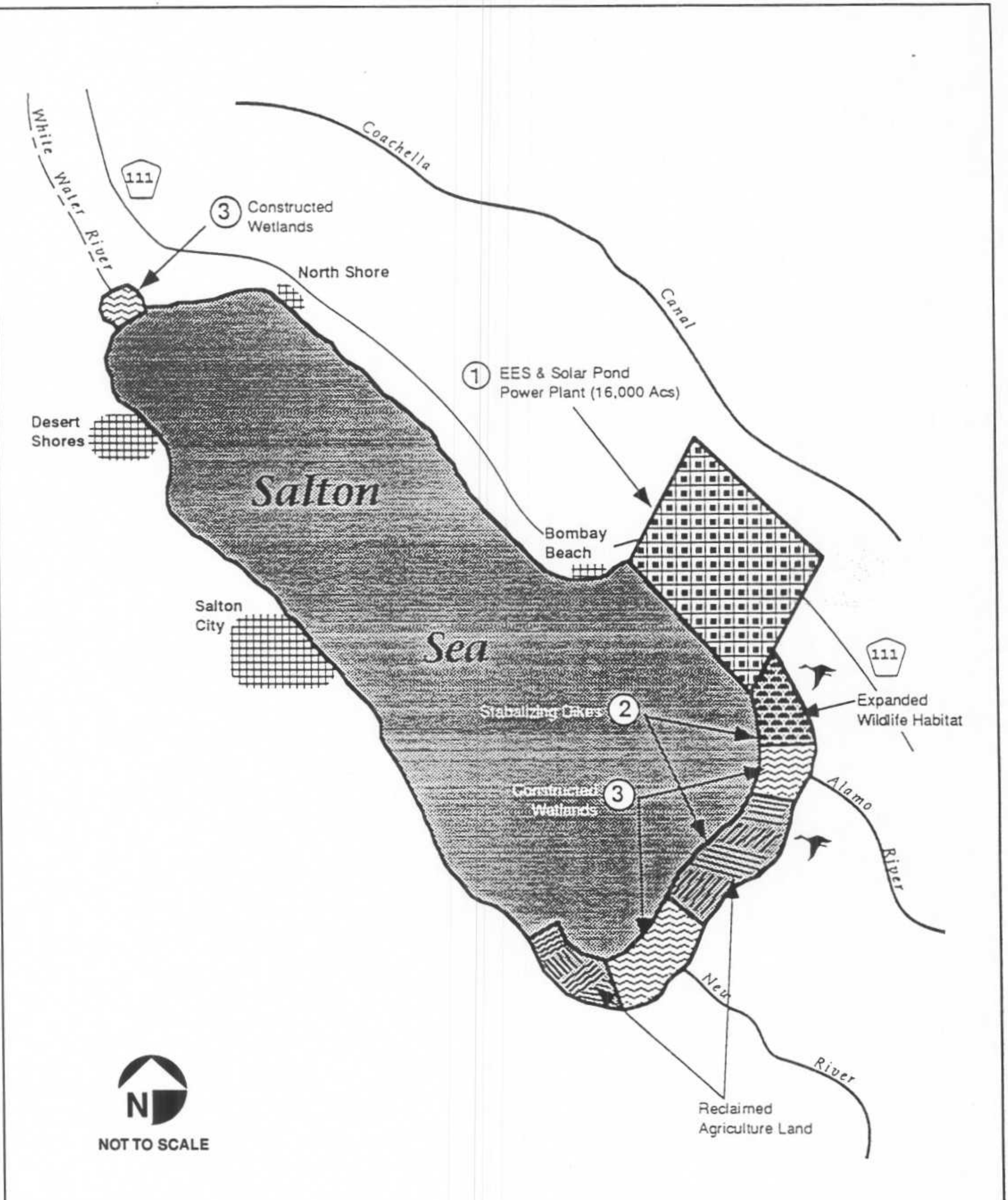
A similar option was proposed in 1974 (USDOI and RAC 1974) that combined an in-Sea impoundment and a pipeline. A 30-square-mile impoundment would be constructed in the southern end of the lake, and a pipeline would be constructed from the northeast end of the lake to Palen Dry Lake. Between 65,000 to 135,000 acre-feet a year would be transported to the dry lake.

4.3.2 Diked Impoundment/Solar Pond Power Generation/Constructed Wetlands

This option proposed by Dangermond and Associates, Inc. (1994) combines diked impoundment, solar pond power plant, and wetland construction alternatives (Figure 4-11). Evaporation ponds and solar ponds with enhanced evaporation systems, as proposed by Ormat (1989), would be constructed adjacent to the Salton Sea between Bombay Beach and the Wister Wildlife Refuge. Evaporation ponds would be used to concentrate approximately half of the salt brine which would reduce the cost of the enhanced evaporation system. The solar pond power plant would generate electricity which could be used to offset the cost and maintenance of the enhanced evaporation system. Additionally, two diked areas located at the south end of the Sea near the Alamo and New rivers would be constructed to stabilize the elevation of the Sea by compensating for withdrawals needed to reduce salinity. The reclaimed land behind these dikes could be used for other purposes such as wildlife habitat or agriculture (Dangermond and Associates, Inc. 1994). Wetlands would be constructed at or near the mouths of the New, Alamo, and Whitewater rivers. Inflow would be funneled through the constructed wetland so that the aquatic plants can absorb, filter, or biodegrade organics and heavy metals.

4.3.3 Freshwater Shoreline/Pumped Storage

Dangermond and Associates, Inc. (1994) described an approach that incorporated many of the previously mentioned alternatives. This alternative had 12 possible components, which could include all or some of these options (Figure 4-12). These are described below (the component numbers below are referenced in Figure 4-12).



SOURCE: Dangemond & Associates, Inc.

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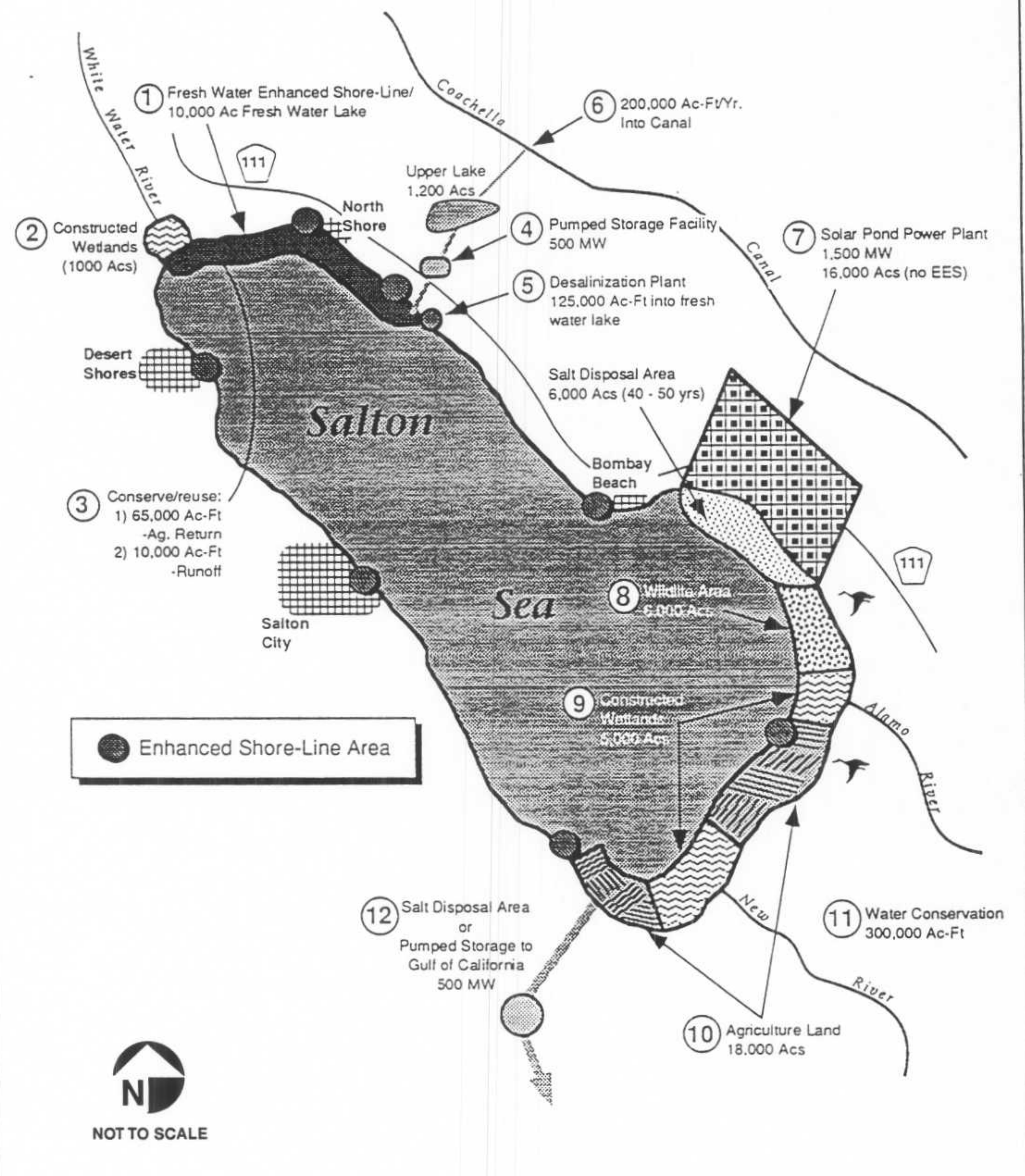
Potential Location of Diked Impoundment/Solar Pond and Power Generation/Constructed Wetlands Alternative

FIGURE **4-11**



SOURCE: Dangemond & Associates, Inc.

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Potential Location of Freshwater Shoreline/Pumped Storage Alternative

FIGURE 4-12

A diked impoundment (1) would be constructed at the north end of the Sea. The Whitewater River would empty into the impoundment through a constructed wetland. This freshwater wetland could be managed for recreation or wildlife habitat. Additionally, a wetland (2) approximately 1,000 acres in size would be constructed at the mouth of the Whitewater River. This would provide additional wildlife habitat and serve to filter contaminants before the water entered the northern diked impoundment. The constructed wetlands would also filter about 75,000 acre-feet of agricultural wastewater and storm run-off water (3), adding additional freshwater to the wetlands.

A pumped storage facility (4) would be constructed on a hill located on the northeast side of the Sea. Water from the impoundment would be pumped into the holding pond at night when electricity is cheaper and allowed to flow back to the freshwater impoundment during the day to generate electricity when rates are higher. Dangermond and Associates, Inc. (1994) estimated up to 500 MW of hydroelectric energy could be generated.

A desalination plant (5) would be constructed on the northeast shore. The plant would convert approximately 100,000 acre-feet of Salton Sea water to freshwater. The freshwater would be mixed with Whitewater River water and the agricultural wastewater to enhance the water quality in the freshwater impoundment. This blended, desalinized water (6) could be pumped to the Coachella Canal, and up to 200,000 acre-feet per year could be sold to water purveyors and used as a revenue source (Dangermond and Associates, Inc. 1994).

A solar pond power plant (7), without an enhanced evaporation system, would be constructed along the southeast shore. Approximately 150,000 acre-feet would be removed per year. The combination of the desalination plant and the solar pond power plant would reduce the salinity from 45 to 35 ppt in about 10 years (Dangermond and Associates, Inc. 1994).

A diked impoundment that would act as a wildlife area (8) enclosing about 6,000 acres would be constructed along the south shore. The constructed impoundment would reclaim land along the south shore of the Sea. The reclaimed land would include two areas, totaling about 5,000 acres, of constructed wetlands (9). The constructed wetland could be used to improve the water quality of the New and Alamo rivers. Two additional areas along the south shore would be used for agriculture or habitat creation (10) that could be leased or sold for mitigation credits. Dangermond and Associates, Inc. (1994) estimated that an additional 300,000 acre-feet of water (11) could be conserved in the Imperial and Coachella valleys with this plan. This water could be sold to urban users to offset costs.

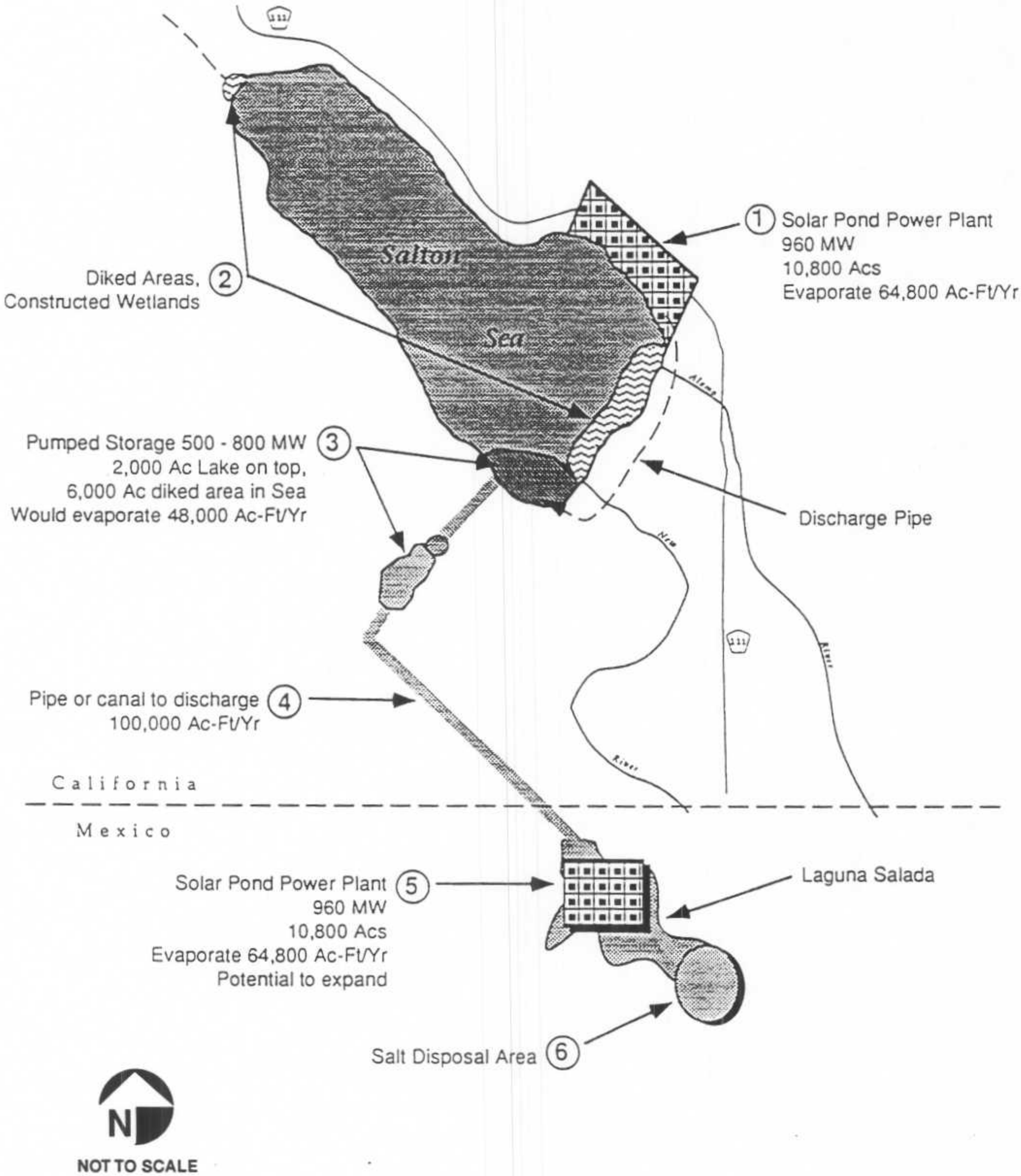
The final component of this plan is the construction of the pumped storage facility to the Gulf of California (12) described in Section 4.2.1. An alternative to the pipeline/canal/storage facility located at the southwest shore is to use this area as a salt disposal area (Dangermond and Associates, Inc. 1994).

4.3.4 Joint USA/Mexico Solar Power Generation/Pumped Storage Laguna Salada Salt Disposal

This alternative combines diked impoundments, solar pond power plants, and a canal/pipeline to Laguna Salada (Figure 4-13). Dangermond and Associates, Inc. (1994) described this alternative in the following manner (component numbers are referenced in Figure 4-13). A solar pond power plant (1), without an enhanced evaporation system, would be constructed along the southeast shore. This facility would evaporate about 65,000 acre-feet and would generate up to 960 MW per year. Diked impoundments (2) would be constructed at the north and south shoreline at the confluence of Whitewater, Alamo, and New rivers. Freshwater wetlands would be constructed within these impoundments providing for wildlife habitat and water quality enhancement.

A 500-800 MW pumped storage facility (3) would be constructed at the southwest side of the Sea. This would consist of a 6,000-acre diked impoundment in the Sea and a 2,000-acre lake at Sea level. These combined areas would evaporate about 48,000 acre-feet of water per year (Dangermond and Associates, Inc. 1994).

A pipeline/canal system (4) would connect the upper lake to the Laguna Salada, carrying about 100,000 acre-feet of Sea water per year. A second solar pond power plant (5), would be constructed in or near Laguna Salada, utilizing the water from the pipeline/canal. This power plant would have the same capacity as the one located on the southeast shore, but could be designed with the potential for expansion for both power generation and evaporation purposes. An additional area within or near Laguna Salada, about 10,000 to 15,000 acres in area, would be set aside to accommodate salt disposal (6) for the entire system.



SOURCE: Dangemond & Associates, Inc.

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Potential Location of Joint USA/Mexico Solar Power Generation/Pumped Storage Laguna Salada Salt Disposal

FIGURE **4-13**

4.4 Removal of Salts from Inflow to the Sea

Several proposals involved the idea of removing salts from the inflow to the Salton Sea. These suggestions included moving the Yuma desalination plant or building a new facility closer to the Sea, using poplar trees as biological filters, removing salts from the New River in Mexico, and special pretreatment reservoirs (Table 4-1). These proposals have not been described in detail.

4.5 Water Imports

Many of the management alternatives discussed above, especially pump-out alternatives, call for the removal of Salton Sea water, which will lower the lake's elevation. The only way to stabilize surface elevation would be to add an equal amount of water to the lake to replace that which is removed. This would also help to decrease the Sea's salinity if the replacement water has low salinity. Currently, the only identified source of freshwater is the Colorado River. Historically, excess water (about 100,000 to 150,000 acre-feet) has been available in approximately 3 of every 10 years (IID and CVWD pers. comm.).

Water removed from the Salton Sea could be replaced by Colorado River water. A contract with the USDOI would be required to deliver extra water to the Salton Sea in years where excess water exists. The water could be delivered through existing canals or an expanded canal system at very little extra cost. Because the Salton Sea Authority has determined that an entitlement for consistent increased water flows from the Colorado River is not possible, this solution would be in the form of surpluses of river water when available. The periodic availability of Colorado River water may not solve the problem of fluctuating water levels but would help to manage it.

Other proposed options for the replacement water include water from the Gulf of California or non-river water from Calexico. Existing canal systems could be used to transport the water from the New River, but a pipeline canal system, as described above, would be required to transport water from the Gulf of California. Use of water surpluses, at this point, is the only option for replenishing water to the lake. However, because of the uncertainties involved with this option, it can be regarded only as a supplemental means to help manage the lake's elevation, not as a means for managing salinity.

4.6 Other Proposed Options

This group of alternatives are those proposed to the Salton Sea Authority TAC that do not directly deal with salinity or surface elevation management. These proposals are listed in Table 4-1 and include metal ion extraction, a canal/conveyor screen system to remove debris, air diffusion, and ultraviolet (UV) ozone systems to improve the water quality, ground water selenium management, water conservation programs, reuse of agricultural drainage water, a foraminifera study to evaluate the effects of pollution on these organisms, partitioning off sections of the Sea for potential use studies, and disposal of salts into the geothermal aquifer with injection wells.

5.0 ALTERNATIVES EVALUATION AND SCREENING

The objective of the alternatives screening is to determine which alternatives have the ability to manage the salinity and elevation of the Salton Sea within the targeted salinity and elevation ranges, have O&M costs less than $10,000,000 per year, and consist of proven technologies. This screening is not intended to provide a complete environmental analysis of potential alternatives but rather to narrow the list of potential alternatives so that more detailed analyses can be performed in subsequent environmental reviews. Evaluation of a "No Project" alternative has not been conducted except for projections of salinity and surface elevation under existing conditions by IID's Pump-out Model.

5.1 Diked Impoundments

The time to reach target salinity and elevation depends on the size of the impoundment chosen. CVWD has developed a computer model to project the changes in salinity of different size impoundments over time. Diked impoundments of 40, 50, 127, and 190 square miles were evaluated using CVWD's model. Of course, the various options for impoundment size and configurations are infinite; however, these sizes reflect the range of likely alternatives and can be used to gauge other impoundment options.

Model assumptions were made for the following parameters in each option, as follows:

Salinity of the Salton Sea	= 50.000 ppt	(S)
Salinity of the diked impoundment	= 50.000 ppt	(ES)
Salinity of drain water	= 2.894 ppt	(INS)

Rainfall rate directly on the surface of the Sea	= X acre-feet/year	(RAIN)
Rainfall rate directly on the surface of the diked impoundment	= X acre-feet/year	(ERAIN)
Inflow from rivers and drains + subsurface and intermittent washes to the Sea	= X acre-feet/year	(I)
Inflow from rivers and drains + subsurface and intermittent washes to evaporation basin (acre-feet)	= X acre feet/year	(EI)
Starting elevation of the Sea	= -272 feet below Sea level	(E)
Starting elevation of the evaporation basin	= -272 feet below Sea level	(EE)
Number of cycles to run the model	= 600 months/12	(YR)
Number of feet evaporated from the Sea surface/month	= 5.9 feet/12	(EVAPK)

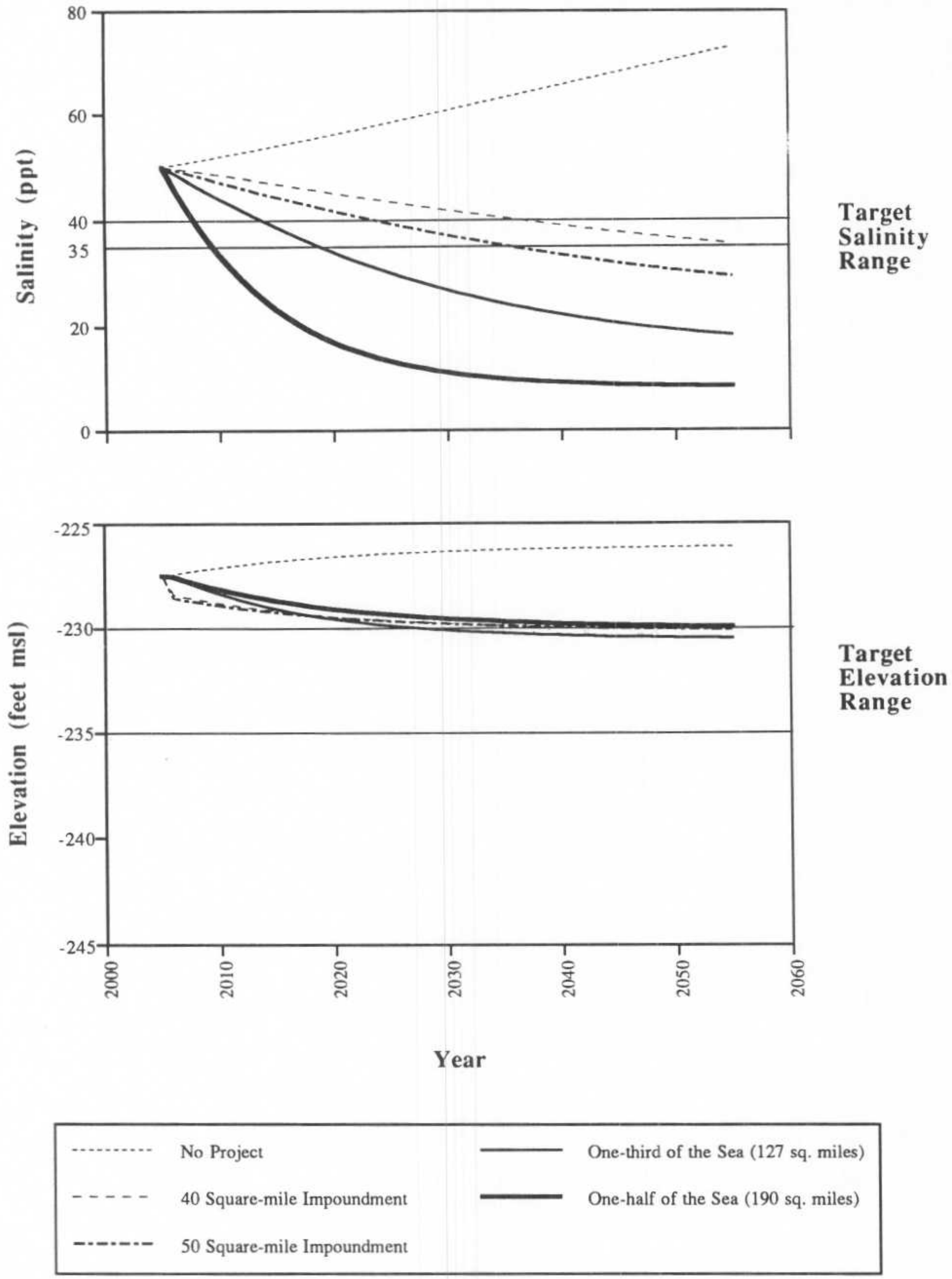
Note: X is variable depending on the alternative used.
Total rainfall on diked impoundment (ERAIN) is equal to 46,478 acre-feet/year.
Total inflow into the Sea (I) is equal to 1,322,000 acre-feet/year.
Total area of the Sea is equal to 382 square miles.
Total volume of the Sea when Sea elevation is equal to -227 msl is 7,356,440 acre-feet

The results of the projections will change by using different assumptions (such as if regional water conservation programs are implemented). The model also does not take variability of factors such as inflow into account.

5.1.1 Time to Reach Target Salinity

The target salinity for the evaluation of alternatives was established as a range from 35 to 40 ppt. The CVWD model predicts that all four of the impoundment sizes can achieve the desired target salinity. The changes in salinity over time for the four impoundment sizes are briefly described here and presented graphically in Figure 5-1. The assumptions and output of the CVWD computer model are provided in Appendix C.

Using a 40-square-mile diked impoundment, the salinity of the Salton Sea would reach 40 ppt in 31 years and 35 ppt in 51 years. After the 56th year, salinity would drop below 35 ppt, and some means of regulation would be required to maintain salinity within the target range.



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Projected Changes in Salton Sea Salinity and Surface Elevation for Various Diked Impoundment Alternatives

FIGURE **5-1**

Using a 50-square-mile diked impoundment, the salinity of the Salton Sea would reach 40 ppt in 18 years and 35 ppt in 30 years. After the 30th year, salinity would drop below 35 ppt, and some means of regulation would be required to maintain salinity within the target range.

Using a 127-square-mile diked impoundment (one-third of the Sea), salinity would reach 40 ppt in 9 years and 35 ppt in 14 years. After the 15th year, salinity would drop below 35 ppt, and some means of regulation would be required to maintain salinity within the target range.

Using a 190-square-mile diked impoundment (one half of the Sea), salinity would reach 40 ppt in 3 years and 35 ppt in 5 years. After the 5th year, salinity would drop below 35 ppt, and some means of regulation would be required to maintain salinity within the target range.

5.1.2 Elevational Changes

The target surface elevation for the Salton Sea was established as a range between -230 and -235 msl. The evaluation of the alternatives assumes the current elevation of the Salton Sea is -227 feet msl. Of the four impoundment sizes evaluated with the CVWD model, three of them achieve surface elevations within the target range within the 50 years the model projects. The results of the model projects are described below, shown graphically in Figure 5-1, and presented in Appendix C.

The elevation of the Salton Sea would decrease from -227 to -230 feet msl in about 35 years using a 40-square-mile diked impoundment. The elevation would stabilize at -230 feet msl until at least the 50th year.

The elevation of the Sea would decrease from -227 to -230 feet msl in about 34 years using a 50-square-mile diked impoundment. The elevation would remain at -230 feet msl until at least the 50th year.

The elevation of the Sea would decrease from -227 to -230 feet msl in about 22 years using a 127-square-mile diked impoundment. The elevation would remain at -230 feet msl until at least the 50th year.

The elevation of the Sea would decrease from -227 to -229 feet msl in about 13 years and remain at this level for the remainder of the 50 years using the 190-square-mile diked impoundment. This is 1 foot above the upper boundary of the target elevation range.

5.1.3 Operation and Maintenance Costs

At this time, O&M costs for many of the diked impoundment alternatives are not available. The most recent O&M costs were estimated at $4,000,000 per year for the 50-square-mile diked impoundment by CVWD in 1994 (CVWD unpubl. data). The only other O&M costs available for diked impoundment alternatives date back to 1974. USDOI and RAC (1974) estimated the O&M costs for a 40-square-mile diked impoundment to be about half that of a 50-square-mile diked impoundment ($416,000 per year for a 50-square-mile impoundment and $251,000 per year for a 40-square-mile impoundment). If this relationship holds true, annual O&M costs for a 40-square-mile impoundment are estimated at $2,000,000. No O&M costs were available for either 127- or 190-square-mile impoundments or the parallel dikes or phased zoning concept. It is unlikely, however, that O&M costs for these alternatives would exceed the $10,000,000 per year target cost.

5.1.4 Other Considerations

While it is not possible to evaluate the potential environmental impacts of the various management alternatives, it is appropriate to briefly discuss a few salient issues concerning the viability of the diked impoundment alternatives. This is not meant to be an all-inclusive discussion of issues.

Salt Disposal

All of the alternatives discussed above would eventually require some means for salt disposal. To date, there is no known viable market or location in which the precipitated salts could be used, stored, or sold; although the potential for marketing the salt requires further investigation. Obviously, the larger the impoundment, the longer the period of time before salt removal is required.

Dredging and Pollution Associated with Channel

The 40- and 50-square-mile impoundments and the two-impoundment configurations will result in the creation of a fresher water channel between the shoreward dike and the Salton Sea shore, where the New and Alamo rivers discharge to the sea. As silt buildup from the two rivers is likely to be high, it will be necessary to dredge the channel on a regular basis. Disposal of dredge spoil will be required. Another potential problem resulting from the formation of a fresher water channel is the possible pollution problems caused by the rivers near the wildlife refuges located along the southern and southeastern shores of the Salton Sea. Sedimentation from the Alamo River within the first zone of the phased zoning concept would likely cause similar problems. In addition, construction of diked impoundments could suspend sediments and associated contaminants in the water column of the Salton Sea, resulting in potentially greater exposure to biological receptors.

Salt and Toxics Accumulation

Along with salts, all other substances present in Salton Sea's water (such as selenium) will be concentrated in the impoundment. Other potential contaminants may pose a potential risk to wildlife that visit the impoundment. As salinities rise within the impoundment, invertebrate species will likely become dominant. Of particular concern would be the potential exposure of invertebrate-eating birds, that may find the impoundment especially attractive due to its increased invertebrate populations, to toxic substances within the impoundment. An additional concern is the potential for precipitated salts and other solids from the impoundments to be transported by winds.

Decrease in Salinity Below the Target Range

Once the target salinity has been reached, all of the alternatives discussed above would require regulation of the salinity and elevation to prevent them from falling outside of the target management ranges. To keep the elevation of the sea from rising, the amount of inflow to the sea in excess of the amount of the evaporation from the sea would have to be moved into the diked impoundment. However, this would eventually cause the salinity to fall below the desired target range of 40 to 35 ppt. One option to prevent this situation from occurring is to regulate salinity by pumping concentrated brine from the diked impoundment to the sea as needed. Another option is to construct an inlet structure on the dike near the freshwater sources (New or Alamo rivers) that could be opened to allow freshwater into the impoundment, as necessary, to prevent the salinity of the Sea from dropping below the target levels (USDOI & RAC 1974; CVWD pers. comm., 1995).

Impacts to Sensitive Resources

Construction of diked impoundments have the potential to adversely affect sensitive biological resources such as wetlands and endangered species. In addition, some of the diked impoundment configurations are located, in part, on National Wildlife Refuge land. Construction of diked impoundments will likely require consultation and mitigation with federal resource and regulatory agencies.

5.2 PUMP-OUT

The decrease in elevation and the time to reach target salinity under a pump-out alternative depends on the volume and salinity of water removed from the lake. To estimate changes in salinity and surface elevation under a pump-out alternative, a Pump-out Model was developed by IID. The assumptions and output of the model for the different pump-out options evaluated are presented in Appendix D. A number of alternatives have been proposed that involve pumping Salton Sea water to various types of filtration units. Very little information exists for these alternatives and, therefore, it is unclear whether these alternatives can satisfy the screening criteria established for this project.

Assumptions for the following parameters in each option were made as follows:

Inflow to the Sea from rivers and drains	= 1,262,000 acre-feet/year	(Wi)
Salinity of inflow from rivers and drains	= 4.0 tons/acre-foot/year	(Ci)
Inflow to the Sea from ground water	= 50,000 acre-feet/year	(Wg)
Salinity of ground-water inflow	= 2.7 tons/acre-foot/year	(Cg)
Inflow to the sea from intermittent washes	= 10,000 acre-feet/year	(Ww)
Salinity of inflow from washes	= 1.4 ppt tons/acre-foot/year	(Cw)
Water pumped from the Sea	= X acre-feet/year	(Wp)
Evaporation rate from the surface of the Sea	= 5.9 feet/year	(Ev)
Salinity of evaporation from the Sea	= 0.0 ppt	(Ce)
Rainfall rate directly on the surface of the Sea	= 0.19 feet/year	(Rn)
Salinity of rainfall	= 0.0 tons per acre-foot/year	(Cr)
Number of years water is pumped from the Sea	= 50 years	(num)

Note: X is variable depending on the alternative used.
Total rainfall on basin is equal to 46,478 acre-feet/year.
Total inflow into the sea is equal to 1,322,000 acre-feet/year.
Salinity of inflow into the sea is equivalent to 3.935 tons/acre-foot (2,894 ppm).
Total volume of the sea when sea elevation is equal to -227 msl is 7,224,296 acre-feet.
A starting salinity of 50 ppt has been assumed for these model runs.

The results of the model will change by using different assumptions than those presented above. In addition, the model does not take variability of factors such as inflow into account.

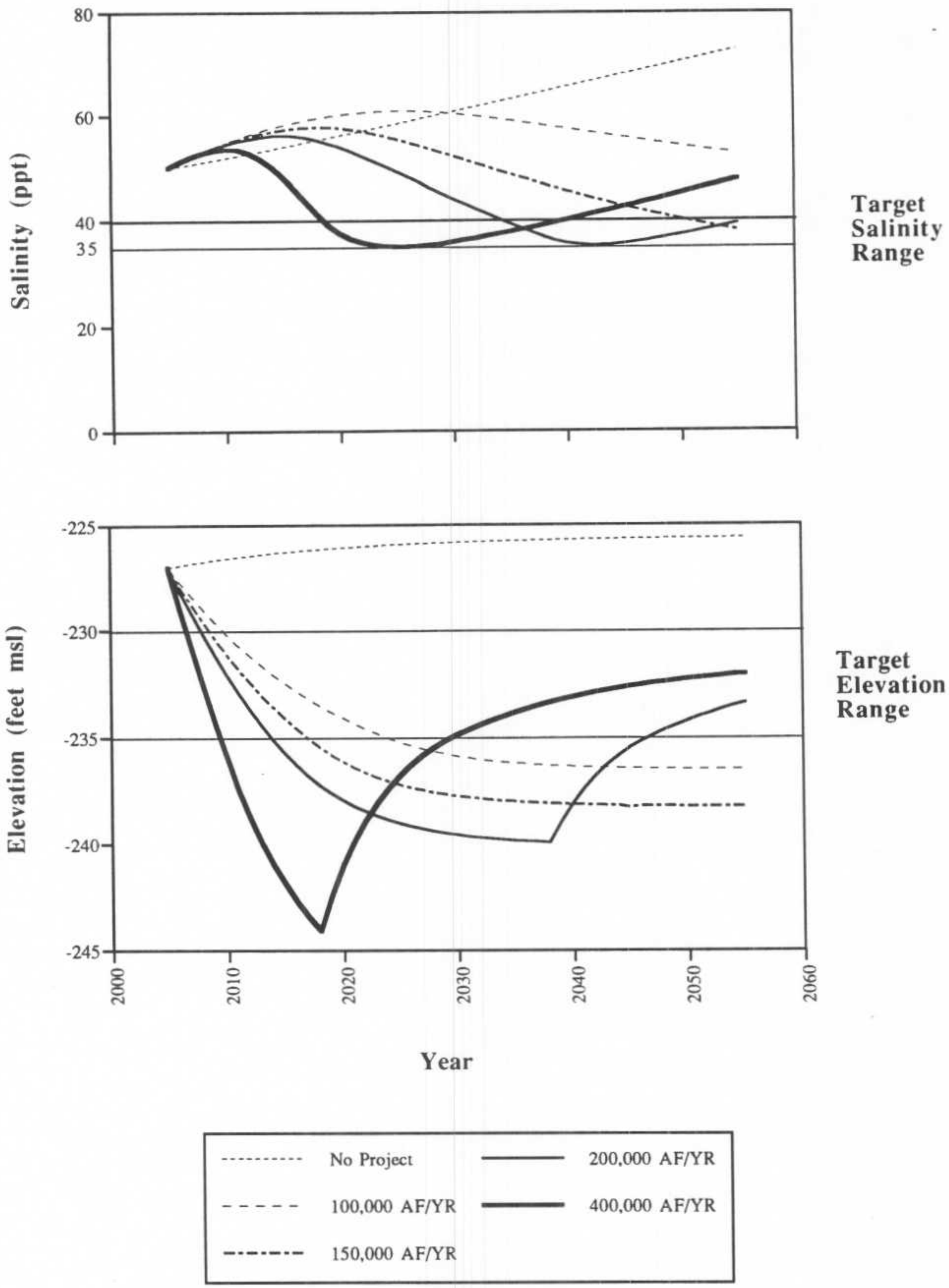
5.2.1 Time to Reach Target Salinity

The IID model results for four pump-out options (100,000, 150,000, 200,000, and 400,000 acre-feet per year) are summarized here and shown graphically in Figure 5-2. The IID model runs for a maximum of 50 years, and three of these four pump-out options reach the target salinity within this 50-year limit. The time to reach target salinity could not be determined for alternatives that involve pump-out to filtration or treatment units.

Using the above assumptions, it was projected that a pump-out rate of 100,000 acre-feet per year would not reach the target salinity in the 50 years that the model was run. Over the course of 50 years, the final projected salinity was actually higher than the initial salinity (53 ppt vs. 50 ppt).

When 150,000 acre-feet of water is removed annually, the Salton Sea's salinity drops from 50 ppt to 40 ppt in 45 years, but does not reach 35 ppt within the 50 years that the model was run.

When 200,000 acre-feet of water is removed annually for 33 years, the Salton Sea's salinity drops from 50 ppt to 40 ppt in 29 years and to 35 ppt in 36 years. The salinity remains around 35 ppt for about 5 years and then begins to increase, at which time pumping could again be initiated. If 200,000 acre-feet of water is removed annually for more than 33 years, salinity would drop below 35 ppt.



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Projected Changes in Salton Sea Salinity and Surface Elevation for Various Pump-out Alternatives

FIGURE 5-2

When 400,000 acre-feet of water is removed annually for 13 years, the salinity drops from 50 ppt to 40 ppt in 14 years, and to 35 ppt in 18 years. The salinity remains around 35 ppt for about 6 years and then begins to increase, at which time pumping could again be initiated. If 400,000 acre-feet of water is removed annually for more than 18 years, salinity would drop below 35 ppt.

5.2.2 Elevational Changes

None of the four pump-out rates evaluated with the IID model stayed within the target elevation range of -230 to -235 feet msl; however, no return of water to the Sea was modeled. These changes in surface elevation under the four pump-out rates are described below and shown graphically in Figure 5-2. Insufficient information was available to determine the ability of alternatives involving pump-out to filtration or treatment units to manage surface elevation of the Sea.

Using a pump-out rate of 100,000 acre-feet per year, the elevation of the Sea would decrease from -227 to -230 feet msl in about 4 years. The elevation would continue to decrease reaching -237 feet msl by the 50th year. This exceeds the minimum boundary of the target elevation range by 2 feet.

The elevation of the Sea would decrease from -227 to -230 feet msl in about 3 years using a pump-out rate of 150,000 acre-feet per year. The elevation would continue to decrease reaching -238 feet msl on the 50th year. This exceeds the minimum boundary of the target elevation range by 3 feet.

The elevation of the Sea would decrease from -227 to -230 feet msl in about 3 years using a pump-out rate of 200,000 acre-feet per year. The elevation of the lake falls from –227 to –240 feet msl during the 33-year pump-out period, at which time pumping would cease so as not to exceed the minimum boundary of the target salinity range. This exceeds the minimum boundary of the target elevation range by 5 feet.

The elevation of the Sea would decrease from -227 to -230 feet msl in about 2 years using a pump-out rate of 400,000 acre-feet per year. The elevation of the lake falls from –227 to –244 feet msl during the 13 year pump-out period, at which time pumping would cease so as not to exceed the minimum boundary of the target salinity range. This exceeds the minimum boundary of the target elevation range by 9 feet.

5.2.3 Operation and Maintenance Costs

As with the diked impoundment alternatives, recent O&M cost estimates for most of the pump-out alternatives were not available. The only alternatives for which a recent O&M cost estimate was available was for the canal/pipeline alternatives. The O&M cost for the canal/pipeline to Laguna Salada or the Gulf of California ranged from $12,600,000 to $33,000,000 per year (IID 1994). The least expensive alternative was a one-way canal/pipeline that carried 150,000 acre-feet per year to Laguna Salada and replenished lost water with Colorado River water for $12,600,000 per year. Based on these estimates, any alternative that included a pipeline/canal to Laguna Salada or the Gulf of California would exceed the $10,000,000 O&M cost target. No O&M costs were available for the canal/pipeline to the Pacific Ocean or any of the other pump-out alternatives.

5.2.4 Other Considerations

Salt Disposal

The alternatives involving evaporation ponds eventually would require some means for salt disposal. To date, there is no viable market or location in which the precipitated salts could be used, stored, or sold. An alternative that involves a dry lake bed, such as Palen Dry Lake or Laguna Salada, may have sufficient storage capacity that disposal would not be required for a very long time, if ever.

Alternatives that involve a canal or pipeline and release the water into the Gulf of California or the Pacific Ocean do not have the problem of salt disposal. However, the discharge of brine water into the gulf or the ocean will potentially affect flora and fauna near the discharge point. Furthermore, the discharge of brine water into upland areas, waters of the U.S., or waters of Mexico are regulated either by the State Water Resources Control Board and Regional Water Quality Control Board, or, presumably, similar authorities in Mexico, and appropriate discharge permits would have to be obtained.

Lake Elevation

Any solution that removes Salton Sea water without replacement will result in a drop in elevation. Therefore, meeting elevation management targets may not be feasible with a pump-out alternative, unless water is returned to the Salton Sea.

Land Acquisition

One major problem associated with evaporation ponds is the amount of land necessary to site the ponds. It would be necessary to acquire between 22 and 70 square miles of land near the lake for many of the alternatives that utilize evaporation ponds. The area being evaluated for onshore evaporation ponds is currently occupied by the Wister Unit of the Imperial Wildlife Area, and therefore some type of land swap or replacement of the lost wildlife habitat would be required if this area is used.

Operating Costs

All of these alternatives require that Salton Sea water be pumped to another area. Electricity necessary for the pumping would have to be purchased. It may be possible to offset the cost with the money generated from some of the alternatives such as solar ponds or aquaculture farms.

Enhanced Evaporation

The use of enhanced evaporation will require more pumping energy than merely pumping water out of the basin and, hence, will be more costly. However, if conventional evaporation ponds are used, 90 percent more land would be necessary to evaporate the same amount of water.

Pipeline to Laguna Salada/Gulf of California

This pump-out alternative has potential problems not shared with the other pump-out alternatives. The first is acquiring the right-of-way requirements and the costs of necessary structures for road and drainage crossings. Second, the length of the pipeline routes increase the potential for significant construction impacts (e.g., impacts to biological or cultural resources). Finally, Mexican government approval for the project would be required, and the associated time and cost necessary to receive that approval is very uncertain.

5.3 Combination of Alternatives

The combined alternatives use both a diked impoundment within the Salton Sea and a pump-out option to reach the target salinity and elevation. There is very little information available for these alternatives regarding their ability to meet the established management targets.

5.3.1 Time to Reach Target Salinity

Dangermond and Associates, Inc. (1994) predicted that the diked impoundment/solar pond and power generation/constructed wetlands, and the freshwater shoreline/pumped storage alternatives would decrease the salinity from 45 ppt to 35 ppt in 10 years, and the joint USA/Mexico solar pond and power generation/pumped storage Laguna Salada salt disposal alternative would decrease the salinity from 45 ppt to 35 ppt in 10 years. Details on their predictions were not provided; however, based on the projections for diked impoundment and pump-out alternatives described above, these estimates seem very optimistic.

5.3.2 Elevational Changes

In general, the surface elevation of the Sea is not expected to change substantially for any of the combined alternatives. All of these alternatives include a diked impoundment within the Salton Sea to specifically control for elevational changes associated with water removal; however, no specifics on elevational changes were available for any of these alternatives. It is assumed that these alternatives would behave similarly to the diked impoundment alternatives described above with respect to elevational changes.

5.3.3 Operation and Maintenance Costs

The O&M costs for a 30-square-mile impoundment combined with pump-out to Palen Dry Lake was estimated in 1974 at $2,500,000 for the first 14 years and then $104,000 per year for pumping 65,000 acre-feet per year and $4,700,000 per year for the first 8 years and then $104,000 per year for pumping 135,000 acre-feet per year. No other O&M costs were provided for any of the other combined alternatives. However, any alternative that includes a pipeline/canal to Laguna Salada or the Gulf of California would most likely exceed the $10,000,000 O&M cost target, as discussed in Section 5.2.3. One advantage of combined alternatives is that the volume of salty water to be "pumped out" can be reduced by partial evaporation, which can reduce costs.

5.3.4 Other Considerations

All of the additional considerations discussed previously, including lake elevation, land acquisition, operating costs, enhanced evaporation, and a pipeline into Mexico, are applicable to this alternative as well. In addition, the locations of several of the components of these alternatives would affect the habitats of federally and state-listed endangered species (e.g., Yuma Clapper rail and desert pupfish).

5.4 Removal of Salts Before Water Enters the Sea

No information is available to determine the ability of these alternatives to meet the established management targets. It is doubtful that any of the three alternatives, (move the Yuma desalination plant to the Sea, use poplar trees as filters, remaining salts from the New River in Mexico, or use special pretreatment reservoirs for filtering out salts) could meet salinity targets. Because no water is removed from the Sea, surface elevation could not be managed by these alternatives either.

5.5 Water Imports

Importing freshwater to the Salton Sea has been proposed as an alternative for managing salinity; however, the amount of water necessary to lower salinity into the target range is not known. O&M costs would include the cost of purchasing the water, estimated at between $5 and $10/acre-foot in 1971 (Aerospace Corporation 1971). The water could be delivered through existing canal systems, at little to no extra cost. Surplus Colorado River could be purchased when available to supplement other management strategies, but because the availability of the water is uncertain, it is unlikely that sufficient volumes would be available to reduce salinity to within the target range.

Several alternatives (e.g., pump-out) have suggested Colorado River or Gulf of California water could be used to compensate for the water removed from the Sea, as a means to manage surface elevation. Sufficient Colorado River water is probably not available on a regular basis to effectively manage elevation under a pump-out alternative. Gulf of California water would have to be imported with a canal/pipeline system as described in Section 4.2. The O&M costs of a canal/pipeline system has been shown to exceed the established $10,000,000 annual threshold.

5.6 Other Proposed Options

These alternatives do not meet the purpose and need of the project as it is currently understood (i.e., managing salinity and surface elevation at levels that maximize economic, environmental, social, and cultural attributes of the region). Unless the purpose and need for the project is redefined, these alternatives should not be considered further.

6.0 CONCLUSIONS

A wide variety of alternatives have been proposed over the years to manage the salinity and surface elevation of the Salton Sea. The various management alternatives can be grouped into six general categories: 1) diked impoundments within the Salton Sea; 2) pump-out of Salton Sea water to another area (e.g., dry lake beds, onshore evaporation ponds, the Gulf of California, the Pacific Ocean, or onshore treatment/filtration units); 3) a combination of alternatives consisting of diked impoundments, onshore evaporation ponds, and a pipeline/canal system to transport concentrated brine to Laguna Salada/Gulf of California, among others; 4) removal of salts from inflowing water before it enters the Sea (e.g., desalination plant, biological filters, or special pre-treatment reservoirs); 5) use of imported water to dilute the Sea; and 6) other proposed alternatives that do not specifically address the problem of stabilizing salinity or surface elevation. These management alternatives are listed in Table 4-1, and are described in Section 4 and in Appendix C.

6.1 Alternatives Screening

The primary objectives of the management project, as it is currently understood, are to stabilize the salinity and elevation of the Salton Sea at levels that maximize the economic, environmental, social, and cultural attributes of the region. To focus future studies and environmental analyses on those alternatives that are most likely to meet the objectives of the project, the Salton Sea Authority set management targets for salinity, surface elevation, and O&M costs (refer to Section 3) that were used to screen potential alternatives, as described in Section 5. In addition, the Salton Sea Authority will only make use of currently available, proven technologies to achieve project objectives. Two computer models were used to predict changes in salinity and surface elevation. These models, however, may differ with respect to certain assumptions and their sensitivity to these assumptions has not been evaluated. Therefore, caution should be exercised when interpreting model results.

Alternatives that did not meet the established screening criteria include some pump-out options, which either do not manage surface elevation (unless replacement water is returned to the Sea), rely on unproven technologies (e.g., treatment/filtration units) and/or are relatively expensive to operate and maintain. In addition, the majority of pump-out options involve siting project components in Mexico, which would result in a loss of control over the project and greater uncertainty in the environmental process for the Salton Sea Authority. Similarly, combinations of alternatives that rely on pump-out or transport of Salton Sea water from the Salton Basin have the same problems as the pump-out alternatives; although the specifics of many of these combinations of alternatives are not available at this time.

Alternatives that propose to remove salts before water enters the Salton Sea also do not appear to meet the established screening criteria. While no specifics are available, it is unlikely that the various proposed alternatives could remove the 4,000,000 tons of salt that enter the Salton Sea each year, except at enormous cost. These alternatives also would not reduce the salinity of the Salton Sea itself. In addition, these alternatives do not manage surface elevation.

Importing water does not appear to be an effective method to manage salinity of the Salton Sea. Sufficient volumes of water from the Colorado River do not appear to be available at a frequency to allow management of the Sea's salinity. Gulf of California water could be used to replenish water removed as part of a pump-out alternative, but pipeline/canal systems to the Gulf of California have been shown to exceed the established O&M cost target.

Numerous other proposals were evaluated for the project that did not meet established management targets. None of these proposals would manage surface elevation, and most would not manage salinity either. Some of the proposals may have merit, however, as basic research topics or for water quality enhancement.

The alternatives that meet the established screening criteria for the project or have not been described in enough detail to complete the screening process are listed in Table 6-1. Diked impoundments appear to have the greatest potential for meeting the project objectives while satisfying the established screening criteria. In general, diked impoundments have the ability to manage both salinity and surface elevation and are relatively inexpensive to operate and maintain. A value engineering evaluation of alternative dike structures (USBR and Salton Sea Authority TAC 1994) concluded that excavation, haul, and dump dike construction is the most flexible, reliable, and cost-effective method. Combinations of alternatives that make use of diked impoundments and certain pump-out alternatives also appear to meet established screening criteria, except O&M costs of these alternatives have not been estimated. Based on the projected O&M costs for pipeline/canal systems, combinations of alternatives that utilize both diked impoundments and pipeline/canal systems are unlikely to meet the established O&M target; however, the O&M costs for many of these systems are uncertain at this time

6.2 ENVIRONMENTAL SCOPING

A number of comments, both public and agency, were received on the draft report circulated for review. These comment letters are provided as Appendix E. Many of these comments related to the lack of detailed environmental analyses quantifying impacts of various management alternatives. It must be emphasized that the purpose of this report was to determine which of the various management alternatives that have been proposed to date have the ability to manage salinity and surface elevation, are affordable, and rely on proven technologies. The conclusions of this report are not intended to identify a least damaging alternative under state and federal environmental regulations.

A brief summary of issues identified during the comment period is provided below.

- More information and justification on how management targets were established was requested. This comment applies to the assumptions used in the two screening models as well.

- Comments suggested that environmental analyses should rely on a complete set of inflow data rather than data collected over the last 5 years. The analyses should also look at variability in inflow (wet and dry cycles).

Table 6-1

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION THAT MEET SCREENING CRITERIA

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[2]	Controls Salinity?[2]	Controls Elevation?[2]	Proven Technology?
I Diked Impoundment									
50 square miles (S end)	1994	CVWD	Equivalent	188.0	4.0	50 ppt to 40 ppt in 18 yrs	Yes	Yes	Yes
	1974	USDOI/RAC	Inflow =	65.0	0.416	42 ppt to 35 ppt in 12 yrs			
	1971	Aerospace Corp	190,000	130.0	?	42 ppt to 38 ppt in 7 yrs			
	1969	USDOI/RAC		110.0	0.173	40 ppt to 35 ppt in 10 yrs			
50 square miles (N end)	1969	USDOI/RAC		183.0	0.023	40 ppt to 35 ppt in 10 yrs			
40 square miles (S end)	1994	USBR	Equivalent	110-154		50 ppt to 40 ppt in 31 yrs	Yes	Yes	Yes
	1988	CVWD	Inflow =	188.0	?	50 ppt to 40 ppt in 31 yrs			
	1974	USDOI/RAC	150,000	58.0	0.251	42 ppt to 35 ppt in 18 yrs			
	1969	USDOI/RAC		?	?	40 ppt to 35 ppt in 19 yrs			
20 & 30 square miles (S end only)	1994	CVWD	Equivalent	?		50 ppt to 40 ppt in 18 yrs	Yes	Yes	Yes
20 square miles (N) & 30 square miles (S)	1969	USDOI/RAC	Inflow = 190,000	168.0	0.025	40 ppt to 35 ppt in 10 yrs			
One third of the Sea (127 sq. miles, N end)	1994	CVWD	?	?	?	50 ppt to 40 ppt in 9 yrs	Yes	Yes	Yes
One half of the Sea (190 sq. miles, N end)	1994	CVWD	?	?	?	50 ppt to 40 ppt in 3 yrs	Yes	Yes	No?
Phased Zoning Concept - 3 diked portions	1994	USBR	?	70.0-90.0	?	1 yr for smaller diked portion	Yes	Yes	Yes
In-Sea evaporation basins (parallel dikes)	?	CVWD	180,000	188.0	?	?	Yes	Yes	Yes
II Pump-out									Yes
Pump-out to filtration/treatment units									
Waste-water disposal units to remove salt	1993	FAE	?	?	?	?	?	?	?
Cogeneration of electrical power/thermal distillation	1992	CPA	60.0	?	?	?	?	?	Yes?
Enzyme-activated cellulose filtering technology	1992	TET	?	?	?	?	?	?	No?
Reverse osmosis filtration slow sand pre-treatment	1992	WRI &	0.087-	?	?	?	?	?	Yes
	1991	Cluff	0.121						
Enhanced solar still desalination/replenishment from Colorado River	1991	Free	?	?	?	?	?	?	Yes?
	1990	EET							
	1977	Bechtel Corp.							
Pulsed plasma discharge wasterwater treatement	1990	AURIX, Inc.	?	?	?	?	?	?	No?
Filtration of Sea water with processing modules	?	Zitelli Trust	?	?	?	?	No?	?	No?
Queen resort hydropower and filtration system	?	Queen	?	?	?	?	?	?	No?
Canal/pipeline to Laguna Salada									
Pumpout/replenish from Gulf of California	1991	USBR	415,000	875.0	?	?	Yes	Yes	Yes
Pipeline to Laguna Salada									
Pumpout/replenish from Gulf of California	1991	USBR	415,000	1,496.0	?	?	Yes	Yes	Yes
Canal/pipeline to Gulf of California									
Pumpout storage/replenish from Gulf of California	1994	Dangermond	?	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
Two-way pumping to Gulf of California	1969	USDOI/RAC	250,000	?	?	?	Yes	Yes	Yes

Table 6-1 (Continued)

PROPOSED ALTERNATIVES TO MANAGE SALTON SEA SALINITY AND SURFACE ELEVATION THAT MEET SCREENING CRITERIA

Management Alternatives	Year	Proposed By[1]	Water Removal (acre-feet/yr)	Const. Costs (Mill. $)	Operating Cost (Mill. $/yr)	Estimated Time to Reach Target Salinity[2]	Controls Salinity?[2]	Controls Elevation?[2]	Proven Technology?
Pipeline to the Pacific Ocean (Camp Pendleton area)	1995	Munro	?	?	?	?	Yes?	Yes?	Yes
Navigable waterway/locks system	1994 1988 ?	Dangermond Meyer Res. CVWD	? ? ?	? 350.0 ?	? ? ?	Stabilize at 35 ppt	Yes	Yes	Yes
III Combination									
Diked impoundment/solar pond and power generation/constructed wetlands	1994	Dangermond	250,000	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
Freshwater shoreline/pumped storage	1994	Dangermond	250,000	?	?	45 ppt to 35 ppt in 10 yrs	Yes	Yes	Yes
Joint USA/Mexico solar power generation/pumped storage Laguna Salada salt disposal	1994	Dangermond	210,000	?	?	45 ppt to 35 ppt in 15 yrs	Yes	Yes	Yes
Diked impoundment/pumping out/replenish from Imperial East Mesa Well Field 30 square miles/pump Palen Lake $95 ft^3/s$ 30 square miles/pump Palen Lake $195 ft^3/s$	1974 1974	USDOI/RAC USDOI/RAC	65,000 135,000	105.0 141.0	0.104+2.5[3] 0.104+4.7[4]	42 ppt to 35 ppt in 14 yrs 42 ppt to 35 ppt in 8 yrs	Yes?	Yes?	Yes
IV Water Imports									
Replenish with Colorado River	1988 1971	Meyer Res. Aerospace Corp	? 100,000 350,000	? $10/20/58/ acre-foot	? ?	- -	- -	Yes? Yes?	Yes Yes
Pump non-river water at Calexico and combine with Salton Sea water	1995	Graves	?	?	?	?	?	?	Yes

\- Not applicable
? Data not available
Yes? Proposal indicates the ability to control salinity or elevation, however, analysis indicates that this is uncertain.
[1]Refer to Table 4-1 for sources of information.
[2]This information is discussed in Section 5.0.

- Contaminants present in sediments and water need to be completely characterized to determine appropriate methods of construction, resource protection, and sediment/soil disposal. Also need to evaluate the potential for toxic substances to be resuspended during construction, and transported under pump-out alternatives.

- Several comments were received noting the potential for evaporation basins and diked impoundments to concentrate selenium and other toxics to levels dangerous to fish and wildlife. An evaluation of how the composition of salts in an impoundment or evaporation basin would vary over time should be conducted. Alternatives that involve fish production for food would need to look at the potential for health impacts to humans. Also, the analysis must look at the potential for wind-induced transport of salts to adversely affect human health, agriculture, recreation, and natural resources.

- Will the composition of salts in the evaporation basin or impoundment influence the salt disposal options? Will the evaporates and precipitates be considered hazardous waste? How will evaporative basins (ponds, diked impoundments, or dry lake beds) be reclaimed in the future?

- Several comments noted that some management alternatives were located on or adjacent to National Wildlife Refuge land or state waterfowl habitat. Impacts and mitigation measures for direct take of these lands, and indirect and cumulative impacts resulting from altered hydrology, contaminant loads, or the presence of evaporation basins need to be assessed. Also, wetland habitat losses, and impacts to endangered species and migratory waterfowl need to be fully assessed and mitigated. Permits for these impacts from the state and federal governments will be required.

- Environmental analyses of water quality must evaluate (at a minimum) salinity, selenium, pollutants (pesticides, metals, boron, nutrients, bacteria), toxicity, general anions and cations, and all beneficial uses. Potential impacts to beneficial uses should be evaluated in light of existing impairment of beneficial uses. Potential impacts to ground-water beneficial uses should be included.

- Descriptions of management alternatives, including implementation, require more detail.

- How would sediment from the New and Alamo rivers be removed and disposed?

- Detailed environmental analyses must be conducted on potential pipeline impacts, water diversions from the Colorado River (water surpluses), and pump-out energy requirements and availability.

- Further description was requested on the nature of any international agreements between the U.S. and Mexico required to implement an alternative involving facilities in Mexico. Comments also related to the need to quantify potential impacts of any project on the environment in Mexico and to determine financing strategies for international alternatives.

- The purpose and need of the project needs to be established. The project's purpose and need should relate to natural resources to the same extent as human uses.

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APPENDIX A

ECONOMIC PROFILE STUDY