Haven or Hazard:
The Ecology and Future of the Salton Sea

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A report of the

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About the Pacific Institute

The **Pacific Institute for Studies in Development, Environment, and Security** is an independent, non-profit center created in 1987 to do research and policy analysis in the areas of environment, sustainable development, and international security. Underlying all of the Institute's work is the recognition that the pressing problems of environmental degradation, regional and global poverty, and political tension and conflict are fundamentally interrelated, and that long-term solutions must consider these problems in an interdisciplinary manner. The Institute's mission is to conduct and distribute meaningful and usable research and policy suggestions on the interactions among these issues. The organization seeks to produce quality, impartial research and to make sure it is accessible not only to public and private-sector decision-makers, but also to community groups and the public at large. The ultimate objective of the Pacific Institute's work is to contribute to equitable and sound development, the reversal of environmental degradation, and regional and international peace and security.

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Special thanks to **Dale Pontius**, who worked as a consultant on the project. Mr. Pontius is an attorney and consultant specializing in western water, natural resources, and endangered species law and policy. Most recently, he completed a report on the critical issues in the Colorado River basin for the Western Water Policy Review Advisory Commission. From 1992 to 1995, he was Vice President for Conservation Programs and Southwest Director for American Rivers, a national conservation organization. He served as Executive Assistant to Governor Bruce Babbitt of Arizona from 1978 to 1980, where he was involved in the development and enactment of the Arizona Groundwater Management Act. Mr. Pontius received his law degree from the University of Arizona and his B.A. and M.A. in Political Science from Indiana University.

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The North American Landscape Characterization (NALC) image was obtained from the Earth Resources Observation Systems (EROS) Data Center Distributed Active Archive Center (EDC DAAC), located in Sioux Falls, South Dakota. This Landsat 4 Multispectral Scanner (MSS) Satellite image was acquired on June 30, 1992 (Path 39 Row 37). The NALC MSS data were resampled to 60-meter pixels in a UTM projection.

EDC DAAC' s Home Page provides detailed technical and ordering information about each data set distributed. The URL address is: http://edcwww.cr.usgs.gov/landdaac

Special thanks to Aljean Klaassen for helping to obtain this image.

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Executive Overview

The Salton Sea, the largest inland body of water in the state of California, lies 35 miles north of the U.S.-Mexico border in one of the most arid regions in North America. With a surface elevation approximately 227 feet below that of the ocean, the Salton Sea is a study in contrasts: it is an agricultural drainage repository that provides vital habitat for more than 380 species of birds, a lake twenty-five percent saltier than the ocean yet teeming with fish, a productive ecosystem marred by frequent fish and bird die-offs. These contrasts reflect the variety of agricultural, ecological, and recreational values provided by the Salton Sea and are emblematic of the challenges faced by those attempting to preserve and enhance them. The objective of this study is to assess and offer guidance on the complex challenges confronting the Salton Sea and the current efforts to restore it. From a public interest perspective, we evaluate the federal/state strategy for restoring the Salton Sea and propose an alternative, long-term framework for preserving and enhancing the regional ecosystem.

The Salton Sea can only be understood in the context of its physical attributes and the human activities in its watershed. The development of large-scale irrigation projects in the Imperial and Coachella valleys has changed the face of the Salton basin, transforming a desert into a productive agricultural region. Today, approximately 1.35 million acre-feet[1] (maf) of water enters the Sea annually, more than 75 percent of which is U.S. agricultural drainage. The quantity of this agricultural drainage sustains the Sea, yet the quality of drainage is responsible for many of the Sea's problems. The Salton Sea is a terminal lake - the only outflow for its waters is through evaporation. As water evaporates, salts, selenium, and other contaminants are concentrated in the Sea and its sediments.

Since 1992, hundreds of thousands of birds have died at the Salton Sea. In the first four months of 1998 alone, 17,000 birds at the Sea, representing 70 species, died from a variety of diseases. Deteriorating ecological conditions have generated concern about the continued viability of the Sea as a stopover for migratory birds on the Pacific Flyway. Massive fish die-offs, linked to eutrophic conditions at the Sea, are also a frequent occurrence. The Salton Sea is also becoming increasingly saline, jeopardizing the future existence of fish in the Sea.

For more than thirty years, private entities and state and federal agencies have developed proposals to restore the Salton Sea. Until recently, these proposals have foundered, primarily due to their considerable costs. The profusion of recent fish and wildlife deaths at the Salton Sea has captured the attention of the media and policymakers, spurring a call for action to address the Sea's problems. As a result, more than $20 million in state and federal funds have been allocated over the last several years to study and address the problems of the Salton Sea. A critical distinction between the current Salton Sea restoration effort and prior initiatives is the explicit recognition of the ecological importance of the Sea.

The restoration of the Salton Sea is an extremely difficult endeavor, complicated by competing interests and limited scientific information. Part of the difficulty in restoration lies in determining the cause of current problems at the Sea, as well as how the costs of restoration should

[1] An acre-foot is 325,851 gallons of water, or 1,233 cubic meters, approximately the amount two families of four use annually. By convention, allocations of Colorado River water are measured in acre-feet.

be allocated. Numerous interests, including lakeshore property-owners, the environmental community, large and small farmers in the basin, and the nation as a whole, stand to benefit from some aspect of restoration of the Sea, though these benefits may not always be compatible.

Even the concept of restoration is not straightforward. The Salton Sea is part of a dynamic system that has witnessed the creation and evaporation of many "seas" in its current location. Restoration connotes the return of the Salton Sea to a previous state of ecosystem health and stability. Given the natural tendency of prior incarnations of the Sea to become increasingly saline and eventually evaporate entirely, returning the Sea to some pre-determined, static state and preserving it there requires the selection of a desired vision for the Sea. Such a constructed, static Sea would be continuously at odds with the natural forces of evaporation and would require continual management and monitoring.

The U.S. Bureau of Reclamation and California's Salton Sea Authority are the lead agencies working to identify potential restoration alternatives for the Sea. A proposed restoration plan is expected by January 1, 2000. The long-term goals of the Salton Sea Restoration Project are to preserve the role of the Sea as a designated agricultural sump, enhance recreational and wildlife values, and increase the economic potential of the area. In order to meet these goals, the lead agencies have developed a set of operational objectives for the restoration effort. These operational objectives are to reduce and stabilize the level of the Salton Sea at 232 feet below mean sea level and to reduce the Sea's salinity to 40 parts per thousand. The lead agencies have stated they will address other factors compromising the ecological health of the Sea through a multi-phase program. For the reasons set forth in this analysis, we conclude that this stepwise approach will not achieve the lead agencies' long-term objectives.

For four interrelated reasons, the current efforts to restore the Salton Sea are flawed:

1. The current strategy of the Restoration Project neither reflects nor satisfies the public interest.

The public expectation and paramount justification for federal intervention is the preservation and improvement of ecological conditions at the Salton Sea. Public concern about the ecology of the Sea suggests that restoring the Sea's ecosystem should be the primary measure by which policy alternatives are judged. However, the lead agencies' strategy is conceptually reversed, as there is little evidence that the emphasis of the restoration plan – infrastructure for salinity and elevation stabilization – will produce ecological benefits at the Salton Sea over the short or long term. This approach ignores the expressed public interest and risks spending billions of dollars on an engineering solution, without a basic understanding of whether the proposed infrastructure will improve or exacerbate environmental conditions in the region.

2. Decisions are being driven by arbitrary and unrealistic political timelines, not by scientific evidence.

Political timelines set by the Salton Sea Reclamation Act of 1998 have precluded sufficient scientific research on the ecology of the Sea from meaningfully informing the restoration process. The lead agencies have already narrowed the restoration plan to five proposed alternatives, but the Science Subcommittee's research on the ecology of the Salton Sea and surrounding ecosystems has only recently been initiated. Until an environmental baseline for the Salton Sea has been established, the feasibility and adequacy of the alternatives cannot be addressed.

3. The major problems may not be related to salinity, which is the focus of the current plan.

The short timeline for the Restoration Project has been justified by the perception that the

Salton Sea is facing an ecological "crisis" due to rising salinity and that immediate action is necessary to prevent a catastrophic ecosystem collapse. Ironically, the crisis at the Salton Sea, if there is one, is the massive fish and bird die offs, which most scientists do not believe are directly related to salinity. Therefore, it is unlikely that the crisis will be resolved by controlling salinity – the cornerstone of the restoration plan.

4. The focus on salinity distracts from other anthropogenic factors in the basin that are more directly linked to the ecological problems of the Salton Sea.

The Restoration Project is flawed by its narrow focus. The current ecological problems of the Salton Sea are much greater than an incremental rise in salinity. A more credible approach would be to address the Salton Sea in the context of a complex agricultural-ecological system, where both natural factors such as climate and elevation and anthropogenic factors such as land use impact the Sea.

This report provides an alternative framework for approaching Salton Sea restoration that is based on principles of environmental sustainability and social equity. The Salton Sea is a component of a larger, regional ecosystem and its restoration must be compatible with longer-term and broader efforts for restoring the Colorado River delta and upper Gulf of California ecoregion. The Pacific Institute believes that the principles and recommendations summarized below should guide the selection and implementation of a restoration plan for the Salton Sea.

Principles for Sustainability and Equity

1. The primary goal of any restoration plan must be to provide for a healthy ecological system and protect human health.

The impetus for public support for federal intervention regarding the Salton Sea is the failing health of the ecosystem. Improving the Sea's ecosystem health and aesthetics are a precursor to economic redevelopment at the Sea, including the ability to attract investment and generate recreation-based revenues. According a high priority to restoring the Sea's ecology is compatible with ensuring that the Sea continues to receive agricultural return flows of reasonable quality, as the wildlife habitat at the Sea could not exist without these flows. In addition, there are a number of human health issues related to water quality in and around the Sea that must be addressed for the Restoration Project to be successful. Almost all of the long-term goals listed by the lead agencies are unattainable without a healthy Salton Sea ecosystem.

2. Any restoration plan should be firmly grounded in a scientific understanding of the ecology of the Salton Sea and related ecosystems.

Sustainable restoration of the Salton Sea requires an understanding of the complex factors creating the current crises, as well as the ecological implications of future actions. Although there is a need to begin ameliorating the problems at the Sea, it is essential that a scientific understanding of the region's ecology be incorporated into the restoration process prior to the selection and implementation of any restoration plan. Significant gaps remain in our knowledge of the relationship between the Sea's water quality problems and ecosystem health, as well as our understanding of what realistically can be done to improve the ecology of the Salton Sea.

3. Any restoration plan should address all the water quality factors responsible for the current problems at the Salton Sea.

Increasing salinity is one of many factors responsible for the ecological and economic problems at the Salton Sea. According to many sources, including the Bureau of Reclamation and the Salton Sea Authority, nutrient and contaminant loading are the primary factors responsible for the widespread fish kills common at the Salton Sea. The lead agencies have acknowledged the need to address nutrient and selenium loading, although not as a first-phase priority.

4. Parties responsible for the current problems facing the Salton Sea and beneficiaries of its restoration should bear an equitable share of the costs.

Many of the current ecological problems at the Salton Sea can be attributed to human action, particularly the intensive use of water and fertilizers in the Imperial Valley. A fundamental premise of any restoration plan must be that the beneficiaries of the Sea's designation as a repository for agricultural waste, as well as those property owners who stand to gain from restoring the Sea, should contribute to the costs of restoration.

5. Any restoration plan must be compatible with region-wide water conservation and voluntary reallocation programs.

Valid engineering and restoration recommendations require reasonably accurate estimates of future inflows and a comprehensive water budget for the Salton Sea. Current inflows to the Salton Sea average approximately 1.35 million acre-feet per year, but for several reasons this figure will likely decrease significantly in the future. To date, the lead agencies have not appropriately integrated expectations of more efficient agricultural water use into the Restoration Project. The lead agencies' projected rates of annual inflows and concomitant lake levels could undermine potential water conservation efforts in the region.

6. Any restoration plan for the Salton Sea must be compatible with protection and restoration of the Colorado River delta, upper Gulf of California, and other ecosystems in the region.

The Salton Sea should be addressed from a regional perspective that includes analyzing potential impacts on interrelated ecosystems. Its restoration should not be accomplished by compromising the ecological and/or human health of other areas, such as the Colorado delta and upper Gulf. Externalizing the problems of the Sea by pumping brine and pollutants out of the basin would inappropriately remove the burden from those responsible for the current problems. A benefit of taking a regional approach is added flexibility. Within this broader context, it is possible to preserve the region's integrity as a stopover on the Pacific Flyway, even if the Salton Sea were to continue to increase in salinity.

7. The Restoration Project must be transparent, inclusive, and fully integrated with other actions impacting the Salton Sea.

The scope and potential magnitude of the Salton Sea Restoration Project require an inclusive process that actively seeks input from a broad array of interests. A comparable initiative, the CALFED Bay-Delta Program, has structured a consensus-based approach with a formal role for representatives from federal, state, and local agencies, as well as the environmental community and other stakeholders. The Salton Sea restoration effort, in comparison, is being run by only two agencies with limited public agency participation and no formal role for public interest groups. An open, inclusive process would provide legitimacy to a restoration project that could cost federal taxpayers more than a billion dollars.

Recommendations

Expand the Restoration Project's objectives to give a higher priority to the restoration and preservation of ecosystems at and around the Salton Sea.

At present, existing plans for Salton Sea restoration do not adequately address the ecological health of the Sea and related aquatic ecosystems. Several of the stated objectives of the Restoration Project are in potential conflict with ecosystem health, but few details have been provided on how protection of natural areas and other designated uses of the Sea will be reconciled.

Explicitly address impacts to human health in the restoration plan.

A detailed plan for protecting and improving human health throughout the Salton Sea basin is not currently a component of any proposed restoration alternative. Similarly, regional efforts to address water quality problems that threaten human health have not been integrated into the restoration process. A potential threat to human health arises from the expected lowering of the surface of the Salton Sea. Unless this process is carefully managed, it could expose tens of thousands of acres of lakebed, potentially dispersing large quantities of airborne pollutants.

Establish a comprehensive environmental baseline for the Salton Sea and its environs before conducting feasibility studies of restoration alternatives.

Baseline assessments of the ecology of the Salton Sea that include the chemical and biological processes that affect wildlife should be the measure against which alternatives for restoration are compared. Federal lawmakers should extend the timeline for the completion of the restoration plan to ensure that the recommended course of action is firmly supported by scientific data.

Consider the benefits and shortcomings of allowing salinity in the Sea to increase unimpeded.

The potential magnitude of the costs and the uncertain ecological benefits and impacts associated with an infrastructure-based restoration plan underscore the importance of an objective analysis of whether a plan to reduce salinity is cost effective and will provide benefits for the ecosystem. Further investigation might demonstrate that it is desirable and more cost effective to manage the Salton Sea as an ecologically-stable salt lake rather than as an artificial, quasi-marine ecosystem that cannot be sustained without costly, ongoing human intervention.

Expand the first phase of the Restoration Project to address agricultural, industrial, and municipal pollutants.

Selectively addressing salinity and elevation while permitting the Sea to remain eutrophic, with increasing levels of selenium, pesticide residues, nutrients, and other contaminants, will undermine and eventually defeat efforts to reinvigorate the Sea's ecological health and improve its recreational potential.

The Regional Water Quality Control Board, Region 7, should place a higher priority on development of Total Maximum Daily Loads (TMDLs) for nutrient loading in water bodies of the Salton Sea watershed.

Region 7 has developed a Watershed Management Initiative "integrated plan" to coordinate the development and implementation of 16 TMDLs to reduce (in order of Region 7's priority) silt, insoluble pesticides, selenium, soluble pesticides, nutrients, and bacteria in the waterways of the Salton Sea watershed. The TMDLs for nutrient loading are not scheduled for development until 2002, but should be given a higher priority to reflect the ecological problems associated with nutrient inputs into the Salton Sea.

Federal funding for the restoration plan should be contingent upon demonstrable benefit to the national interest.

Benefits to the public interest include, but are not limited to, protection of endangered species habitat, restoration of the National Wildlife Refuge, and meeting international obligations under treaties and multilateral environmental agreements, as well as improving the quality of life of people in the region.

Beneficiaries of transfers of Imperial Irrigation District water to the metropolitan areas of Southern California should internalize some of the costs associated with restoring the Sea.

Current and proposed water transfer agreements involving IID could exacerbate the concentration of salinity and other constituents in the Sea by reducing inflows. Parties to these transfer agreements should contribute an equitable share of the costs associated with restoring the Sea.

Address the likelihood that inflows to the Salton Sea will decrease substantially in the future.

The likelihood of significant reductions in the quantity of inflows to the Sea suggests that the chosen restoration plan must be sufficiently flexible to incorporate markedly different inflows and lake levels. Any restoration plan must account for and integrate planned water conservation efforts within the basin.

Exporting brine and contaminants to protected international ecological reserves in Mexico is not an acceptable solution.

Forcing other regions to bear the costs of the Salton Sea's problems is neither sustainable nor equitable. The majority of the restoration alternatives currently under consideration would export concentrated brine to sites outside the Salton basin, including Mexico's Colorado River Delta – Upper Gulf of California Biosphere Reserve. Such pump-out schemes would not only have negative ecological effects, but most likely economic ones as well, potentially compromising the local shrimping and tourism industries in the region.

Colorado River surplus flows should not be diverted from the Colorado River delta to restore the Salton Sea.

Vestiges of the expansive wetlands that once characterized the Colorado River delta have re-emerged due to flood releases since the early 1980s. Today, the delta provides vital habitat for a broad array of flora and fauna, requiring little management and limited inputs beyond sporadic flood flows of Colorado River water. Proposals to divert Colorado River water into the Salton Sea would desiccate remaining high-quality habitat in the delta region.

Identify and fully integrate ongoing and planned efforts in the Salton basin that could impact the restoration of the Sea.

Numerous public agencies are conducting activities in the basin that have implications for the Salton Sea, but these efforts have yet to be fully integrated into the restoration process. In particular, the lead agencies should work with the Regional Water Quality Control Board, Region 7, to implement their existing integrated basin plan. Also, the Bureau of Reclamation's efforts to reduce wasteful water use practices in the Imperial Valley should be formally integrated into the Salton Sea restoration process. To date, Reclamation has segregated its role as lead agency for the Restoration Project from its regulatory responsibilities to curtail inefficient agricultural water use in the basin.

Include all the affected stakeholders in and around the Salton basin.

The restoration process should include outreach to local communities. The Administration and Congress should also commit to a process whereby the settlement of the long-standing property claims of the Torres-Martinez Desert Cahuilla Indians is given priority as a component of the restoration plan. Outreach efforts in Mexico and elsewhere that emphasize collaboration, rather than mere dissemination of information, will strengthen the restoration process and expand possible solutions.

Incorporate successes of similar regional restoration initiatives.

The CALFED Program provides a useful model for the Salton Sea Restoration Project, particularly in terms of its inclusive process. Many of the same federal and state agencies are active in both the Bay-Delta and the Salton Sea. Both initiatives seek to balance ecological and agricultural interests in a large-scale, potentially multi-billion dollar restoration effort, and both seek to implement long-term strategies. The CALFED program invests agricultural, environmental, and urban interests in the process – the Salton Sea Restoration Project should follow this example.

Epilogue

Early this year, the lead agencies of the Salton Sea Restoration Project began incorporating several of the recommendations suggested by the Pacific Institute and other interested parties during and since the Scoping Phase of the restoration process. The Pacific Institute applauds these developments and encourages further changes that can lead to a more sustainable and equitable outcome for the region. We look forward to continuing to participate productively in the restoration process as it evolves.

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Introduction

The aim of this study is to assess the complex environmental and socio-economic problems confronting the Salton Sea and current efforts to restore it. In particular, it critically evaluates from a socio-ecological perspective the federal/state strategy for restoring the Sea, and proposes an alternative, long-term framework for restoration of the regional ecosystem.

Section I of the study provides an overview of the geologic and hydrologic history of the Salton Sea basin, as well as the history of early land use and development of agriculture in the area. Section II discusses the current status of the Salton Sea, including the extent of irrigated agriculture, quantities and qualities of inflows to the Salton Sea, and institutional factors that may impact these inflows in the future. In addition, Section II briefly describes the Salton Sea ecosystem, the recent mortality events, and the connection between the Salton Sea and the Colorado River delta ecosystem.

Section III describes the institutional and legal contexts framing the Salton Sea Restoration Project, including the legislation authorizing restoration studies, other relevant federal and state laws, and the major stakeholders, interest groups and agencies involved in the restoration process. Section III also presents a brief review and evaluation of the general restoration approaches currently under consideration, as well as a description of parallel activities occurring in the basin that have implications for the Salton Sea but have yet to be fully integrated into the restoration process.

Section IV sets forth seven general principles and corollary recommendations that should guide the selection and implementation of an environmentally sustainable and socially equitable restoration plan for the Salton Sea. These principles are compared with the stated and unstated goals and assumptions driving the Salton Sea Restoration Project.

A. Physical History

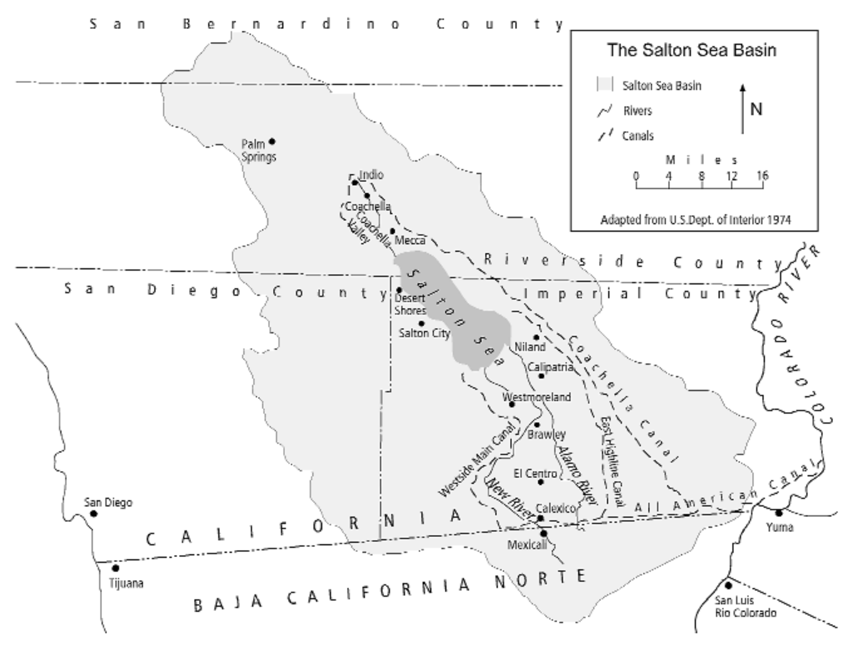
The Salton Sea is a terminal lake located roughly 35 miles north of the U.S.-Mexico border, 90 miles east of San Diego and 60 miles west of the Colorado River (see Figure 1). Presently, the Sea is 35 miles long, 9 to 15 miles wide and has about 120 miles of shoreline. At its current (1999) elevation of 227 feet below mean sea level (msl), it has a surface area of 380 square miles and a volume of roughly 7.3 million acre-feet. The maximum depth of the Sea is about 51 feet with an average depth of approximately 31 feet.

The physical characteristics of the Salton Sea are the result of a complex interplay of natural and human influences that have taken place over this century. The current form of the Sea is but the most recent manifestation of a terminal sump for the Colorado River in a seismically active region characterized by extreme temperatures and limited precipitation.

Geology and Seismicity of the Basin

The Salton Sea lies atop a geological structure known as the Salton Trough. Geologically, the Salton Trough is a rift valley formed by a down-dropped block along the San Andreas Fault. The Salton Trough is a zone of crustal spreading which has been taking place for over four million years. At present, the western side of the rift valley is moving northwestward at

Figure 1
The Salton Sea Basin



about 8 cm/year relative to the east side of the valley, forming a basin. Additionally, the ground level on the south shore of the Salton Sea is subsiding at a rate of more than 20 mm/year (Elders et al. 1972). The Salton Trough lies within a series of northwest/southeast-trending mountain ranges (Setmire et al. 1990). The Salton basin consists of a layer of thousands of feet of water-saturated alluvial deposits (US DOI 1974). Since 1900, 15 earthquakes measuring at least an estimated 6.0 on the Richter scale and another 45 earthquakes of estimated magnitude 5.0 or greater have occurred in or near the basin (US DOI 1974). As recently as October 1998, two earthquakes measuring 3.9 on the Richter scale were recorded near the southeastern shore of the Sea (L. Anderson 1998a). The largest recorded earthquake in the region was the 1940 El Centro event, with a magnitude of 7.1, generating horizontal displacement of as much as fifteen feet and vertical displacement of four feet (US DOI 1974).

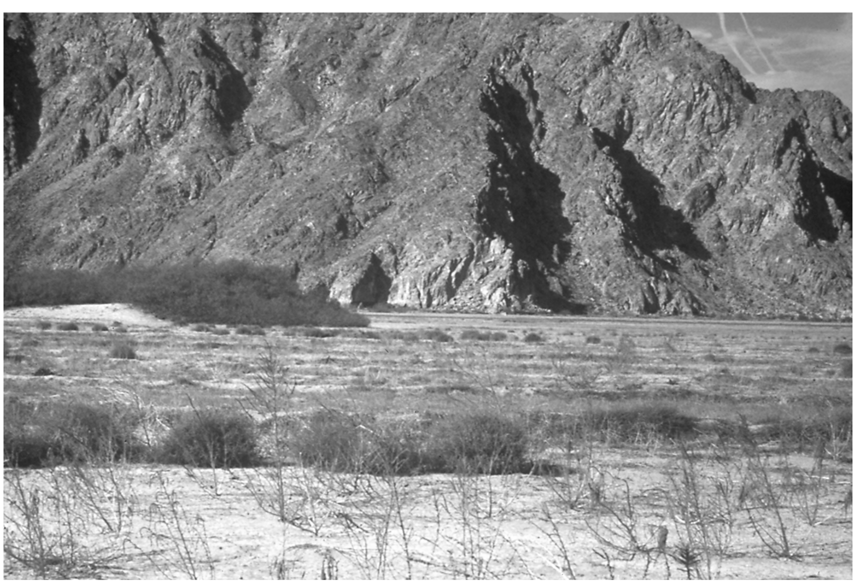
It is estimated that during one episode the prehistoric Lake Cahuilla took 20 years to fill and grew to a size approximately 26 times that of the Salton Sea.

Formation of the Salton Basin

The Salton Basin is one arm of the lower Colorado River delta system. Thirty million years ago, the Salton Trough was the northern-most extension of the Gulf of California. Over the millennia, the Colorado River carried more than a trillion tons of sediment from the Rocky Mountains and the Grand Canyon to its delta terminus (Sykes 1937). As the river cut its way through the Colorado basin, it deposited much of its suspended residue within an extensive delta region that reaches as far north as present day Indio, California (see Figure 2). Some four million years ago, this sediment began to form a natural berm, which eventually separated the Salton basin from the Gulf of California (de Stanley 1966). At times, the Colorado River flowed into the closed basin, forming a prehistoric lake known today as Lake Cahuilla, after the local Indians who lived along its shores and harvested its bounty (US ACE 1989).

It is estimated that during one episode the prehistoric Lake Cahuilla took 20 years to fill and grew to a size approximately 26 times that of the Salton Sea (US ACE 1989). Eventually, the Colorado shifted course and returned to the Gulf of California, leaving Lake Cahuilla to evaporate under the desert sun. In a process identical to that challenging current restoration efforts at the Salton Sea, the terminal lake became increasingly saline as water evaporated, concentrating the remaining salts. The saline lake evaporated over time, leaving behind nine billion tons of salt, thick layers of marine fossil shells, and sediment beds more than two miles deep (Setmire et al. 1990). The most recent incarnation of Lake Cahuilla evaporated about 300 to 500 years ago (Ogden 1996).

Prior to the introduction of irrigated agriculture, shallow ephemeral lakes periodically appeared in the Salton basin, in response to Colorado River flooding in the delta region. Such events were reported in 1828, 1840, 1849, 1852, 1859, 1862, 1867, and again in 1891 (Littlefield 1966). The 1891 inflow covered an area in the basin roughly 30 miles long and 10 miles wide, to a depth of about six feet (U.S. Army Corps of Engineers 1989). The shallow lake created by the 1891 flood event slowly evaporated, leaving a series of salt marshes (Setmire 1979) and an interconnected series of lakes on the west side of the Imperial Valley as late as 1905 (de Stanley 1966).



Earlier incarnations of Lake Cahuilla peaked at an elevation as high as 160 feet below sea level, leaving a recognizable "bathtub ring" on the Santa Rosa mountains. (Courtesy of Jim Setmire)

Figure 2
The Colorado River Delta and the Salton Sea

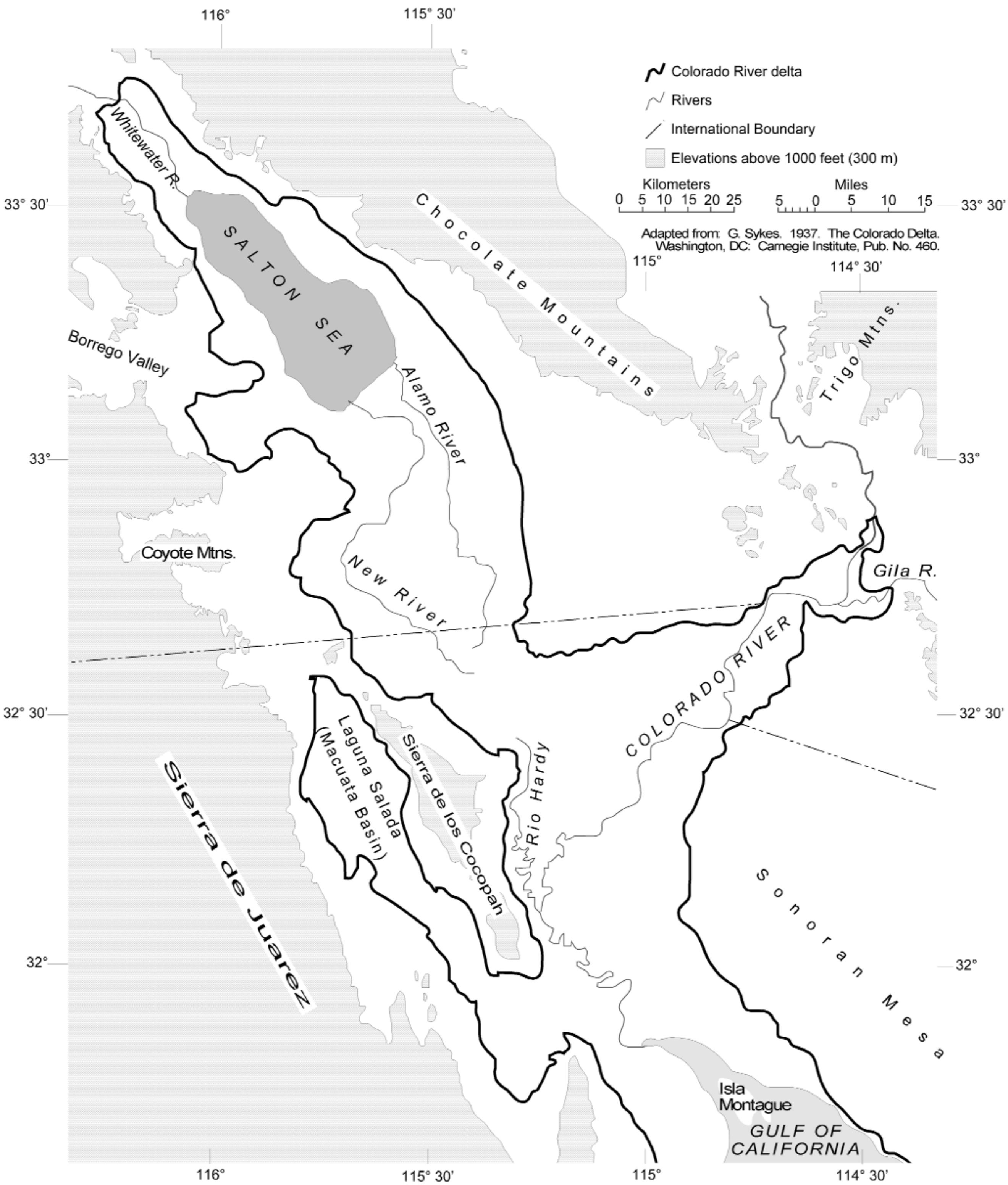
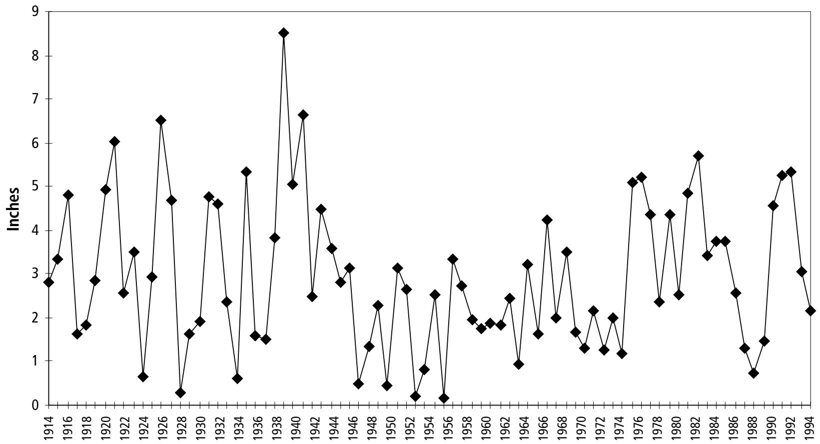
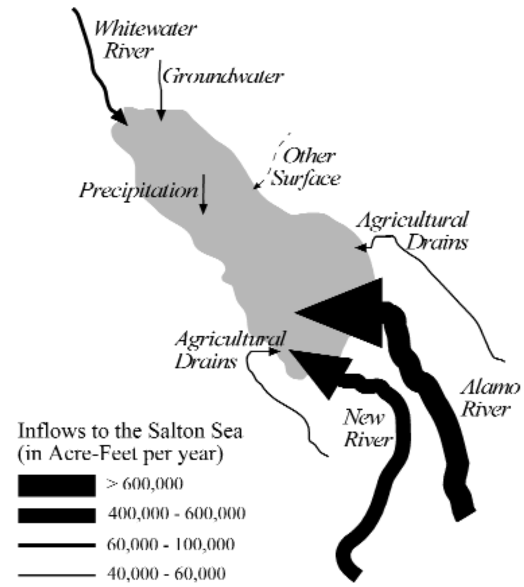


Figure 3
Precipitation on the Salton Sea



Source: IID

Figure 4
Relative Location and Magnitude of Inflows to the Salton Sea



Sources: USGS, USBR, Ogden 1996

Climate

The Salton Sea lies in the hottest, driest part of California, between the Imperial and Coachella valleys. Maximum temperatures in the basin exceed 100° F (38° C) more than 110 days each year, and climb above 110° F (43° C) more than 15 days each year (IID undated). Winter lows tend to be in the 40s (~7° C), with temperatures dropping below freezing only in unusual years (IID undated). The arid climate generates annual evaporation rates between 5.5 and 6.0 feet per year, depending upon the salinity of the Sea (Hely et al. 1966), which means that the elevation of the Salton Sea would decrease by this amount each year if no water flowed into the Sea. Annual precipitation in the Salton basin averages less than three inches (Hely et al. 1966; IID undated), though actual rainfall varies considerably on an annual basis (see Figure 3). Most of the rain falls in the basin from December through March, with occasional thunderstorms occurring August through October.

Hydrology

The Salton Sea's natural watershed encompasses roughly 8,360 square miles, extending from San Bernardino County south into the Mexicali Valley (see Figure 1). Prior to agricultural development, natural drainage into the closed Salton basin consisted of limited runoff from surrounding mountains and sporadic overflows from flooding events of the Colorado River. Today's Salton Sea and its surrounding environs are the product of inflows from agricultural drainage and, to a far lesser extent, precipitation and municipal and industrial effluent. Average precipitation in the watershed accounts for less than eight percent of annual inflows to the Salton Sea. Current annual inflows to the Sea average 1.35 maf/year, roughly equivalent to annual losses to evaporation. The natural annual inflow of roughly 85,000 acre-feet includes both rainfall on the surface of the Sea and surface and subsurface flows from the surrounding mountains. In rare instances, such as the appearance of tropical storm Kathleen in 1976, unusually heavy rainfall can raise the level of the Sea as much as 0.8 foot.

The majority of groundwater enters the Sea from Coachella Valley, with smaller amounts from the alluvium surrounding San Felipe Creek, other washes, and a trace amount from the Imperial Valley (US DOI 1974). Groundwater includes both natural subsurface flows and seepage from irrigation canals and drains. Figure 4 displays the relative location and magnitude of inflows, based on average flows from 1961 to 1995. Inflows from the New and

Alamo rivers consist almost entirely of agricultural drainage from the U.S., and, to a lesser degree, from Mexico.

B. Human History of the Region

The Cahuilla Indians

Despite the inhospitable climate, there is a long history of human habitation in the Salton basin, including the Desert Cahuilla Indians in the northern part of the basin, the Kamia in today's Imperial Valley, and the Quechan, who live on the Colorado mainstem near present-day Yuma. The Cucupa lived farther south in the delta region. (Gifford 1931; Sturtevant 1986). The sporadic appearance of Lake Cahuilla provided a source of fish and game that supported limited human populations in the Salton basin.

The Explorers

In 1539, within 50 years of Christopher Columbus' epic voyage, Francisco de Ulloa, a Spanish captain searching for a route to California, sailed up the Gulf of California to the tidal area marking the mouth of the Colorado River. He was the first European explorer to reach the upper Gulf. A year later, another Spaniard, Hernán de Alarcón, who commanded a fleet in support of Coronado's land expedition, sailed up the Gulf to the mouth of the Colorado, anchored, and ascended the river in small boats (deBuys 1998). In that same year, Melchior Diaz commanded a land expedition, crossing the Colorado River somewhere north of the delta and exploring the area to the west of the river. Diaz may have been the first white man to visit the Imperial Valley (Sykes 1937). Finding neither riches nor a navigable passage north, the Spanish eventually lost interest in this desolate and seemingly unproductive land.

The gold rush of 1849 sent a wave of fortune seekers across the southern deserts to California. Approximately 10,000 crossed the Colorado at Yuma, Arizona and then the harsh desert to the west, along the southern rim of the Salton Sink. The interior of the Salton basin remained unexplored until the 1850s when the U.S. Army was given the task of locating a route for a railroad to link California with the rest of the Union. A young geologist, William Blake, was selected to accompany the party. Near what is now Palm Springs, the expedition encountered bands of Cahuilla Indians who told them stories passed down by their ancestors of the great lake that had come and gone. The expedition explored and crossed the dry sink, observing the calcareous deposits on the crags and rocks that Blake concluded was the high water mark of an ancient sea (deBuys, in press). Blake was also one of the first to deduce that the soils deposited in the great valley were suitable for producing crops if only water could be supplied.

Writing some years later, the famous Colorado River explorer and first head of the Geologic Survey, John Wesley Powell, also recognized the fertility of the thick sediments left behind. Powell (1891) predicted that "in the near or distant future, [man] will control the river, and by its aid regulate the condition of the valley." He cautioned that diverting the river could create problems due to the increased ratio of "impurities" near the river's mouth, but concluded that "if all difficulties, physical and chemical, can be overcome the reward is great, for in that climate every farm is a garden. It is the land of the date palm—the Egypt of America." Powell, like Blake and others to follow, foresaw the greening of the Imperial Valley.

Settlement of the Imperial Valley and the Creation of the Salton Sea

Irrigation began in earnest in the Salton basin in 1901 when George Chaffey invested $150,000 in the new California Development Company (CDC) to build irrigation canals and bring 400,000 acre-feet of Colorado River water to the valley. Chaffey renamed the Salton Sink the Imperial Valley to attract investors. Soon after the Imperial Canal was completed in 1901, the CDC was supplying water to thousands of settlers, signaling the beginning of modern, irrigated agriculture in the basin. By 1905, 10,000 people lived in the valley, farming roughly 120,000 acres (48,600 hectares) of land.

The under-capitalized CDC, however, failed to make needed additional improvements to its rudimentary canal system, and the canals soon clogged with silt, restricting water deliveries at critical times, causing crop failure and increasing demands for improvements. Despite uncertainty about approval from the Mexican government for a new diversion cut, time was of the essence in the Winter of 1904-05. In the Fall of 1904, after dredging proved inadequate, a new intake was cut south of the international border where water could be routed into the old channel of the Alamo River. The company's engineers gambled that the location of the temporary diversion could be secured before the summer's high water. Based on their understanding of the records kept at Yuma for 27 years, there had been only three winter floods and never two winter floods in the same year (Kennan 1917). But in the Winter of 1904–05, the river flooded powerfully on three occasions, the third coming in March. Despite numerous attempts to close the new intake, the river continued pouring into the old channel and flowing north into the Salton basin. At the height of the flood, 6 billion cubic feet of water a day was pouring into the valley – at one point the Salton Sea rose seven inches a day, eventually covering 400 square miles (103,600 ha)(Kennan 1917).

It took over 18 months and the herculean efforts of the Southern Pacific Railroad Company to turn the Colorado River back into its bed. The man-made flood caused millions of dollars of damage, but did not long deter agricultural development. Despite the disaster, the enormous agricultural potential of the valley was obvious, if only the river could be regulated to control floods and deliver water when it was needed (Kennan 1917).

In 1911, the Imperial Irrigation District (IID) was formed, acquiring the water rights and irrigation system from the now bankrupt CDC. By 1918, over 350,000 acres (142,000 ha) were being irrigated. In 1928, Hoover Dam and the All-American Canal were authorized by Congress, virtually ensuring that the disaster of 1905 would not be repeated. Hoover Dam was dedicated by President Roosevelt in 1934 and the All-American Canal was completed in 1938. With the completion of the new infrastructure, the valley had an abundance of water to apply to its rich soil; since the post-war era it has become one of the most productive agricultural areas in the world.

Economic Development of the Valley

In the late 1950s, there was a concerted effort to develop the Salton Sea's real estate and recreational potential, including the development of resort areas, marinas, and several small communities. By the early 1960s, speculators and developers had subdivided thousands of acres on the western shore of the Sea and sold them as part of a land development promotion effort to create a "Salton Riviera," a complex of resort cities that would attract buyers from across the country. Promoters billed it as a recreational mecca that would include golf courses and a marina for boating, sport fishing, and other water sports. When sales opened, the first day brought in $4.25 million (deBuys, in press). The boom didn't last long, however, and few homes were ever built. Lack of industry and infrastructure were problems, as well as the isolation, scorching heat, and sometimes-odorous waterfront environment.

Despite the collapse of the real-estate market, recreational uses at the Sea persisted. The major attraction was fishing, although waterskiing and related activities also attracted thousands of people. A vibrant sport fishery developed after the California Department of Fish & Game introduced saltwater species from the Gulf of California in the 1950s to replace freshwater fish. Fishing for the abundant corvina, croaker, and sargo provided a third of the total recreation use of the Sea for a number of years. In 1969, an annual use rate of 1.5 million recreation days was recorded for the Sea, contributing almost $100 million to the local economy (CIC 1989). By 1987, however, the recreational use of the Sea had dropped by 50 percent from the 1960s (CIC 1989).

The Salton Basin Today and Tomorrow

The physical and ecological characteristics of the Salton basin, and agriculture in the Imperial Valley, are crucial elements impacting the Sea's current state. The consequences of the absence of a natural outlet, the high evaporation rate, and the extent of irrigated agriculture in the basin are readily apparent. The impacts of the institutional framework shaping water use in the region and the vested economic interests of the major stakeholders are less obvious. This section describes the current status of the Salton Sea in terms of demographics and land use, the quantity, quality, and sources of inflows to the Sea, and the potential for reduced future inflows. This is followed by a discussion of the ecology of the Salton Sea and its relationship with surrounding ecosystems.

A. Land Use in the Basin

Current land use and demographics in the basin provide a ready guide both to the source and nature of inflows to the Salton Sea and to some of the forces driving the current efforts to restore the Sea. Figure 5 displays current land ownership around the Salton Sea, while Table 1 lists 1995 land ownership within one-half mile of the current (-227 feet msl) shoreline.

The growing population of the Coachella, Imperial, and Mexicali valleys puts increasing pressure on the Salton Sea, most notably in the quantities of municipal effluent discharged to the Sea. Table 2 displays population growth in the Salton basin. This population, especially in the border region, is poorer and less educated than people in other areas of California, making them more vulnerable to economic downturns (Gomez and Steding 1998). In 1994, Imperial County as a whole had the third-lowest per capita income of any county in California, and ranked last in education, as measured by the fraction of persons 25 years or older with a high school diploma (Gomez and Steding 1998). In 1996, seasonal unemployment in Imperial County exceeded 30 percent, four times the state average (Gomez and Steding 1998). Annual average agricultural employment in Imperial County in 1994 was 9,760 workers and 10,680 in Riverside County (CA EDD 1995). Agriculture accounts for roughly 35 percent of total employment in Imperial County, and 4 percent of total employment in Riverside County (CA Department of Finance 1998).

Agriculture

In terms of land use, irrigated agriculture is the most prevalent human activity in the Salton basin. It has changed the face of the region, transforming a desert valley into an extremely productive agricultural area. The Salton Sea lies between the fertile Coachella and Imperial valleys, where agriculture generates more than $1.4 billion in annual revenue. The Imperial Irrigation District (IID) is the largest irrigation district

Table 1
Ownership of Property Surrounding the Salton Sea

Agency	Acreage [a]
U.S. Bureau of Land Management	4,974
U.S. Fish & Wildlife Service	1,816
U.S. Military	2,143
Torres-Martinez Desert Cahuilla Indians	1,639
CA Dept. of Fish and Game	198
CA Dept. of Parks and Recreation	951
Private	20,585
Total	**32,306**

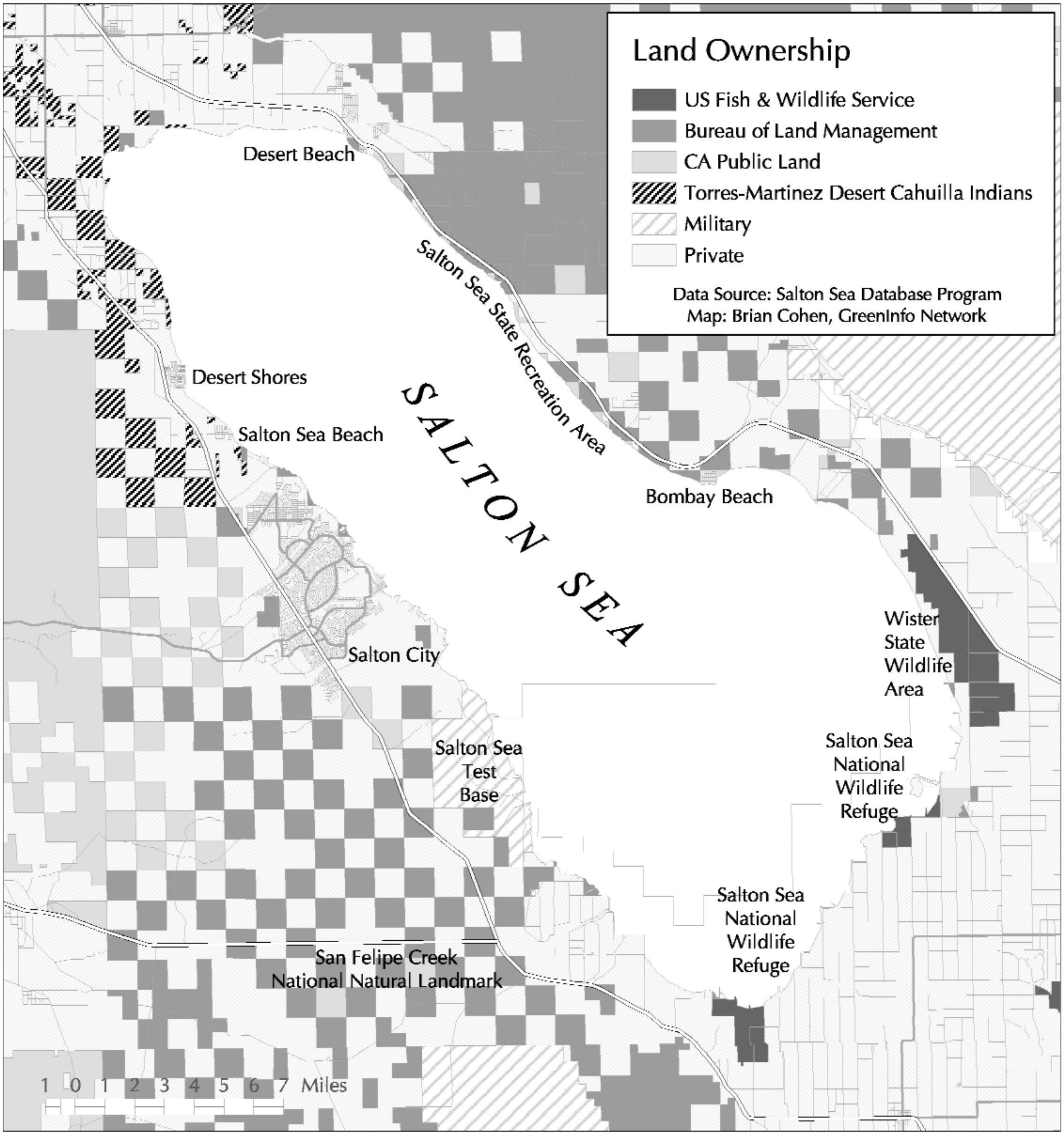
[a] Total acreage within one-half mile of current shoreline (-227 feet msl), as of 1995.
Source: Salton Sea Database Program

Table 2
Population Growth in the Salton Basin

Year	Total	Coachella Valley	Imperial Valley	City of Mexicali
1940	116,000	12,000	59,740	44,399
1950	214,000	27,000	62,975	124,362
1960	408,000	54,600	72,105	281,333
1970	558,000	87,600	74,400	396,324
1980	739,000	135,900	92,500	510,664
1990	932,000	220,000	110,400	601,938
1995	1,119,000	282,000	141,500	695,805

Sources: Ganster 1996; DWR Bulletin 132 series and Bulletin 108 in Tostrud 1997.

Figure 5
Land Ownership Around the Salton Sea 1995



in the U.S., providing water to more than 458,500 cultivated acres (185,550 hectares) in 1995 (IID fact sheet, undated). The major crops grown in 1995 were alfalfa, which accounted for 43 percent of the land under cultivation, sudan grass (17 percent), and wheat (14 percent) (IID fact sheet, undated). Total farm revenues for IID exceed $1 billion annually (IID fact sheet, undated). In 1996 the leading commodity, in terms of value of production, was cattle, generating more than $152 million in revenue (CA Department of Finance 1998).

In 1995, the Coachella Valley Water District (CVWD) delivered water to 78,600 acres (31,800 ha), with more than 85 percent of that acreage devoted to high-value fruits and vegetables—total value of that year's production was more than $432 million (CVWD 1996). Table grapes were the leading commodity, in terms of value of production, in Coachella Valley in 1995, generating more than $104 million in revenue (CVWD 1996). Total irrigated acreage in the Mexicali Valley in 1990 was approximately 485,000 acres (19,600 ha), with wheat and cotton accounting for 54 percent of the land planted (Morrison et al. 1996). Total farm revenues generated in that year were US$236 million (CNDA 1991).

Recreation

Recreational use of the Salton Sea has declined from its peak in the 1960s, when more people visited the Salton Sea Recreation Area than visited Yosemite National Park. A combination of factors are responsible for this decline, including the inundation of resort areas and wildlife habitat, diminished aesthetics due to the proliferation of fish and bird die-offs, and perceived health threats from untreated effluent from Mexico and health advisories regarding consumption of fish caught in the Sea. Today, most of the waterfront recreational areas developed in the 1950s and 1960s have been abandoned or inundated.

Yet the Salton Sea continues to generate revenue for the region. A broad public survey (CIC 1989) estimated that visitors to the Sea generate $53 million in direct local expenditures, with multiplier effects bringing the total local economic impact to approximately $100 million annually. Of this amount, bird watchers contribute an estimated $3.1 million to the local economy each year.

Plans for economic redevelopment of resort areas around the Salton Sea are at least partly responsible for current efforts to restore the Sea. Enhancing recreational values is an explicit goal of the current Salton Sea Restoration Project. The late Representative Sonny Bono, a driving force in the most recent restoration effort, was clear in his interest in restoring the Sea to its status as a prime recreational destination. The Salton Sea Reclamation Act of 1998 (PL 105-372) reflects this interest, directing the Secretary to study "the feasibility and benefit-cost of various options that … enhance the potential for recreational uses and economic development of the Salton Sea."

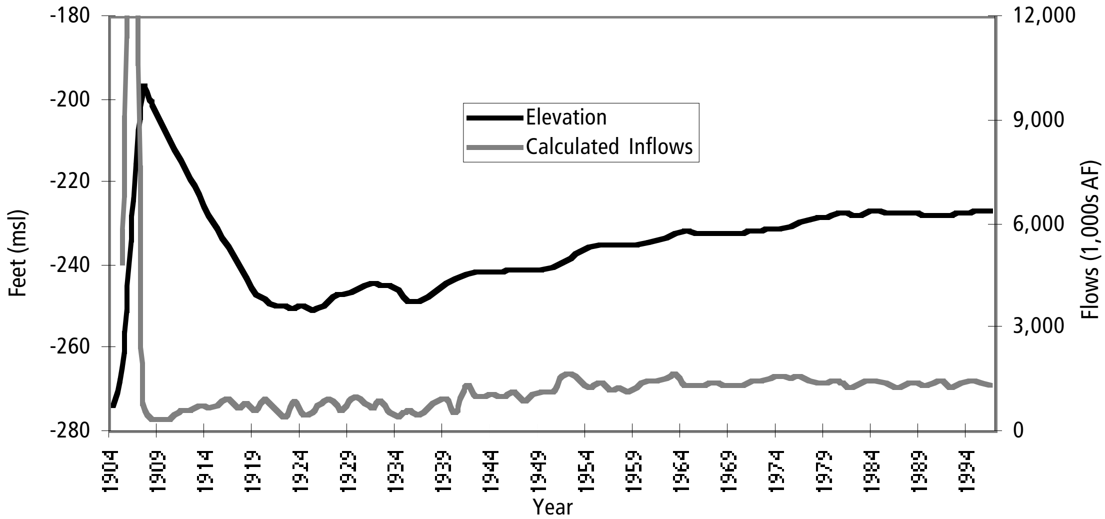
B. Water Use and the Manmade Sea

Agricultural water use in the region has had a profound impact on the Salton Sea, even to the extent of its continued existence. Absent additional inflows, the Salton Sea created by the flooding from 1905 to 1907 would have evaporated completely by 1928. After reaching a maximum elevation of 195 feet below mean sea level (msl) in 1907, the elevation of the Sea decreased to a surface elevation of roughly -250 feet msl by 1920. Increasing levels of irrigation drainage reversed this downward trend and the elevation of the Sea gradually rose until reaching and stabilizing at its present level of about –227 feet msl. Today, without continued agri-

Absent additional inflows, the Salton Sea created by the flooding from 1905 to 1907 would have evaporated completely by 1928.

Rising Sea levels flooded many of the waterfront recreational areas developed in the 1950s and 1960s. (Courtesy of Jim Setmire)

Figure 6
Elevation and Inflows of the Salton Sea 1905–1996



Sources: USGS, Dept. of Interior 1974, Tostrud 1997.

cultural drainage, the Salton Sea would completely evaporate in less than 10 years. Figure 6 shows the elevation of the Salton Sea, along with total annual inflows to the Sea.

The foundation for Southern California's agricultural economy is a legal framework guaranteeing ready access to large quantities of inexpensive Colorado River water (see Section III; Hundley 1975, Fradkin 1981, Reisner 1993). IID and the CVWD deliver a combined annual average of approximately 3.2 million acre-feet of Colorado River water to their respective valleys (Colorado River Board of California 1990 and 1992). Water use in the Mexicali Valley exceeded 2.4 maf in 1990, of which more than 1.6 maf came directly from the Colorado River and the remainder from groundwater (Morrison et al. 1996). A considerable portion of Mexicali's groundwater supply, however, originates as Colorado River water diverted for irrigation. Water that does not evaporate or transpire percolates into the aquifers after being applied by farmers. As a result, Colorado River water represents an even higher portion of total supply for the region.

The Imperial Valley boasts one of the most complex hydraulic engineering projects in the world, with nearly 1,700 miles of canals and more than 32,000 miles of subsurface tile drains that remove water used to leach salts and other constituents from the soil (IID fact sheet, undated). Roughly one-third of the water applied to agriculture in the Imperial Valley eventually makes its way to the Salton Sea, from surface and tile drainage. The remainder is accounted for through evapotranspiration or percolation or is embodied in the harvested crops.

Inflows to the Sea

Current annual inflow to the Salton Sea averages approximately 1.35 maf and has achieved a dynamic equilibrium with evaporation. The Sea is an officially designated repository or "sump" for U.S. agricultural drainage, which accounts for over 75 percent of total inflows (see Table 3). Roughly 10 percent of the total inflows to the Salton Sea originate in Mexico. Of Mexico's contribution, almost 75 percent is agricultural drainage and the remainder is municipal and industrial effluent (CH2MHill 1997). Total flows of the New River at the Mexican border averaged approximately 152,000 af/year from 1960 to 1995; total flows of the Alamo River at the border averaged

Table 3A
Average Annual Inflows to the Salton Sea by Source

Source	Percent	Acre-feet/year
Alamo River	45	605,000
New River	32	424,000
Agricultural Drains	9	123,000
Whitewater River	5	62,000
Groundwater	4	50,000
Rainfall	4	53,000
Other surface	2	29,000
Total:	100	**1,346,000**

Sources: USGS, USBR, IID, Ogden 1996, Tostrud 1997

Table 3B
Average Annual Inflows to the Salton Sea by Sector

Inflows by Sector	Percent	Acre-feet/year
Agriculture	85	1,145,000
United States	77	1,040,000
Mexico	8	105,000
Municipal and Industrial	9	116,000
United States	6	80,000
Mexico	3	36,000
Natural	6	85,000
Total:	100	**1,346,000**

Sources: USGS, USBR, IID, Ogden 1996, Tostrud 1997

1,700 af/year (USGS 1970 et seq.). Considerable quantities of IID agricultural drainage join the New and Alamo rivers before they enter the southern end of the Salton Sea. The New and Alamo rivers each run approximately 60 miles before emptying into the Sea. Tables 3A and 3B show the source and average (1966–1995) annual quantity of inflows to the Salton Sea.

Inflows to the Sea vary annually in response to changes in cropping patterns, the amount of land irrigated, and irrigation methods, as well as changes in levels of precipitation and the implementation of water conservation measures. For example, the average annual flow of the Whitewater River for the period 1966-1985 was 89,000 acre-feet, but declined to 62,000 acre-feet for the period 1986-1995. This decline is partly attributable to changes in irrigation practices, as Coachella Valley farmers increasingly employed drip irrigation systems (CVWD 1996).

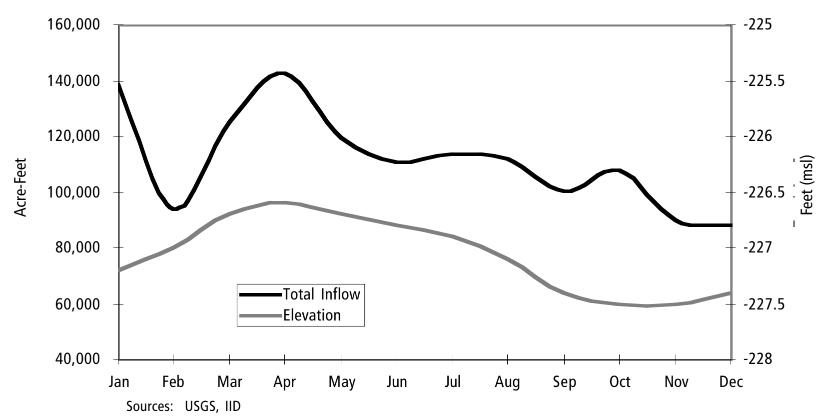
Monthly flows to the Salton Sea also vary over time. Figure 7 shows monthly inflows from the Alamo and New rivers for 1995. Changing quantities of inflows combine with seasonal changes in evaporation rates to raise and lower the elevation of the Sea. The elevation of the Salton Sea varies by as much as a foot annually, reaching its maximum elevation in late Spring and its minimum elevation in late Fall. Since the basin is relatively level, a small change in elevation can result in a large difference in surface area, inundating surrounding regions.

The Alamo River delta near the Salton Sea National Wildlife Refuge. (Courtesy of Jim Setmire)

Efforts to Decrease Water Use in the Basin

The amount of water flowing into the Salton Sea is likely to decrease in the future due to a variety of factors. Presently, California uses an average of 5.2 maf a year of Colorado River water. However, considerable pressure is being exerted on California by the federal government and Colorado River Compact states to reduce its consumption to its 4.4 maf legal entitlement. Given increasing water demands in Arizona and Nevada, Southern California will be unable to rely on unused

Figure 7
Monthly Inflows to the Salton Sea in 1995



lower basin entitlements to keep its aqueduct full in the future. This realization is spurring changes in water use practices and policy in the state, and continued conversion of Imperial Valley agricultural water to urban uses appears likely if California is to implement a successful plan to live within its long-term water entitlement (McClurg 1998).

California State Water Resources Control Board and Conservation Agreements

The availability of relatively cheap water, the extremely arid climate, irrigation practices utilized to flush salts, and the reliance on water-intensive crops all contribute to the present rates of water use in the Imperial Valley. There is potential for California to reduce its use of Colorado River water without permanently retiring agricultural land by increasing the efficiency of agricultural water use practices in the region. In June 1984, the California State Water Resources Control Board (SWRCB) issued Decision 1600,[1] which found that IID's water conservation measures at the time were unreasonable and constituted misuse of water in violation of Article X, Section 2 of the California Constitution (SWRCB Decision 1600). In 1988, the SWRCB entered a subsequent order (Order 88-20) directing IID to submit a definite implementation plan and time schedule for water conservation measures sufficient to conserve at least 100,000 af/year. Several other studies also document the excessive use of water in the Imperial Valley (NRC 1992). Although not precisely quantified, the IID has entitlements to approximately 3 maf of Colorado River water – roughly 20 percent of the river's average annual flow.

There is potential for California to reduce its use of Colorado River water without permanently retiring agricultural land by increasing the efficiency of agricultural water use practices in the region.

In 1989, after a series of legal challenges and contentious negotiations, IID reached an agreement with the Metropolitan Water District of Southern California (MWD). MWD agreed to finance water conservation improvements in the Imperial Valley. In return, MWD is entitled to receive the conserved water (106,000 af/year) for a period of 35 years (cf. Reisner and Bates 1990; NRC 1992). It was estimated that the conservation measures and resultant decrease of inflows would lower the surface elevation of the Salton Sea by two feet (NRC 1992). However, due to an increase in double and triple cropping in the Imperial Valley, total use by IID has actually increased since the implementation of the conservation agreement. The resultant irrigation return flow has contributed to a one-foot rise in the surface elevation of the Salton Sea between 1989 and 1995 (Jensen 1995).

Over the last few years, the Bureau of Reclamation (Reclamation) has also increased its scrutiny of agricultural water users in California's low desert. In 1995, the Jensen Report, commissioned by Reclamation, concluded that IID was using water in excess of reasonable and beneficial use. In response to IID's criticisms of the report,[2] Reclamation commissioned a second report, which has been provided by a consultant in draft form to Reclamation, and also to IID, but is not available for public review. According to Reclamation sources, the second Jensen report considers a 10-year period, yet still validates the findings of the first report. IID has not yet responded publicly to these findings. In late 1997, Reclamation refused to approve IID's full water delivery request for the year, on the grounds that it exceeded reasonable beneficial use. However, this refusal apparently was only a formality, as IID received and used as much water as it requested, due to the fact that the Colorado River Reservoir System was full and flood control releases were occurring. Nevertheless, Reclamation's refusal made clear that IID should not assume future approval would be forthcoming in non-surplus or shortage years.

[1] Prior to the Board's hearing, an investigation by the California Department of Water Resources concluded that 438,000 af/year in the IID was being used in excess of beneficial use and could be conserved (SWRCB Decision 1600).

[2] IID called for a longer study period of water use (10 years), which they believed would support their contention that the district was not wasting water.

IID-SDCWA Water Transfer

A major development that may reduce inflows to the Salton Sea is the July 1998 water transfer agreement between the San Diego County Water Authority (SDCWA) and IID, enabling the former to purchase up to 200,000 af/year of water conserved by IID farmers. While the agreement still faces significant legal, political, and environmental hurdles, it augments the conservation measures implemented by the 1989 IID-MWD conservation agreement. The impact of the latter water transfer on the Salton Sea and its associated environmental problems are yet to be determined.[3] In addition to decreasing the freshwater inflow into the Sea, water conservation measures have the potential to exacerbate some water quality problems and remedy others. Specifically, measures such as tailwater pumpback[4] would serve to decrease silt, pesticide, and nutrient loadings, but would reduce the volume of dilution water and lead to an increase in selenium and salinity levels (J. Angel, RWQCB, personal communication, 1999).

Reduced Flows from Mexico

Inflows to the Sea originating in Mexico are also expected to decrease in coming years. Through a partnership with the U.S. Environmental Protection Agency, the city of Mexicali is presently constructing a wastewater treatment plant to expand the limited capacity of its current system. It is likely that this treated wastewater will be reused in Mexico, decreasing flows into the Sea by as much as 22,400 af/year (CH2MHill 1997). Further reductions from Mexico are likely as conservation measures in the Imperial Valley, particularly the proposed lining of the All-American Canal, limit the amount of groundwater seepage currently pumped in the Mexicali Valley and returned to the Sea as agricultural drainage.

Due to these anticipated changes in water management on both sides of the border, it has been estimated that inflows to the Salton Sea will likely drop below 1 maf/year, and may decrease to 0.8 maf/year or less. The latter reduction is acknowledged in the Salton Sea Reclamation Act of 1998 (PL 105-372). The resulting decrease in elevation of the Sea will challenge efforts to develop shorefront properties and will impact ecological systems. Decreasing the elevation of the Sea could expose rookeries on isolated areas such as Mullet Island, reducing the availability of nesting habitat for species such as cormorants. A potential ecological benefit of lowered lake levels would be the re-exposure of a large area of former marshland where the New and Alamo rivers enter the Sea. If managed correctly, this could present an opportunity for restoration of the currently inundated wetland habitat of the National Wildlife Refuge.

The Threat of Air Pollution

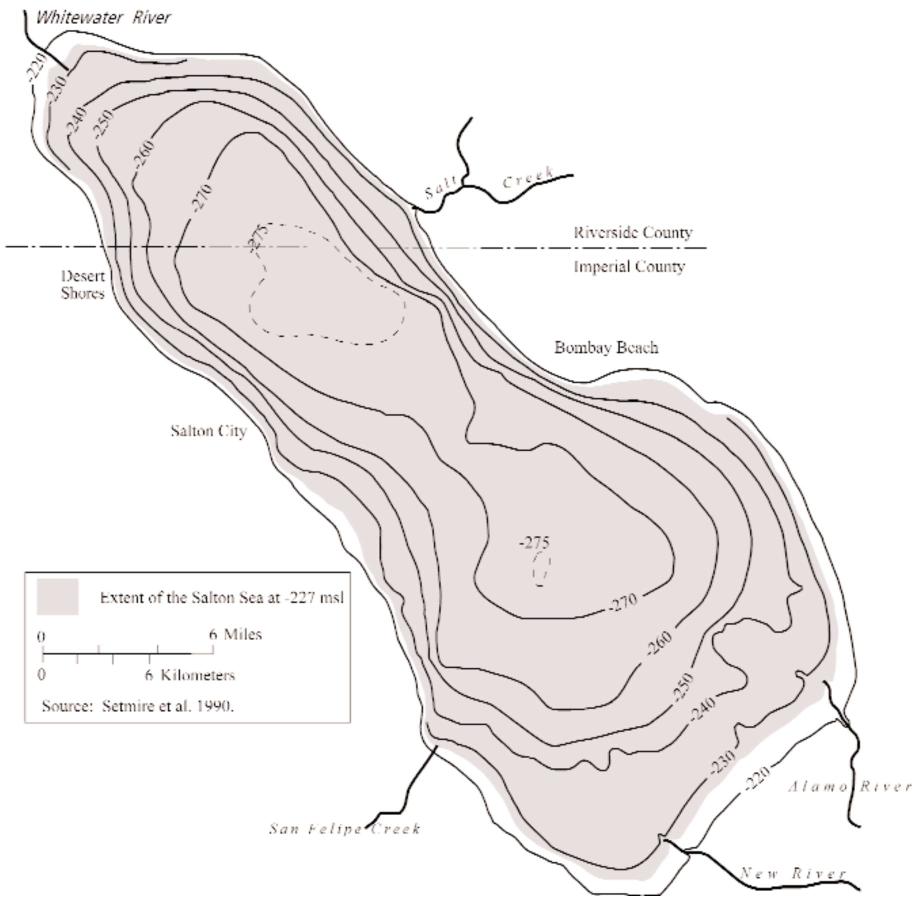
As inflows are reduced, the Sea's elevation will decrease and sediments will be exposed, raising the possibility of air quality problems from wind-driven dust and pollutants. One of the stated objectives of the Salton Sea Restoration Project is to reduce and stabilize the elevation of the Salton Sea approximately five feet, to –232 feet mean sea level (msl). Absent levees or dikes, this would result in the exposure of roughly 14,000 acres of presently inundated lakebed. According to models generated by the University of Redlands' (1998) Salton Sea Database Program, if inflows to the Salton Sea are reduced from their present level of 1.35 maf/year to 1 maf/year, the level of the Sea would stabilize at –242 feet msl, exposing 41,400 acres of lakebed. If inflows were reduced to 800,000 af/year, the lake level would eventually stabilize at –251 feet msl, exposing 73,600 acres of lakebed. This exposure would occur disproportionately on the southern end of the Sea, closer to the major population centers of the Imperial Valley and the city of Mexicali (University of Redlands 1998) (Figure 8).

Lakebed exposure can result in the aerial

[3] IID is currently in the process of preparing an Environmental Impact Report/Assessment (EIR/EIS).

[4] In this process, runoff is captured prior to entering the drains and stored in end-of-field reservoirs for future reuse on the fields.

Figure 8
Bathymetry of the Salton Sea



dispersion of particulate matter and contaminants such as selenium that may be contained in the sediment. These dusts can have deleterious health effects on the region's population. Aerial dispersion of salts could also negatively impact agriculture in the Coachella, Imperial, and Mexicali valleys. There are several examples of the significant human health and economic costs associated with lakebed exposure that bear directly on the Salton Sea. The Los Angeles Department of Water and Power (LADWP) recently reached an agreement with the Great Basin Unified Air Pollution Control District to release water back into the presently dry Owens Lake. The agreement was part of an effort to reduce the dust pollution (as much as 11 tons/day) that periodically swirls off the lakebed, causing a variety of respiratory ailments (Cone 1998). The agreement may cost the LADWP $120 million and 40,000 acre-feet of water per year (Cone 1998). The Aral Sea and Mono Lake have also experienced significant problems arising from the exposure of hypersaline lakebed, as windblown salts and dust there have adversely affected both human and animal populations (Postel 1993). Some 70 percent of the human population near the Aral Sea report severe health problems associated with the annual airborne dispersion of an estimated 40-150 million tons of salt and dust from the dried, exposed bed of the Aral Sea.

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Water Quality

The quality of the inflows to the Salton Sea is a major component affecting the ecology of the Sea. Three major water quality challenges currently confront the Salton Sea: salinity, nutrient loading, and selenium.[5] Attention to date has primarily focused on salinity, although in addition to approximately four million tons of dissolved salts, annual inflows to the Sea contain 15,000 tons of nutrients such as nitrogen and phosphorus,[6] variable levels of selenium and other metals, and pesticide residues and other contaminants. The water quality of the Salton Sea has steadily declined over time, as the only outflow for water entering the Sea is through evaporation. The process of evaporation extracts only water from the Sea, concentrating other constituents such as salts, selenium, and other contaminants.[7]

Figure 9
Salinity and Elevation of the Salton Sea 1905-1996

** Salinity for the years 1907–1916, 1923, 1929 and 1995–1996 are measured values. Other years reflect calculated values, from Tostrud 1997.*

Sources: USGS, Hely et al. 1996, Tostrud 1997, IID.

Salinity

The average salinity of the Salton Sea is currently 44 parts per thousand[8] (ppt), 25 percent higher than that of the ocean. By comparison, the salinity of the Great Salt Lake has ranged from 55 to 180 ppt and Mono Lake from 42 to 99 ppt (Hart 1996; USGS 1998). Salinity of the Salton Sea varies across its surface, with the lowest values at the mouths of the Alamo and New rivers and the highest values found in isolated shore pools (Setmire et al. 1993). Barlow (1958) reported salinity as high as 62 ppt in a large shore pool. The salinity of inflows also varies considerably, from trace amounts of dissolved solids present in rainfall to 2.9 ppt in drainage canals from the Imperial Valley (Kratzer et al. 1985). The average annual salinity of the Colorado River at Imperial Dam from 1966-1995 was 0.78 ppt (US DOI 1997). Measured salinity at the mouth of the Alamo River is approximately 2.9 ppt (Kratzer et al. 1985). In 1996, the salinity of the New River at the Mexican border was approximately 2.6 ppt (IBWC undated).

The Sea's hypersalinity is not a new issue. The inflow of the Colorado River into the Salton basin in 1905 created a lake with an estimated salinity of 3.5 ppt, many times greater than the river's estimated salinity of 0.6 ppt, due to the absorption of salts from the dry lakebed (Hely et al. 1966). Evaporation concentrated the Sea's salinity to that of the ocean by 1918, with salinity continuing to increase to roughly 40 ppt by 1925 (Hely et al. 1966). By the late 1920s, the salinity of the Sea decreased, as the number of irrigated acres in the Imperial Valley grew and surface drains were installed, and fluctuated in following years due to varying quantities of inflows from agricultural drainage. During the Great Depression, in response to a decrease in agricultural inflows (partially attributable to a prolonged drought in the Colorado River basin), the salinity of the Sea exceeded 43 ppt (Littlefield 1966). Figure 9 illustrates the salinity of the Salton Sea over time, plotted against the elevation of the Sea.

[5] The presence of pesticides and other contaminants in the Sea are also of concern, but these factors do not appear to have the short-term system-wide impacts demonstrated by the three major factors.

[6] Data compiled by Richard Thiery, Coachella Valley Water District, in Cagle 1998.

[7] Trace amounts of nutrients and contaminants are exported from the Sea in the tissues of non-marine organisms.

[8] Average of semi-annual (April and October 1997) monitoring data compiled by the Imperial Irrigation District.

The future threat posed to fish by increasing salinity is one of the driving forces of current efforts to restore the Sea (see Section III). The Bureau of Reclamation estimates that five million tons of salt flow into the Sea annually, with the Sea's salinity increasing by about 0.51 ppt each year, or about one percent (USBR 1998b). However, this estimated increase in salinity is not supported by the measured levels of salinity at the Sea.[9] From 1968 to 1997, the measured increase in salinity at the Salton Sea was roughly 0.22 ppt/year, or roughly 0.5 percent annually (IID data, in Tostrud 1997). The Bureau of Reclamation's estimates are only accurate for the period 1980-1992; salinity at the Sea increased more slowly than the Bureau's projections both prior to and subsequent to this period.

The salinity of the Salton Sea is a function of several factors, including total inflows, the rate of evaporation, and the salt load of the inflows. Fluctuating inflows partly explain the variation in measured salinity of the Sea. Preliminary studies (Tostrud 1997; Richard Thiery, CVWD, personal communication, 1999) suggest that another factor, the precipitation of salts out of solution, may also explain the variation. Tostrud's (1997) preliminary calculations suggest that the Sea's solubility limit for several salts, especially sulfates, has been reached. If correct, this has significant ramifications for efforts to restore the Sea: the salinity of the Sea may continue to rise at a slower rate than initially estimated, and efforts to reduce the salinity of the Sea may be more difficult than projected due to precipitated salts dissolving back into Sea water (Tostrud 1997).

Eutrophication is responsible for the deaths of millions of fish at the Sea, and may be responsible for creating an environment that fosters the spread of avian diseases

Nutrient Loading

Nutrient-rich inflows to the Salton Sea facilitate extremely high biomass production in the Salton Sea, yet these same inflows have also created eutrophic conditions[10] in the Sea. Eutrophication is responsible for the deaths of millions of fish at the Sea, and may be responsible for creating an environment that fosters the spread of avian diseases (Setmire et al. 1993; USGS 1996; Costa-Pierce 1997; USBR et al. 1997; USFWS 1997b). The correlation between high nutrient levels and algal blooms is well documented (cf. Vollenweider 1968; Schindler 1977; Lathrop and Carpenter 1992). Eutrophication can generate anaerobic conditions, which are also associated with the release of noxious hydrogen sulfide gas, reducing aesthetic and recreational values. Nutrient loading may also encourage the growth of phytoplankton species that are toxic to fish (USFWS 1997a). Table 4 shows nutrient concentrations and annual loadings to the Sea, based on data collected by the RWQCB from 1980-92. Table 5 displays recommended and dangerous levels of nutrients for water bodies, as well as areal loadings for the Salton Sea. Recommended and dangerous levels are from Wetzel (1983) and are for water bodies with an average lake depth of 33 feet. The average depth of the Salton Sea is approximately 31 feet.

Although some relatively recent records exist on nutrient inflows to the Salton Sea, there are few long-term historical data on nutrient loads in and around the Salton Sea (USFWS 1997a). California's Regional Water Quality Control Board, Region 7 periodically tests several water-quality parameters for the Salton Sea and its major tributaries, although the rate at which nutrients concentrate in the Sea and the spatial distribution of nutrient loads across the Sea are largely unknown.

[9] IID data, compiled by Tostrud 1997. At the time of publication, salinity data was not available from the Salton Sea Database Program, the Salton Sea Authority, or the Bureau of Reclamation.

[10] Eutrophication is caused by the introduction of large quantities of nitrates, nitrites, ammonia, and phosphates into an aquatic or marine environment. These constituents are used in fertilizer and are also present in effluent from dairy and cattle operations, as well as municipal and industrial effluent. Nutrient-rich conditions lead to excessive plant growth. Algal respiration and the decomposition of dead algae consume large quantities of oxygen, leading to diminished concentrations of dissolved oxygen (DO) in the Sea and the asphyxiation of fish. The concentration of DO in aquatic habitats partially determines the rates of three biological processes: decomposition; respiration; and the chemical oxidation of microbes (Covich 1993). Many factors influence the DO of a body of water, including biological and chemical oxygen demand, temperature, salinity, and aeration via wind or movement over obstructions. DO levels at the Salton Sea fluctuate on an annual basis and vary spatially across the vertical water column, with the highest rates at the surface and anaerobic conditions often encountered at depths of thirty feet or more (Setmire et al. 1993).

Selenium

Selenium toxicity can lead to reproductive failure, deformities, and death among aquatic organisms and water birds, and can also adversely affect people. Selenium toxicity is not yet a major ecological concern at the Salton Sea (Setmire et al. 1990), but continuing inputs of selenium into the system threaten to re-create the widespread selenium toxicity that occurred at California's Kesterson Wildlife Reserve. Kesterson was also a designated repository for agricultural drainage.

The Salton Sea is a selenium sink—the concentration of selenium in the Sea's water is much lower than in its tributaries and surrounding agricultural lands, where selenium in Colorado River water used for irrigation is concentrated in tilewater by evaporation (Setmire et al. 1993). The selenium concentration in the water column of the Sea is relatively low at 1 part per billion (ppb), compared with inflows to the Sea, with concentrations between 4 to 8 ppb (Setmire et al. 1993). Much of the selenium in the Salton Sea is concentrated in its sediments, apparently by the metabolic activity of certain bacteria. Even in the absence of additional selenium inflows, selenium within the sediment of the Sea would continue to enter the food chain for years to come (Setmire et al. 1993).

Selenium bioaccumulates in animal tissue as it passes up the food chain. Selenium levels in animals in and around the Sea have been recorded at levels ranging from 3.5 to 20 parts per million (ppm) in tilapia and corvina, to as high as 42 ppm in cormorants and black-necked stilts (Setmire et al. 1990). Measured levels of selenium in eared grebes have risen significantly in recent years, potentially weakening their immune systems (Setmire et al. 1990). Elevated levels of selenium may be responsible for an estimated 4 percent reduction in the reproductive success of black-necked stilts at the Sea (Setmire et al. 1990). In response to concerns about selenium accumulation, California's Health Advisory Board has issued a warning stating that people should not consume more than four ounces of fish caught in the Salton Sea in any two week period.

Table 4
Phosphate-Phosphorus and Total Nitrogen Inflows to the Salton Sea

	Alamo River	New River	Whitewater River	Total
Concentration (milligram/cubic meter)				
Phosphate-Phosphorus	882	906	1,031	
Total Nitrogen	9,745	6,794	13,693	
Annual Loading (tons)				
Phosphate-Phosphorus	556	555	140	1,251
Total Nitrogen	7,730	4,158	1,862	13,750

Source: Primary data collection by CRWQCB 1980-92. Data compiled by Richard Thiery, CVWD, in Cagle 1998

Table 5
Recommended Phosphorus and Nitrogen Loading Levels and Annual Areal Loadings of the Salton Sea
(grams/cubic meter)

Permissible		Dangerous		Salton Sea	
Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen
0.1	1.5	0.2	3.0	1.19	15.4

Source: Primary data collection by CRWQCB 1980-92. Data compiled by Richard Thiery, CVWD, in Cagle 1998

Other Contaminants

Other contaminants that enter the Salton Sea include pesticide residues, such as DDE, trace amounts of PCBs, and heavy metals such as arsenic and boron (Setmire et al. 1993).[11] Pesticide residues wash off agricultural fields in the Coachella, Imperial, and Mexicali valleys and eventually enter the Sea where, like selenium, they tend to bioaccumulate (Ogden 1996). High levels of DDT residues have been detected in some birds at the Salton Sea, particularly in birds that feed on invertebrates in agricultural fields (Setmire et al. 1993).

[11] The majority of these are historic residues of older halogenated pesticides that are currently banned in the United States and are no longer in use in the Imperial Valley. Some of these older chemicals, however, are still used in Mexico (Carpio-Obeso 1998).

Today, over 6 million pounds of pesticides are applied to crops in the Imperial Valley annually (de Vlaming et al. 1998). A water quality monitoring study conducted from 1993 to 1998 has revealed significant river-wide, pesticide-related aquatic organism toxicity in the Alamo River for five months out of each year (de Vlaming et al. 1998). The most recent two years of monitoring data showed that the Alamo River discharges toxic concentrations of two organophosphorus pesticides (chlorpyrifos and diazinon) into the Salton Sea near the National Wildlife Refuge for at least two to three months each year (de Vlaming et al. 1998). Pesticide residues in other parts of the Sea have not been detected at levels of concern (Eccles 1979; Setmire et al. 1993), but more research is needed on the presence and impacts of pesticide residues and other contaminants in the Sea (USFWS 1997a).

Water Temperature

The temperature of the Salton Sea affects many of the species in the Sea. Because the Sea is a relatively broad and shallow body of water, it responds relatively quickly to changes in air temperature. Average water temperatures in the Sea vary seasonally from the low 50s to the upper 90s (10° C to 36° C) (Barlow 1958); temperatures at the surface of the Sea vary more than 70 degrees annually. Water temperature is inversely correlated with dissolved oxygen concentrations, exacerbating fish kills in hot summer months (Molina 1996). Tilapia, the most abundant fish in the Salton Sea, are sensitive to water temperatures below 55° F and are subject to die-offs in cold winter months (Setmire et al. 1993). The range of water temperatures in the Sea is inversely correlated with the size of the Sea, suggesting that fluctuations will become more extreme as the Sea shrinks in coming years due to reduced inflows.

B. Ecology of the Salton Sea

The Salton Sea provides important habitats for a broad range of species, from open water to estuaries to salt marsh to riparian corridors, supporting extraordinarily high avian diversity. These habitats are especially vital given the elimination in the past century of more than 90 percent of the wetlands throughout coastal Southern California and California's Central Valley (Vileisis 1997), which formerly supported birds on the Pacific Flyway (USFWS 1997a).

Salton Sea Biodiversity[12]

The Salton Sea is characterized by large populations, short food chains, and frequent mortality events (Setmire et al. 1993). Nutrient-rich conditions in the Sea sustain huge numbers of invertebrates and a productive fishery that in turn support high avian diversity and populations. This ecosystem is disturbed periodically by fluctuations in concentrations of nutrients in the inflows and water temperatures, impacting both the populations of microorganisms and levels of dissolved oxygen.

The Salton Sea is home to the second-largest number of bird species in the United States (Setmire et al. 1990). More than 380 species of birds have been observed at the Salton Sea, including threatened and endangered species such as the Yuma Clapper Rail (*Rallus longirostris yumanensis*), the peregrine falcon (*Falco peregrinus anatum*) and the brown pelican (*Pelecanus occidentalis*). Large numbers of waterfowl, shorebirds, and fish-eating birds use the Sea for wintering and nesting (Setmire et al. 1990). At certain times of the year, the Salton Sea provides important habitat for tremendous populations of migrating birds. On one day in March 1998, an estimated 26,000 American white pelicans (*Pelecanus erythrorhynchos*), roughly the entire western population, were at the Sea (Anderson 1999). Species diversity at the Sea is highest in the expansive mud- and salt flats at the southern end of the lake, near the brackish

[12] See Appendix B for a more complete discussion of the Sea's biodiversity.

estuaries formed at the mouths of the rivers and drainage ditches (Setmire et al. 1993).

Yet many of the species inhabiting the Sea and its environs are non-native, a result of unsuccessful efforts to create an attractive recreational climate in the area. With the exception of the endangered desert pupfish (*Cyprinodon macularius*), all of the fish species in the Salton Sea are non-native. Most of these were introduced from the Gulf of California by the California Department of Fish & Game to create a sport fishery at the Sea (Setmire et al. 1993).[13] Of the 36 introduced anadromous and marine species, three—the gulf croaker, orangemouth corvina, and sargo—became established in the Salton Sea (Saiki 1990). The most common fish in the Sea, the ubiquitous tilapia, apparently entered the Sea from agricultural drainage ditches, where they were introduced by farmers to control aquatic weeds. No reliable estimates exist for the number of fish in the Salton Sea (USFWS 1997a).

Wetland habitat near Salton Sea National Wildlife Refuge. (Photo by M. Cohen)

Mortality Events

Recent widespread epidemics on the Salton Sea, in which more than 150,000 birds have died in a single year (USFWS 1997b), have attracted national attention. Large die-offs involving up to a million fish have also been observed at the Sea (USGS 1997b). Despite the paucity of longitudinal studies or reliable record keeping, a variety of sources indicate that fish and bird kills have occurred at the Sea for decades. Historical data at the Salton Sea National Wildlife Refuge document bird kills dating back to 1939 (K. Sturm, USFWS, personal communication, 1998). Large scale fish kills on the Sea dating back at least 30 years have also been reported by other sources (de Stanley 1966; Niver 1998), suggesting that the problems confronting the Sea are not new. There appear to be several different factors at play in the deaths of fish in the Salton Sea, reflecting an interaction of environmental factors, the presence of disease agents, and a surfeit of fish to serve as hosts. Major parasitic infestations appear to be widespread in the Sea (Kuperman and Matey 1999), potentially weakening fish and increasing their vulnerability to other factors. Environmental factors, such as de-oxygenation of the water column during Summer, and chilling injury of tilapia during Winter, are also responsible for mass fish kills (Setmire et al. 1993; Costa-Pierce 1997).

Despite recent interest in the ecology of the Salton Sea, there are huge gaps in the scientific understanding of the cause of specific disease events at the Sea. The genesis of the recent outbreaks at the Salton Sea of Type C avian botulism among fish-eating birds—the first recorded incidence of this strain of botulism in such birds—has not been conclusively determined. Several theories explaining this unusual occurrence have been proposed, generally identifying fish as a vector.

The Salton Sea tilapia mass-mortality events are an attractant for a variety of fish-eating birds (USGS 1996; Costa-Pierce 1997). Birds concentrate over schools of sick or dying fish in shallow water, though they appear to be less attracted to dead fish washed onto the shore (K. Sturm, USFWS, personal communication, 1998). Fish kills may be responsible for transmitting avian botulism and perhaps other diseases to the birds,

[13] See Walker 1961 for a historic description of the sport fishery at the Salton Sea.

1998 Gulf croaker die-off near Salton City. (Courtesy of Milton Friend)

Dead birds awaiting disposal at the Salton Sea National Wildlife Refuge incinerator. (Courtesy of Ken Strum)

which has resulted in the loss of thousands of migratory birds since 1992 (USGS 1996; USFWS 1997b; K. Sturm, USFWS, personal communication, 1999). Recent studies indicate that tilapia, the main food source for fish-eating birds in the Sea, are hosts for *Clostridium botulinum*, which produces botulism toxin (USFWS 1997b; Rocke 1999). At least some of the birds kills at the Salton Sea may be linked to infected fish (USGS 1996), although such linkage has not yet been established by rigorous research, nor has research demonstrating such a link been published in peer reviewed sources.

The total numbers of birds that have died at the Salton Sea is not known, though estimates exist for recent years.[14] More than 1,200 endangered brown pelicans died of avian botulism at the Salton Sea in 1996, in addition to nearly 19,000 waterfowl and shorebirds representing 63 other species. In 1992, more than 150,000 eared grebes died within a three-month period; the cause remains unknown. More than 10,000 birds, representing 51 species, died at the Sea in 1997. Another 17,000 birds, representing 70 species, died in the first four months of 1998, many from Newcastle disease and avian cholera. Efforts to address incidences of disease at the Sea have largely been limited to collecting and incinerating dead birds to limit the transmission of disease (Bloom 1998).

Connected Ecosystems: The Colorado River Delta and Upper Gulf

The Salton Sea and the Colorado River delta are part of the same regional, lower Colorado River ecosystem (Sykes 1937; Morrison et al. 1996). Hydrologically, the Salton basin formed part of the Colorado River delta and can therefore be considered part of the Colorado River basin. They are connected by riparian corridors along the Colorado, Hardy, New, and Alamo rivers, and by desert corridors through the Cocopa and Coyote Mountains and Laguna Salada. Both the Salton Sea and the delta support diverse habitat types, including low deserts, desert foothills, riparian woodlands, brackish wetlands, and hypersaline aquatic ecosystems.

The Colorado River delta-upper gulf ecosystem is one of the areas most adversely affected by the long history of water development in the Colorado basin. Human demands have dramatically reduced the natural flow of water

[14] Many of the mortality figures reflect carcass counts, in some cases augmented by estimates of additional, uncounted carcasses, and therefore almost certainly underestimate total mortality. Accuracy is higher for larger and endangered species, such as pelicans, while figures for smaller species, such as grebes, tend to reflect estimates and incidental counts (K. Sturm, USFWS, personal communication, 1999).

reaching the area, with impacts on fish, birds, plants, and the human communities dependent on these resources. Prior to major dam construction, the delta was lush with vegetation. It supported some 200 to 400 plant species, along with numerous birds, fish, and mammals. Although much of the delta has been converted into irrigated farmland, some 617,000 acres (250,000 hectares) of delta land remain at its southern end (Glenn et al. 1992). The loss of freshwater flow, however, has desiccated this portion of the delta, turning it into a mix of mud flats, salt flats, and dry sand. Wetland areas have shrunk dramatically, and now exist mainly where agricultural drainage water is discharged or where groundwater upwells onto mud flats. Despite these effects, the remaining ecoregion still comprises the largest and most critical series of desert wetlands in North America. Proposed as a Ramsar Site[15] because of its importance for migratory waterfowl and shorebirds, the Colorado River delta-upper gulf ecosystem supports a variety of endangered species.[16]

At its northern end, the delta contains the largest stands of cottonwood and willow gallery forest left on the Colorado River, as well as salt cedar and mesquite bosques.[17] Recent studies (Glenn et al. 1992; Glenn et al. 1996; Valdes et al. 1998) show that the flood flows since 1981 have created more riparian habitat in the delta than exists on the perennial stretch of river in the United States, from Davis Dam to the northerly international border. From Davis to Morelos Dam (just below the border) there are 82,500 acres (33,400 ha) of vegetation, whereas the delta has almost 150,000 acres (60,700 ha)(Valdes et al. 1998). Of that, almost 4,100 acres (1,660 ha) are high-quality cottonwood and willow-dominated gallery forest, in comparison to roughly 250 acres (100 ha) in the U.S (Valdes et al. 1998). The delta supports over 14,300 acres (5,800 ha) of marshlands compared to 10,000 (4,047 ha) acres in the U.S region.

The southern end of the delta links the riparian ecosystem with the upper Gulf of California marine zone, with estuary and shoals included in Mexico's federally protected Upper Gulf of California and Colorado River Delta Biosphere Reserve (Glenn et al. 1996; Valdes et al. 1998). The Biosphere Reserve was established in June 1993, and is operated through Mexico's National Institute of Ecology (INE), a division within the Secretariat of Environment, Natural Resources, and Fisheries (SEMARNAP). The Biosphere Reserve encompasses a total area of roughly 2.3 million acres (935,000 ha), comprised of a core zone of over 400,000 acres (165,000 ha) and a buffer zone of 1.9 million acres (770,000 ha). The Biosphere's main objective is to preserve the social development of the region, and to protect and restore the delta ecosystem. The core zone follows the United Nations Educational, Scientific, and Cultural Organization's (UNESCO) model for biospheres, prohibiting fishing,[18] petroleum exploration or extraction, hunting, or aquaculture (Turk Boyer 1993). Human activities in the core zone are limited to nonmanipulative research, ecotourism, monitoring, and environmental education. Sustainable resource extraction and the development of infrastructure to enable acceptable activities in the core zone are permitted in the buffer zone. Only 60 miles (100 km) separates the Salton Sea National Wildlife Reserve from the Biosphere Reserve in Mexico; the same birds may visit both reserves in one day. Figure 12 shows the core and buffer zones of the Biosphere Reserve.

Proposed as a Ramsar Site because of its importance for migratory waterfowl and shorebirds, the Colorado River delta-upper gulf ecosystem supports a variety of endangered species.

[15] The Ramsar Convention on Wetlands of International Importance, which came into force in 1975, is the intergovernmental treaty that provides a framework for international cooperation for the conservation and wise use of critical wetland habitats and resources.

[16] See Mellink et al. 1996, 1997 and Ruiz-Campos and Rodriquez-Merez 1997 for recent descriptions of the birds of the delta.

[17] See Ohmart et al. 1988 for a description of the United States reach of the lower Colorado River and Valdes et al. 1998 for a description of the delta.

[18] With the exception of the indigenous Cucupa people, who live in the delta.

Figure 10
Major Wetland Areas of the Delta Region

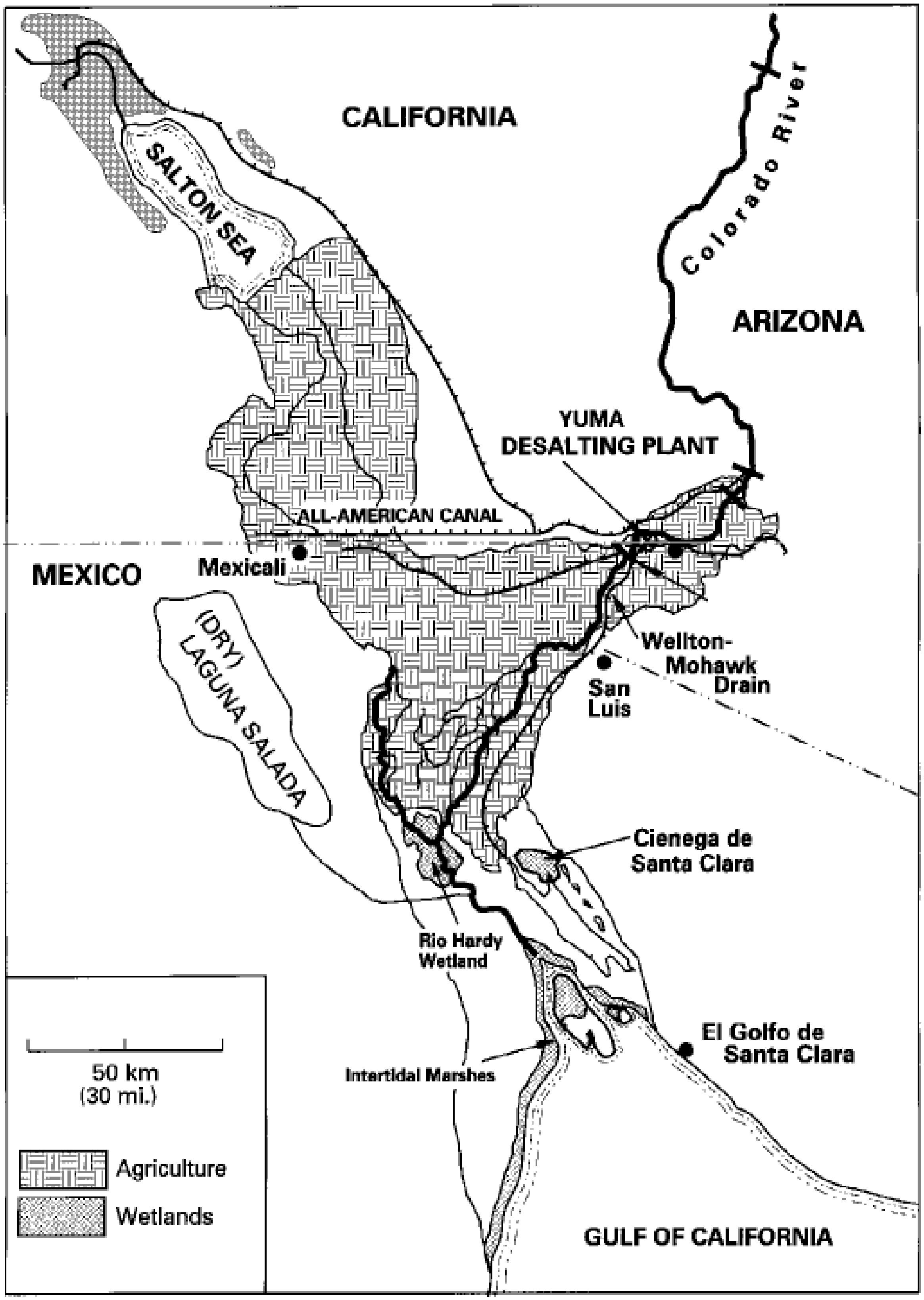
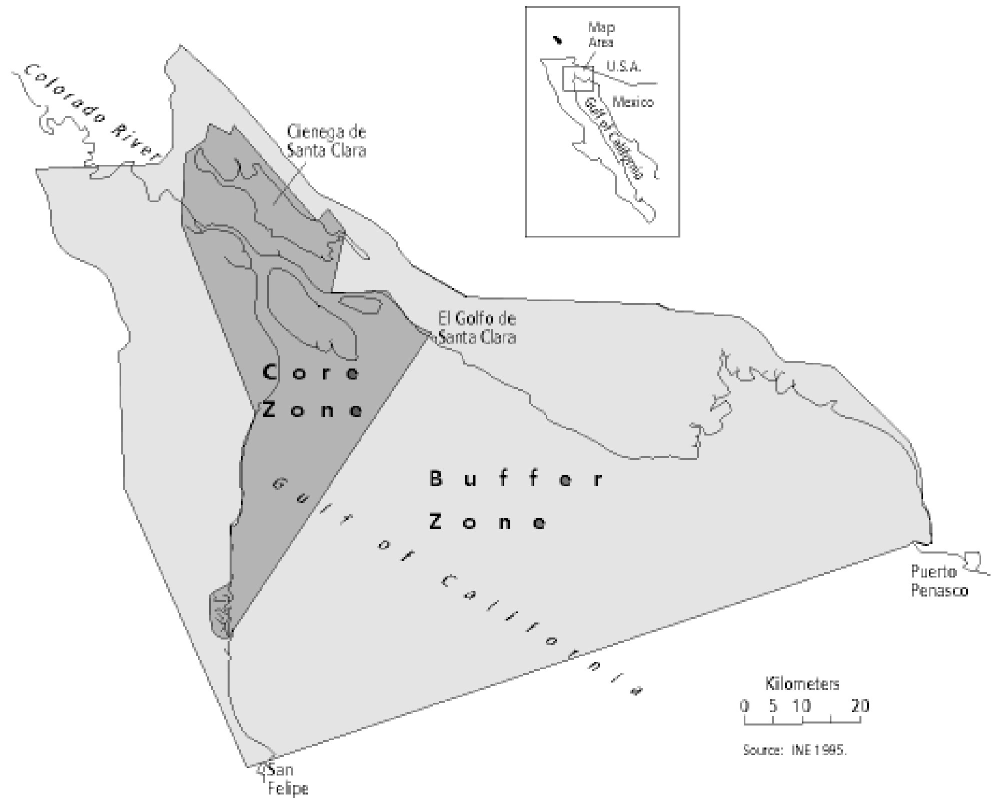


Figure 11
Colorado River Delta – Upper Gulf of California Biosphere Reserve



The reduction in freshwater flow from the Colorado River has reduced the influx of nutrients to the Gulf of California, one of the world's most productive marine ecosystems, and reduced critical nursery habitat for fisheries that thrive in the upper portion of the Gulf. Catches from the Gulf's shrimp fishery have dropped off steeply, and other fisheries are in decline as well. Unfortunately, empirical data do not exist to separate the effects of ecosystem changes from overfishing. However, flood flows into the marine zone have been shown to be positively correlated with the shrimp catch, creating an economic link between flood releases and the fishing communities of the northern Gulf of California (C. Gallindo-Bect, University of Baja California, submitted to NOAA Fisheries Bulletin).

A large number of species that depend on the lower Colorado-upper gulf ecosystem are now threatened or endangered, including the green sea turtle, the Yuma Clapper Rail, and the desert pupfish. Much attention has focused on the vaquita, the world's smallest porpoise and most endangered sea mammal, whose population in the upper Gulf is believed to number just a few hundred. Also of special concern is the totoaba, a steel-blue fish that grows up to 6 feet in length (2 meters) and 300 pounds (135 kilograms) in weight and that once supported a popular sports and commercial fishery. The fish used to breed in large numbers in the formerly brackish, shallow waters of the Colorado estuary while spending most of its adult life in the deeper waters of the upper Gulf. Between habitat degradation and overfishing, the totoaba is now threatened with extinction (Postel et al. 1998).

Flood flows into the marine zone have been shown to be positively correlated with the shrimp catch, creating an economic link between flood releases and the fishing communities of the northern Gulf of California.

Section III

Salton Sea Restoration

For more than 30 years, private entities and state and federal agencies have developed numerous proposals to restore the Salton Sea. Proposals have ranged from the construction of levees, impoundments, and solar power ponds to recent proposals to pump out contaminated brine and pump in ocean water from the Gulf of California or wastewater from metropolitan areas in Southern California. Most of these proposals have specifically addressed the salinity of the Sea, with varying economic and energy costs. Until recently, these proposals have foundered, primarily due to their considerable costs and the inability to secure funding. The proliferation of wildlife die-offs in recent years and the skiing death in 1997 of Representative Sonny Bono, an ardent proponent of Salton Sea restoration, have stimulated federal interest in the Sea's revival. A major factor in this new federal interest is the growing perception that the vital habitat offered by the Salton Sea makes it a national asset. Over the last four years, more than $20 million in state and federal funds have been allocated to study and address the problems of the Salton Sea.

The restoration of the Salton Sea is an extremely complicated endeavor, challenged by a paucity of baseline information pertaining to the biology of the Sea. Numerous interests, including landowners, large and small farmers in the Imperial Valley, and the nation as a whole, stand to benefit from some aspect of preservation or restoration of the Sea, though these benefits may not always be compatible. Further, crucial gaps exist in the scientific understanding of the cause of specific disease events in the Sea, as well as general processes such as nutrient cycles and the physical, chemical, and biological composition of the Sea's sediments. This makes it difficult to predict the long-term ecological impacts of any effort to restore the Sea.

Even the concept of restoration is not straightforward. The Salton Sea is part of a dynamic system that has witnessed the creation and evaporation of many "seas" in its current location. Restoration connotes the return of the Salton Sea to a previous state of ecosystem health and stability. Given the natural tendency of prior incarnations of the Sea to become increasingly saline and eventually evaporate entirely, returning the Sea to some pre-determined, static state and preserving it there requires the selection of a desired vision for the Sea. Such a vision would have to be clearly defined, both to ensure that any selected restoration plan can achieve the desired outcome and to generate public support for federal and state expenditures. Such a constructed, static sea would be continuously at odds with the natural forces of evaporation and would require continual management and monitoring.

Given the natural tendency of prior incarnations of the Sea to become increasingly saline and eventually evaporate entirely, returning the Sea to some pre-determined, static state and preserving it there requires the selection of a desired vision for the Sea.

This section describes the institutional and legal contexts framing the Salton Sea Restoration Project, including a discussion of the legislation authorizing restoration studies, other relevant federal and state laws, and the major stakeholders, interest groups and agencies involved in the process. In addition, this section includes a brief review and evaluation of the general restoration approaches currently under consideration, as well as a description of parallel activities occurring in the basin that have implications for the Salton Sea but have yet to be fully integrated into the restoration process.

A. Legal and Institutional Framework

The current restoration process is embedded in an institutional and legal framework of water rights and water uses. This framework also forms the backdrop for the ecological crisis at the Salton Sea, as well as the context for efforts to protect and restore threatened habitat and species in the West (cf. Williams and Deacon 1991). Federal water policy over the last century was designed to encourage settlement and the development of local, primarily agricultural, economies by subsidizing land acquisition and water and power infrastructure and prices (NRC 1992; Reisner 1993). These subsidies, in turn, have supported agricultural production as well as industrial development in the West, which is now the fastest growing and most urbanized region in the country (WWPRAC 1998). The doctrine of prior appropriation and federal reclamation law and their descendants, coupled with an era of water development, allocated a vast majority of western water to agricultural districts and provided access to large quantities of inexpensive water in areas such as the Imperial Valley (Fradkin 1981; Reisner 1993; deBuys in press).

More than 90 percent of the current inflows to the Salton Sea consist of Colorado River water. The Colorado River is governed by a complex body of state and federal laws, compacts, court decisions, and international treaties, collectively known as the Law of the River. California's use of the Colorado is defined within the Law of the River. Agriculture in Southern California holds water rights senior to those of all the Southern California metropolitan areas. California's Seven Party Agreement of 1931 established the priorities among the state's Colorado River water users. In order of decreasing priority, these seven parties are the Palo Verde Irrigation District, the Yuma Project, the Imperial Irrigation District (IID), the Coachella Valley Water District (CVWD), the Metropolitan Water District (MWD), and the City and County of San Diego. Imperial and Coachella Valley irrigation districts use an average of almost 3.2 million acre-feet (maf) of water annually, which is more than 20 percent of the Colorado River's annual average flow, and in turn contribute more than 80 percent of the water flowing into the Salton Sea.

The California Legislature enacted the California Limitation Act of 1929 to codify the state's agreement to limit its use to the 4.4 maf (plus its share of surplus flows) allocated by the Boulder Canyon Project of 1928. Yet California's Seven Party Agreement allocates 5.362 maf of Colorado River water, generating demand in excess of the legal entitlement and creating animosity with the other Colorado River basin states (Hundley 1975; 1986). Over the past decade, California has diverted on average more than 5.0 maf a year from the Colorado. Pressure is growing from the Secretary of the Interior and other basin states for California to reach agreement on a plan to reduce California's annual use to its legal entitlement.

Environmental Protections

Several environmental protection statutes, including the Endangered Species Act (ESA), the National Environmental Protection Act (NEPA), the California Environmental Quality Act (CEQA), and the Clean Water Act (CWA), directly affect the restoration of the Salton Sea. The ESA requires that federal agencies consult with the U.S. Fish & Wildlife Service (FWS) regarding projects that may impact endangered species or their designated critical habitat. Actions that jeopardize the survival of listed species are prohibited under the ESA.[19]

The ESA requires that the FWS designate critical habitat for listed species.[20] Critical habitat is defined as areas essential for the conservation of the species (Section 3(5)(A)). Section 3(3) of the ESA defines conservation as "the use of all methods and procedures which are necessary to bring any endangered or threatened species to the point at which the measures provided pursuant to the Act are no longer necessary." The designation of critical habitat proscribes the destruction or adverse modification of elements deemed essential for the survival of the species. This protection only applies to federal actions; however, the federal permitting process for actions on private property that include wetlands triggers the critical habitat review process.

The ESA has significantly impacted water use in the West, forcing a few water projects to be abandoned entirely (Wilson 1994). In

[19] Of the species identified in the Salton basin, the FWS has listed the desert pupfish, the peregrine falcon, the brown pelican, the Yuma clapper rail, and the bald eagle.

[20] The desert pupfish is the only species with designated critical habitat in the basin, along portions of San Felipe Creek, Carrizo Wash, and Fish Creek Wash near the Salton Sea (50 Fed. Reg. 10842).

United States v. Glenn-Colusa Irrigation District (1992), the court found that the irrigation district's water consumption was jeopardizing the survival of an endangered salmon species and diminished the district's water rights accordingly (Doppelt et al. 1993). In *Pacific Coast Federation of Fisherman's Associations v. Lujan* (1992), the court held that the ESA's protection of endangered salmon outweighed the Bureau of Reclamation's contractual obligations to provide water for consumptive use (Bolin 1993). A federal district court's decision in *Carson-Truckee Water Conservancy District v. Clark* (1984) required the Bureau of Reclamation to prioritize the habitat needs of endangered fish over municipal and industrial requirements when determining reservoir levels (Shupe 1986). While the ESA could potentially have significant implications for the Salton Sea Restoration Project, at this time it is uncertain the degree to which it will influence the process.

NEPA requires the preparation of an Environmental Impact Statement (EIS) for major federal actions significantly impacting the environment. CEQA requires the preparation of an Environmental Impact Report (EIR) for actions potentially affecting the environment in California. The primary purpose of an EIR is to disclose potential impacts on sensitive resources. Such impacts can often be mitigated by restorative actions elsewhere. An EIR is a discretionary document; even required mitigation can be avoided in some cases provided that sufficient benefits result from the action. An EIS is required to account for cumulative impacts in the area, including ongoing impacts generated by other parties and the potential for the proposed action to exacerbate the adverse effects of these other actions. The Salton Sea Restoration Project is subject to the procedural and substantive requirements of these environmental laws. The lead agencies are developing a joint EIS/EIR for release by January 1, 2000.

B. The Salton Sea Restoration Project

Initial authorization and funding for Salton Sea restoration came through Title XI of the Reclamation Projects Authorization and Adjustment Act of 1992 (PL 102-575). PL 102-575 directed the Secretary of the Interior, acting through the Bureau of Reclamation, to conduct a research project for the development of a method, or combination of methods, to reduce and control salinity, provide endangered species habitat, enhance fisheries, and protect human recreational values at the Salton Sea.

In response to pressure from the Inland Empire Congressional Delegation[21] and public concern regarding avian mortality at the Sea, Congress expanded both the authorization and funding available for the restoration of the Salton Sea. The Salton Sea Reclamation Act of 1998 (PL 105-372) directs the Secretary of the Interior (Secretary) to conduct formal feasibility studies and cost analyses of various options for restoring the Salton Sea. PL 105-372 states that these options must permit the continued use of the Salton Sea as a reservoir for irrigation drainage and: 1) reduce and stabilize salinity; 2) stabilize the surface elevation; 3) reclaim, in the long term, healthy fish and wildlife resources and their habitats; and 4) enhance the potential for recreational uses and economic development. Concurrent with the appraisal of restoration alternatives, PL 105-372 provides for scientific research on the ecology of the Sea.

In accordance with PL 105-372, the federal Bureau of Reclamation[22] and California's Salton Sea Authority are the lead agencies responsible for overseeing the Salton Sea Restoration Project. The lead agencies are expected to complete the feasibility study by January 1, 2000 and propose recommended restoration alternatives. Specifically, the Act directs the Secretary to identify options that are economically feasible and cost effective,

[21] U.S. Representatives Bono, Brown, Calvert, Hunter, and Lewis, from southern California.

[22] The Secretary of the Interior designated the Bureau of Reclamation as the federal lead agency for the Salton Sea Restoration Project. The Salton Sea Program is managed under Reclamation's Lower Colorado Regional Office. The Regional Office also manages the contracting and delivery of Colorado River water and power from Reclamation facilities in the lower basin, including water deliveries to the IID and CVWD.

to identify additional information needed to develop construction specifications, and to submit the Secretary's recommendations to the appropriate Congressional committees, consistent with a memorandum of understanding entered into among the Secretary, the Salton Sea Authority, and the Governor of California. PL 105-372 specifically states that these recommendations are to be based solely on whatever information is available at the time the report is submitted.

PL 105-372 states that the options to be considered in the feasibility study include, but are not limited to: impoundments to segregate portions of the Sea in evaporation ponds in the basin; pumping water out of the Sea; augmenting flows into the Sea; or a combination of these options, as well as any other economically feasible options the Secretary deems appropriate. The Secretary is to apply assumptions that take into account water conservation and water transfers out of the basin that may reduce inflows to the Sea to 800,000 acre-feet or less a year. The Secretary is also to consider the ability of various entities to cost-share capital, operation and maintenance, energy, and replacement costs with the federal government.

The Salton Sea Authority (Authority), the state lead agency for the project, is a public agency formed in 1993 as a Joint Powers Authority by the California Legislature under Articles I and II, Chapter 5, of Title I of the Government Code. The Authority was established for the purpose of "directing and coordinating actions relating to the improvement of water quality and stabilization of water elevation and to enhance recreational and economic development potential of the Sea and other beneficial uses, recognizing the importance of the Sea for the continuation of the dynamic agricultural economy of Imperial and Riverside Counties." The Salton Sea Authority is comprised of two representatives each of IID, CVWD, and Imperial and Riverside Counties. Currently, five ex-officio members sit on the Authority, representing the Torres-Martinez Desert Cahuilla Indian Tribe, the Coachella Valley Association of Governments, the California Department of Fish & Game, the Southern California Association of Governments, and the California State Resources Agency. Noteworthy is the fact that the legal mandate for the Authority focuses on continued agriculture in the region and recreational and economic development, and excludes any mention of ecological restoration. This narrow mandate excludes a significant element of the public interest.

Funding the Restoration Effort

Funding for the restoration effort has come from a variety of federal and state sources, including the U.S. Environmental Protection Agency (EPA) and a large water bond (Proposition 204 – The Safe, Clean, Reliable, Water Supply Act) approved by California voters in 1996 (see Table 6). Funding is important because it demonstrates priorities and the interest of legislators and the public to address the issue. Total funding for the restoration of the Salton Sea and related projects since 1994 exceeds $20 million. This does not include funding for the numerous studies of the Salton Sea over the past 30 years or other local or private efforts.

Stated Goals and Timeline for the Process

The Bureau of Reclamation and the Salton Sea Authority enumerate five long-term goals for the Salton Sea Restoration Project:

1. Maintain the Sea as a reservoir for agricultural drainage
2. Provide a safe and productive environment for resident and migratory birds and endangered species
3. Restore recreational uses
4. Maintain a viable sport fishery
5. Identify opportunities for economic development

The feasibility study portion of the restoration project is an iterative process, as the lead agencies have reviewed and eliminated proposed alternatives, based first on a set of screening criteria and subsequently on a set of evaluation criteria. The lead agencies developed three screening criteria to identify proposals that meet a pre-determined set of objectives: 1) stabilize the Sea's elevation at a

Table 6
Funding for the Study and Restoration of the Salton Sea

Year*	Amount	Source	Purpose
Various	$2,600,000	National Irrigation Water Quality Program	Basin water quality studies and programs
1994	$100,000	Title XI of Reclamation Projects Authorization and Adjustment Act of 1992 (PL 102-575)	Research on restoration of the Salton Sea
1995	$100,000	PL 102-575	As above
1996	$100,000	PL 102-575	As above
1997	$200,000	PL 102-575	As above
1998	$400,000	PL 102-575	As above
1996	$2,500,000	California Proposition 204	Salton Sea Restoration
1997	$60,000	California State Water Resources Control Board CWA 205(j)(2)	UC Davis modeling of New and Alamo rivers
1998	$900,000	EPA Office of Research and Development	Univ. of Redlands Salton Sea Database Program
1998	$1,000,000	U.S. Fish & Wildlife Service	Use at the Salton Sea
1999	$5,000,000	Salton Sea Reclamation Act, Title I (PL 105-372) (general authorization, appropriation through EPA)	Salton Sea Authority – Science Subcommittee research funding
1999	$3,000,000	Title II of PL 105-372 (appropriation through EPA)	Demonstration wetland projects on the Alamo and New rivers
1999	$2,800,000	EPA Office of Research and Development	University of Redlands Salton Sea Database Program
1999 operations	$1,000,000	California General Funds	Salton Sea Authority and California Fish & Game
1999	$300,000	California SB 1765	Study on seepage and subsurface inflows from All-American Canal
1994-99	$20,060,000	Federal and State Funding	Salton Sea Restoration Project and Related Scientific Research

** year = fiscal year*

Sources: Salton Sea Authority 1998; Johnson 1997.

target elevation of -232 feet msl; 2) reduce salinity to 40 ppt; and 3) only use proven technology. The lead agencies initially reviewed 68 proposals, drawn from a 1997 report[23] (USBR et al. 1997) and supplemented by suggestions from private companies and individuals. By October 1998, the lead agencies had eliminated 30 of these proposals due to their failure to meet the three screening criteria. These screening criteria reflect portions of the authorizing language of both PL 102-575 and PL 105-372; however, they exclude alternatives that would satisfy the other mandates listed in the authorizing language, such as those that would explicitly address other water quality issues or ecological considerations.

The evaluation criteria, on the other hand, reflect the weighted set of priorities of a broader public interest. The evaluation criteria and their relative weights are shown in Table 7. The lead agencies applied the evaluation criteria to rank those proposals that met the screening criteria. By December 1998, the lead agencies had further reduced the number of alternatives under review from the 38 that passed the screening criteria to five, using the evaluation criteria drawn from an April 1996 public workshop (cf. USBR et al. 1997). At this workshop, representatives from

[23] The lead agencies are no longer limiting themselves to the recommendations of their September 1997 report (USBR et al. 1997), which established as one of four criteria that operations and maintenance costs of any restoration program not exceed $10 million annually. This criterion excluded pump-out and desalinization alternatives.

Table 7
Evaluation Criteria Developed at April 1996 Public Workshop

Criteria	Weight
Agricultural Interests	33
Wildlife	32
Elevation	31
Disposal	24
Water Quality-Salinity	24
Water Quality-Other	21
Operation & Maintenance Costs	19
Finance Costs	17
Location	17
Construction Costs	14
Sport Fishery	14
Recreation	12
Economic Development	11
Intergovernmental Cooperation	9
Land	7
Time to Solution	6
Time to Construction	3
Partners	2

Source: USBR et al. 1997

IID, CVWD, Imperial and Riverside counties, the Bureau of Reclamation, the U.S. Fish & Wildlife Service, the California Department of Parks, the California Department of Water Resources, the California Department of Fish & Game, and the general public determined the relative weights of these evaluation criteria, using a paired comparison matrix.

The above evaluation criteria ascribe roughly equivalent priority to agricultural interests, wildlife, and elevation, and rank non-salinity water quality issues slightly below salinity issues. Yet these values are not captured by the lead agencies' screening criteria, which create arbitrary parameters giving priority to salinity and elevation while effectively excluding proposals that directly address wildlife values and other water quality issues. The three screening criteria favor the selection of a set of proposed alternatives that do not fully consider other public values. As shown in Table 7, wildlife values received the second-highest value, yet it is not clear how, if at all, the three screening criteria capture this interest. Also uncertain is whether the proposals selected using the three screening criteria can satisfy the other long-term objectives set forth by the agencies.

The legal mandate for the restoration of the Salton Sea only specifically addresses salinity. Yet salinity is only one of a number of water quality problems threatening the Salton Sea ecosystem. The mandate of the Salton Sea Authority is broader and includes improving water quality in general. However, as demonstrated by the specific project objectives, the lead agencies have limited themselves to a narrow definition of improving conditions at the Salton Sea. To date, the lead agencies have only selected alternatives that address salinity and elevation. For example, alternatives such as wetland filtration and better management practices for the application of fertilizers fail to meet the initial screening criteria established by the lead agencies and will not be considered for implementation in the first phase of the Restoration Project. The lead agencies maintain that data limitations constrain efforts to address water quality considerations beyond salinity.

To address expected needs in areas such as wildlife restoration and water quality in general, the lead agencies have indicated that they will institute a phased management program, initially called the Foundation for Adaptive Management. According to public presentations by the lead agencies, adaptive management:[24]

- allows for identification of activities that need additional research;
- stipulates that each proposed future action will require project-specific EIR/EIS documentation; and
- requires that assurance statements are incorporated into the EIR/EIS.

Phased management represents an important step, indicating that the lead agencies recognize that issues beyond salinity and elevation require remediation. However, the

[24] At the time of publication, the lead agencies had no publicly available information on the Adaptive/Phased Management component of the Restoration Project.

phased management program is not defined. Requiring additional EIR/EIS documentation for each additional action will create a significant institutional obstacle, imposing a large transaction cost on future efforts to address problems such as nutrient and selenium loading. Additionally, fragmenting the Restoration Project into a stepwise approach (i.e., first salinity and elevation, then water quality and ecological health) exposes the project to additional uncertainty and reduces the likelihood of broad support, due to multiple, incremental requests for additional funding and efforts.

The EIS/EIR component of the Restoration Project formally began June 1, 1998 and was initiated with a series of public scoping meetings held in the Salton basin from July 15-17, 1998. According to the lead agencies, public comments from the scoping phase are being compiled and will help inform the assessment of project alternatives. Table 8 depicts the official timeline for the Salton Sea Restoration Project.

Table 8
Timeline for the Salton Sea Restoration Project

Task	Date
Public Scoping Meetings	July 15–17, 1998
Preliminary Designs	August 1–September 18, 1998
Alternatives Screening	September–October, 1998
Appraisal Designs	November 15, 1998–February 15, 1999
Feasibility Design	March 15–November 1, 1999
Biological Assessment	July 1, 1998–June 30, 1999
Hydrology/Water Quality, Cultural Resources & Other Analyses	July 1, 1998–June 30, 1999
Draft EIR/EIS	September 1, 1999
Final EIR/EIS	January 1, 2000

Source: Salton Sea Authority & USBR 1998

Concurrent Research Activities

The Salton Sea Reclamation Act of 1998 authorizes a multi-track process. Concurrent with the feasibility study and the EIR/EIS, the Act establishes a Research Management Committee (Committee) to serve as an advisory body for scientific issues. The Committee is comprised of the Secretary of the Interior, the Governor of California, the Executive Director of the Salton Sea Authority, the Chairman of the Torres-Martinez Desert Cahuilla Tribal Government, and the Director of the California Water Resources Agency.

The working body of the Committee is known as the Science Subcommittee (Subcommittee), an entity that is responsible for coordinating studies (see Table 9) intended to address the significant lack of knowledge about the Salton Sea (cf. FWS 1997a). The Subcommittee was established to serve as an independent and objective body to determine information gaps, identify scientific research needs, and provide recommendations to the full Committee for funding priorities regarding the science activities. Scientific evaluations and recommendations are intended to guide the NEPA/CEQA process toward sound conclusions regarding alternative actions for restoring the Salton Sea. The Subcommittee serves as the key coordinating body for such scientific efforts.

The Subcommittee is comprised of individual scientific and technical experts appointed by officials of the following agencies:

- U.S. Army Corps of Engineers
- U.S. Bureau of Land Management
- U.S. Bureau of Reclamation
- U.S. Environmental Protection Agency

Table 9
Current Research Efforts Coordinated by the Science Subcommittee

Project Activity	Research Grant	Completion Date
Assessment of contaminants in bottom sediments	$210,000	April 2000
Avifauna – Species, Numbers, and Distribution	$209,000	February 2000
Biological limnology assessment	$750,000	February 2000
Fish biology and fisheries ecology	$250,000	February 2000
Physical/chemical limnology assessment	$300,000	February 2000
Survey of selected microbial pathogens	$300,000	February 2000

Source: Salton Sea Authority

- U.S. Fish & Wildlife Service
- U.S. Geological Survey
- Torres-Martinez Desert Cahuilla Indian Tribe
- California Department of Fish & Game
- California Department of Water Resources
- California Environmental Protection Agency
- Salton Sea Authority
- Imperial County
- Riverside County
- Coachella Valley Water District
- Imperial Irrigation District
- Imperial Valley College
- San Diego State University
- University of California, Riverside
- University of Redlands
- Los Alamos National Laboratory

Neither the Research Management Committee nor the Science Subcommittee includes representation from public interest groups or the environmental community. Also notable is the absence of scientists and public agencies from Mexico, which is significant because most of the proposed restoration alternatives would impact regions south of the border. Further, there is concern regarding the scope of research and the ability of the Subcommittee to have timely input. For a more detailed discussion of these concerns, see Section IV.

Salton Sea Restoration Alternatives [25]

Using the screening and evaluation criteria, the lead agencies have selected five alternatives for further consideration, in addition to the "no action" alternative required under NEPA and CEQA. These alternatives are:

- Pumping Salton Sea water to the Gulf of California and importing water through the Yuma area.
- Pumping Salton Sea water to the Gulf of California or the Pacific Ocean near Camp Pendleton and importing treated wastewater from San Diego.
- South Pond System (Dikes).
- Desalting Plant.
- Desalting Plant, Solar Salt Ponds.

The Pump-in/Pump-out Approach

The pump-in/pump-out alternatives are based on the premise that an outflow will address the accumulation of salts in the Sea. The pump-out alternatives would remove salts and reduce the volume of the Sea, while increasing the rate of dilution through a pump-in mechanism. Final locations of these pipelines have yet to be determined. Initial estimates for construction field costs of these alternatives range from $800 million to $1.45 billion, with annual operation, maintenance, energy, and replacement costs ranging from $8 million to $73 million[26] (USBR 1998b).

The benefits of pump-in/pump-out are that the salinity and elevation of the Sea could be managed effectively. Pumping water out of the Sea would also have some impact on other water quality concerns. The major drawbacks of this approach include the economic cost and the unknown ecological impacts. At the time of publication, the lead agencies had not decided the final locations of intakes and outflows for the system. The most recent published material (USBR 1998b) shows the pump-out alternatives terminating at the upper end of the Gulf of California, in the core zone of Mexico's Colorado River Delta-Upper Gulf of California Biosphere Reserve. The core zone is a rich nursery area for fish and crustaceans and is protected from disturbance by Mexican federal law (Morales-Abril 1994). Discharging Salton Sea water into the upper Gulf of California would have unknown, but potentially significant impacts on this protected ecosystem. A particular concern is that the discharge from the Salton Sea

[25] This does not include restoration alternatives proposed by other entities, such as the $5.1 billion proposal of the Salton Sea Authority's Economic Development Task Force. This proposal envisages the building of canal systems to the Gulf of California, including a 50-foot wide canal for water exchange between the Gulf and the Salton Sea and a 450-foot wide shipping canal that would extend from the Gulf to the southern outskirts of Mexicali, 8 miles south of the border (L. Anderson 1998b).

[26] Most of the cost estimates are based on assumed inflows of 1.35 maf/year. Assuming inflows of 1.0 maf/year could increase the cost of the project by more than sixty percent (USBR 1998b).

would adversely impact the eggs, larvae and fry of marine organisms in the core zone (S. Alvarez-Borrego, University of Baja California, unpublished observations).

Mexico's Laguna Salada has also been considered as a potential site for receiving Salton Sea effluent (cf. Quinlan 1997), though this alternative is not one of the five recently selected alternatives (USBR 1999). During dry years, discharge of Salton Sea effluent into Laguna Salada would potentially lead to the evapoconcentration of salts, nutrients, selenium and other toxic elements in the disposal basin, which could become an attractive nuisance to visiting wildlife, much like the current Salton Sea. Pumping out effluent into the Laguna Salada (and the Gulf of California) would also face institutional obstacles, including potential opposition from Mexico.

Diked Impoundments

The South Pond System calls for the construction of two dikes within the Salton Sea. The first would bisect the Sea at a location to be determined, while the second would create an isolated evaporation pond in the southern half of the Sea. Water from the Alamo and New rivers would be conveyed to the northern half of the Sea. This would lead to the dilution of the northern half of the Sea and would concentrate brine in the southern half (USBR 1999).

Potential benefits of this approach are that a diked impoundment would stabilize elevation and lower salinity and could maintain the shoreline of part of the Sea. Also, diking does not externalize the problem (aside from disposal of resultant salt residues), but does maintain recreational values and potentially enhances property values of reclaimed shoreline lands. A potential problem with a diked impoundment is that it would create an impounded area within the Sea containing supersaturated saline water, potentially a trap for wildlife. Further, diking would reduce the total usable area of the Sea by 10 to 30 percent or more, and may reduce the usable shoreline, depending on the location of the impoundment. Also of particular concern is the fact that the South Pond System would isolate the Salton Sea National Wildlife Refuge and the wildlife management area. Cost is also a significant consideration. Construction costs for this alternative have not been determined, but likely exceed $1 billion and potentially could cost as much as $2 billion, depending on the desired resistance to earthquakes (USBR 1998b). A dike failure could release concentrated brine into the rest of the Sea, with potentially catastrophic effects. Given the considerable seismic activity in the basin, this is a significant concern.

Discharging Salton Sea water into the upper Gulf of California would have unknown, but potentially significant impacts on this protected ecosystem.

Also, diked impoundments do not address—and may in fact exacerbate—problems associated with eutrophication, selenium, or contaminants in the Sea. At a November 1998 workshop (UC-MEXUS Workshop on the Salton Sea, Riverside, California), some of the potential effects of dikes on wind-driven circulation patterns in the Salton Sea were discussed. Diking could reduce the strength of the gyre (a whirlpool-like current), which mixes water in the southern part of the Sea, potentially increasing lake stratification and allowing a buildup of ammonia, hydrogen sulfide, and anoxic water on the lake bottom. Eventually, this bottom water could be rapidly mixed with the upper layers through storm events, leading to catastrophic fish kills. Mixing of anoxic bottom water into the water column is responsible for many of the current fish kills in the Salton Sea (Costa-Pierce 1997).

Desalinization

The two desalinization alternatives under consideration would pump water from the Sea to a reverse osmosis or multiple effect distillation desalting plant on the southern shore of the Sea. The resulting brine, with an estimated salinity of 69 ppt or 75 ppt, respectively, would be pumped to the Gulf of California. The filtered fresh water, with an estimated salinity of 0.45 ppt or 0.02 ppt, would then be returned to the Sea "or used for some other project purpose" (USBR 1999). Estimated construction costs are $435 million and $551 million, respectively, with annual costs of $56 million and $26 million[27] (USBR 1998b).

Benefits of desalinization include the ability to manage the salinity and elevation of the Sea, with potential beneficial implications for other water quality concerns. There are several potential drawbacks to desalinization. The solar pond alternative would require more than five square miles of solar pond surface area, replacing existing habitat with a potential ecological trap. Additionally, the low-salinity filtered water generated by the plants would be a valuable resource and could be used for some other project purpose, reducing or eliminating the diluting return flow to the Sea (USBR 1999).

Alternatives Eliminated from Further Consideration

The lead agencies have eliminated from consideration 62 of the 68 alternatives. These include simple pump-out operations, various combination plans, in-sea barriers, various other diking permutations, and a variety of other, generally untested proposals. The lead agencies have also eliminated from consideration alternatives that specifically address nutrient loading and other related water quality considerations. As noted above, the lead agencies eliminated these alternatives from consideration due to their failure to meet the initial screening criteria or because they did not rank sufficiently high according to the evaluation criteria.

C. Other Efforts Impacting the Salton Sea

A variety of public efforts with definite and quantifiable implications for the Salton Sea are presently occurring or are anticipated in the Salton basin. Yet to date there has been a pronounced lack of coordination among these various state and federal actions and the Salton Sea Restoration Project. Following is a brief review of these other efforts and their potential impact upon the Sea and restoration efforts.

Water Conservation Efforts

As discussed in Section II, numerous federal, state, and private-sector efforts are currently underway that will likely reduce the consumptive use of water in the Salton basin, with the expected result of reducing both the quantity and quality of inflows to the Sea.[28] These activities include the Bureau of Reclamation's efforts to reduce wasteful water use practices in the Imperial Valley and the recently signed transfer agreement between the San Diego County Water Authority and IID. Although extremely pertinent to the Restoration Project, these efforts have yet to be formally integrated into the process.

Over the last few years, Reclamation has increased its scrutiny of agricultural water use in California's low desert, particularly within the IID. However, to date, Reclamation has kept separate its role as the lead agency for the Restoration Project and its efforts to curtail inefficient agricultural water use in the basin. The lack of integration is evidenced by the current base assumption (used for modeling proposed alternatives) that 1.35 maf will continue to flow to the Sea on an annual basis (cf. USBR 1998b). In effect, one office of the Bureau of Reclamation is working actively to encourage IID to reduce its water consumption, while another office is ignoring these efforts and continues to assume that water use in the basin will continue at historical levels.

To date, Reclamation has kept separate its role as the lead agency for the Restoration Project and its efforts to curtail inefficient agricultural water use in the basin.

Further reductions in inflow are expected due to the recently signed water transfer agreement between the San Diego County

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[27] The lower annual costs of the latter alternative reflects projected savings in energy costs due to power generation of the associated solar salt pond.

[28] For a more detailed description of potential water quality changes, see the IID-SDCWA Water Transfer discussion in Section II.

Water Authority and IID, and canal lining projects associated with the transfer. In 1998, the California state legislature appropriated $235 million (SB 1765) from the General Fund for the purpose of assisting efforts to bring California's use of Colorado River water within its legal apportionment of 4.4 maf. SB 1765 appropriated an additional $300,000 to the Salton Sea Authority to fund a study, coordinated by the Science Subcommittee, on seepage and subsurface inflows to the Salton Sea from the All American and Coachella canals. SB 1765 calls for mitigation of foregone wildlife values that result from the lining of the canals. Environmental compliance documentation (EIS/EIR) will be compiled for several of these actions, yet little effort is being made to coordinate this documentation or to develop a holistic overview of the cumulative efforts of such actions on the Salton Sea and its environs.

Ongoing Attempts to Improve Water Quality in the Salton Sea Watershed[29]

Parallel efforts to improve regional water quality have not been adequately incorporated into the Salton Sea Restoration Project. In 1994, the Colorado River Basin Regional Water Quality Control Board (Region 7) adopted an updated Water Quality Control Plan (Basin Plan) that set forth designated beneficial uses, numerical and narrative water quality objectives, and implementation plans for the Colorado River Basin Region (RWQCB 1994a). In that same year, the Regional Board's Executive Officer sent a letter to IID requesting that IID "take accelerated action to address degraded water quality conditions in the Imperial Valley drainage ways" (RWQCB 1994b). In response, IID committed to developing a Drain Water Quality Improvement Program to address the non-point source problems in the District. The objective of the program is to reduce the amount of pollution in tail water and drainage discharges in order to protect the beneficial uses of the water bodies in the Imperial Valley—the New River, the Alamo River, Imperial Valley drains, and the Salton Sea itself.

By May 1998, the State Board and Region 7 developed the Watershed Management Initiative "integrated plan" to address water quality issues in the Salton basin. The integrated plan acknowledges that non-point source pollution from agricultural practices in the Imperial Valley represents a major threat to water quality in the Salton Sea Transboundary Watershed (RWQCB 1998). The primary management strategy for addressing this pollution in the Salton Sea and other regional water bodies is to develop and implement Total Maximum Daily Loads (TMDLs) for 16 water quality parameters, as required by the Clean Water Act. Region 7 will rely on non-regulatory, voluntary actions to improve water quality in the Salton basin. This includes working with stakeholders, such as IID and CVWD, the Authority, the Citizens Congressional Task Force on the New River, and federal and other state agencies.

Region 7 has announced its intention to coordinate its TMDL program for nutrients, salt, and selenium in the Sea with the Salton Sea Authority and the EIS/EIR process now underway. However, to date, these efforts to improve regional water quality have not been formally incorporated into the first phase of the Restoration Project. In fact, two primary arguments advanced by the lead agencies for focusing on salinity have been a lack of information regarding the effects of other water quality parameters, and the inability to adequately address them.

In addition to the efforts of the RWQCB, several small demonstration projects in the basin offer the potential for reducing the nutrient and contaminant loads of inflows to the Sea. The Bureau of Reclamation, IID, and Desert Wildlife Unlimited, a small locally-based environmental organization, are presently constructing demonstration projects (a 68-acre wetland and a 7-acre wetland) on the New River to investigate the potential for filtering agricultural drain water prior to dis-

[29] See Appendix A for more detailed information on the Clean Water Act and the efforts of the Colorado River Basin Regional Water Quality Control Board.

charge into the Sea. The Bureau of Reclamation is currently managing a small demonstration project to investigate the potential for anaerobic filtration of selenium from inflows to the Sea. The Torres-Martinez Desert Cahuilla Indian Tribe has also initiated a small reforestation project on the Whitewater River, intended to restore part of the riparian corridor that once thrived there. None of these programs has been integrated with the first phase of the Restoration Project.

Unsettled Torres-Martinez Indian Water Claims

The Torres-Martinez Band of Desert Cahuilla Indians is involved in several aspects of the current Restoration Project. As noted below, the Torres-Martinez has several outstanding claims regarding the Salton Sea. In addition to the Tribe's legal claims for reservation lands that have been inundated by the rising Sea, the Torres-Martinez has specific concerns about the preservation of its cultural resources. The federal, state, and local governmental agencies maintain that legal issues pertaining to the claims of the Torres-Martinez are separate and will have to be resolved by Congress and the appropriate parties, and not through the restoration process. However, without linking the two processes, there is a danger that actions taken within the context of the Restoration Project may preclude a just settlement of the Tribe's claims.

The Torres-Martinez Band of Desert Cahuilla Indians: The "Underwater Reservation"[30]

In 1909, the US Department of the Interior (DOI) reserved in trust for the Torres-Martinez Band 10,000 acres of land that had been inundated by the Sea as a result of the Colorado River breakout in 1905-06. This added to its existing reservation, much of which had also been inundated by the accidental diversion. It was presumed at the time that the Sea would evaporate in about 14 years and the land could be reclaimed and farmed. However, by 1920, it was clear that the irrigation drainage water from the Imperial Valley was going to sustain the Sea and the Tribe's land would continue to be inundated.

In 1924 and 1928, President Coolidge designated the lands occupied by the Salton Sea, including lands reserved for the Tribe, as a drainage reservoir for the Imperial Irrigation District's waste water. This was done, apparently, without realizing that some of these lands had previously been reserved for the Tribe in 1891 and in 1909.

In 1982, the Department of Justice filed suit against the IID and the Coachella Valley Water District on behalf of the Torres-Martinez, alleging trespass and asking for damages for the loss of use of the lands. The Tribe was never formally notified of the lawsuit and learned of it indirectly. The Tribe was unable to have its own attorneys represent them in the case and had to accept representation by the Department of Justice. The case dragged on for years while, in the meantime, the IID settled scores of private lawsuits for damages from the inundation, for millions of dollars.

The lawsuit on behalf of the Tribe was finally tried in 1992, with the government asking for some $69.5 million in damages. During the trial, no member of the Tribe was called to testify. The judge awarded only $3.9 million in damages (the defendants had offered to settle for $5.3 million).

The Tribe later sued the U.S. for malpractice and breach of trust based on inadequate representation of the Tribe. In subsequent negotiations with the U.S., the Tribe asked for lands in replacement of the submerged lands and additional money damages. A tentative deal was struck whereby the Tribe would receive 11,800 acres of Bureau of Land Management (BLM) land and

[30] This summary is taken from a chapter of a forthcoming book by William deBuys, entitled *Salt Dreams*.

about $7 million from the government in additional damages. The Justice Department, however, refused to approve the deal. Opposition to the deal also was expressed by the gaming industry based on the Tribe's expressed desire to build casinos on the reservation. Opposition included the Cabazon Band, which has a casino, and also the Marriott Corporation, which did not want to see casino hotels competing with its destination resorts in the Coachella Valley. Bills introduced in Congress in 1996 to implement a settlement failed in large part because of this opposition. In addition, the proposal to exchange the submerged lands for other BLM lands to the north failed because the California Desert Protection Act had removed much of the BLM desert lands as exchange lands.

The 1992 decision is still on appeal before the Ninth Circuit Court of Appeals, but the appeal has been stayed pending efforts to negotiate a settlement. Since efforts to reach a settlement in Congress have stalled, the appeal may proceed.

The government is in a somewhat conflicted position; the Justice Department must argue in the appeal that the judge should have enjoined the continued inundation of tribal lands and could not legally "take" tribal lands (only Congress can do that), while at the same time the Department of Interior is pursuing an EIS to determine a clean-up plan for the Sea that could maintain the inundation. Currently, the Tribe is seeking an appraisal of the fair market value of the submerged and damaged lands (some 28,000 acres, which is most of its trust lands). Presumably, if the appeal is successful, Congress will have to address this issue at some point.

According to the Tribe's attorneys, Representative Sonny Bono supported including a settlement of its claims in the legislation. However, when the Salton Sea legislation was introduced in the 105th Congress, this was not included. The Torres-Martinez advocates attempted to add a $100 million settlement component to the bill, but this was unsuccessful.

Section IV

Principles and Recommendations for Environmentally Sustainable and Socially Equitable Salton Sea Restoration

In this section we present a set of seven principles that can be used to guide the selection and implementation of an environmentally sustainable and socially equitable restoration plan for the Salton Sea. More specifically, we describe each of the seven general principles and their rationale, as well as a set of specific corollary recommendations for each. We compare these principles with the goals and assumptions driving the Salton Sea Restoration Project. It is our contention that some of Restoration Project's assumptions are not well grounded, that they limit the scope of the assessment, and that they will not satisfy the stated long-term objectives of the restoration. The principles below provide a framework against which existing and future proposals may be judged.

1. *The primary goal of any restoration plan must be to provide for a healthy ecological system and protect human health.*

The impetus for public support for federal intervention regarding the Salton Sea is the failing health of the ecosystem. The continuing decline of the Salton Sea ecosystem, rather than economic investment in a recreational area or the protection of agricultural interests, is the most salient rationale for federal economic assistance for the Sea. The restoration and preservation of the Salton Sea's ecosystem are important for four reasons: the protection of endangered and threatened species and their habitat is required by the Endangered Species Act; public support for federal intervention is contingent upon ecological preservation; four of the five long-terms objectives listed by the lead agencies are unattainable without a healthy Salton Sea ecosystem; and adequate protection of human health requires reversing environmental degradation.

Improving the Sea's aesthetics and ecosystem health is a precursor to economic redevelopment around the Sea, including the Sea's ability to attract investment and generate recreation-based revenues. According a high priority to the Sea's ecology is compatible with ensuring that the Sea continues to receive agricultural return flows, as the wildlife habitat at the Sea could not exist without these flows. However, the quality of agricultural drainage will have to improve over time in order to ensure the long-term viability of the system.

The general public associates the Restoration Project with an effort to address the ecological problems that characterize the Salton Sea. The Project is not viewed as an economic redevelopment effort; economic benefits may accrue from ecological restoration, but are not seen by the public as the main goal and justification for public funds. Ecological preservation should be the primary objective of the Project.

According a high priority to the Sea's ecology is compatible with ensuring that the Sea continues to receive agricultural return flows, as the wildlife habitat at the Sea could not exist without these flows.

Recommendations

A. Expand the Restoration Project's objectives to give a higher priority to the restoration and preservation of ecosystems at and around the Salton Sea.

At present, existing plans for Salton Sea restoration do not adequately address the ecological health of the Sea and related aquatic ecosystems. The Restoration Project's stated objective, "provide a safe, productive environment for resident and migratory birds and endangered species," is too restrictive and should be expanded to include the health of the ecosystem as a whole.

The project should evaluate the potential impacts of restoration actions on the full range of biota in and around the Salton Sea. The complex mosaic of habitats associated with the Salton Sea should be assessed and protected as part of any restoration effort. This includes the riparian corridors buffering the major tributaries to the Sea. Restoration of riparian corridors and wetlands along the New and Alamo rivers could provide vital habitat and also serve as a filtering mechanism for improving water quality before it reaches the Sea. The implications of Salton Sea restoration alternatives for the regional ecosystem, including the Colorado River delta and upper Gulf, must also be considered.

Several of the stated objectives (i.e., restore recreational uses, economic redevelopment) of the Restoration Project are in potential conflict with ecosystem health, but few details have been provided on how protection of natural areas and other designated uses of the Sea will be reconciled. Any restoration plan should consist of a clearly defined strategy for accommodating competing values for the Sea, including a spatial analysis of the impacts of recreational areas and commercial lakeshore development on wildlife habitat areas. Further, several of the restoration alternatives currently under consideration, such as dikes or potential sites for pumping or filtration infrastructure, would adversely impact existing habitat near river deltas and in and around the National Wildlife Reserve. Such alternatives should be evaluated in terms of their potential impacts on habitat; preserving shorefront access in resort areas should not be preserved at the expense of national wildlife refuge land.

B. Explicitly address impacts to human health in the restoration plan.

A detailed plan for protecting and improving human health throughout the Salton Sea basin is not currently a component of any proposed restoration plan. Human health is threatened by current conditions at the Sea, as evidenced by the Health Advisory Board's warning against consuming more than limited amounts of fish from the Sea. Also, scientific studies have identified the presence of agents in the Salton Sea that "could result in episodes of human disease, including polio, typhoid, cholera, and tuberculosis" (USFWS 1997a).

A credible restoration plan for the Salton Sea should carefully evaluate future impacts to human health in the region. A potential threat to human health arises from the expected lowering of the surface of the Salton Sea. Unless this process is carefully managed, it could expose tens of thousands of acres of lakebed, potentially dispersing large quantities of airborne pollutants. Addressing this potential threat will require a better understanding of wind patterns in the basin, as well as the composition and friability of the lakebed. The socio-economic impacts of contaminated dust storms blowing through the basin should be specifically addressed in the EIS/EIR. Recent efforts of the Salton Sea Science Subcommittee to coordinate with California's Air Resources Board on this topic represent a positive step toward addressing these concerns, and should be continued.

2. Any restoration plan should be firmly grounded in a scientific understanding of the ecology of the Salton Sea and related ecosystems.

It is critical that a scientific understanding of the biology of the region be incorporated into the restoration process prior to the implementation of any restoration plan. Sustainable restoration of the Salton Sea requires a sufficient understanding of the factors creating the current crises, as well as the ecological implications of future actions. Although there is a need to begin ameliorating the problems of the Sea, current scientific understanding of the relationship between the Sea's water quality problems and ecosystem health is limited. Recent reports (cf. FWS 1997) attest to the significant gaps in our understanding of the existing species and processes in the Sea, as well as the limits to our understanding of what realistically can be done to improve the ecology of the Salton Sea.

The current research sponsored by the Science Subcommittee is an important and useful step in addressing these research gaps. However, it is uncertain whether this initial research will be sufficiently integrated into the selection of a restoration alternative. The fact that the lead agencies are moving forward with the selection of preferred alternatives prior to the completion of the Science Subcommittee-sponsored research indicates the lack of a scientific foundation for the current process. The scientific baseline studies will not be completed by January 2000, by which time the feasibility study is scheduled for submittal to Congress. Recent discussions of the Science Subcommittee suggest that the lead agencies' selection of a preferred alternative will be delayed until more information is available from the Subcommittee. This would be a critical and welcome step forward, recognizing the importance of developing a solid understanding of the ecology of the Salton Sea before taking steps to restore it. The decision to postpone the selection of a preferred alternative until the scientific baseline research is completed should be memorialized and publicized by the lead agencies.

To limit the spread of disease, U.S. Fish and Wildlife Service staff collected and incinerated dead birds. (Courtesy of Ken Sturm)

Recommendations

A. Establish a comprehensive environmental baseline for the Salton Sea and its environs before conducting feasibility studies of restoration alternatives.

The arbitrary and unrealistic scope and deadlines in the Salton Sea Reclamation Act of 1998 hamper the lead agencies' ability to develop an effective and sustainable plan for the restoration of the Salton Sea. Federal lawmakers should extend the timeline for the completion of the restoration plan to ensure that the recommended course of action is firmly grounded in the science of the Sea. It is fundamentally unsound policy to invest substantial sums of federal dollars for ecosystem restoration until there is an understanding of whether the proposed infrastructure will in fact improve ecological conditions at the Sea.

The environmental baselines for the Salton Sea ecosystem should be the measure against which alternatives for restoration are compared. The current process is flawed for several reasons. The lead agencies developed the screening criteria without a full understanding of the processes affecting the Sea, meaning that the lead agencies selected alternatives based on incomplete and perhaps tangential information. This selection process threatens the implementation of a restoration plan based on a sufficient understanding of the Sea, increasing the probability that any such restoration plan will fail. Restoration of the Sea based on inadequate scientific research will likely squander the best opportunity available to address the long-term problems confronting the Salton Sea and its environs. The Secretary of the Interior should not succumb to political pressure to submit a plan to Congress until the long-term environmental and economic impacts can be fully considered to ensure that the public interest will be protected. The lead agencies should publicize any decision to change the current process.

The arbitrary and unrealistic scope and deadlines in the Salton Sea Reclamation Act of 1998 hamper the lead agencies' ability to develop an effective and sustainable plan for the restoration of the Salton Sea

B. Consider the benefits and shortcomings of allowing salinity in the Sea to increase unimpeded.

Although the Pacific Institute does not necessarily endorse allowing the salinity of the Salton Sea to continue to increase unimpeded, we believe this alternative must be thoroughly considered. The potential magnitude of the costs and the uncertain ecological benefits and impacts associated with an infrastructure-based restoration plan underscore the importance of an objective analysis of whether a plan to reduce salinity is cost effective and will provide the expected benefits for the ecosystem. However, to date, the lead agencies for the Restoration Project have not given serious consideration to allowing salinity at the Sea to increase. In fact, one screening criterion – stabilize salinity at 40 parts per thousand – automatically precludes this alternative from consideration. It should be noted that all of the stated long-term objectives for Salton Sea restoration, with the exception of maintaining a viable sport fishery, can potentially be achieved without reducing and stabilizing salinity.[31] Upon further investigation, it might become evident that it is much easier and more desirable to manage the Salton Sea as an ecologically-stable salt lake than as an artificial, quasi-marine ecosystem which cannot be sustained without massive, ongoing human intervention.

The potential magnitude of the costs and the uncertain ecological benefits and impacts associated with an infrastructure-based restoration plan underscore the importance of an objective analysis of whether a plan to reduce salinity is cost effective and will provide the expected benefits for the ecosystem.

The lead agencies project that the salinity of the Salton Sea is increasing at a rate double that revealed by the empirical record. Preliminary studies (Tostrud 1997; Richard Thiery, CVWD, personal communication, 1999) suggest salinity is increasing at a lower than expected rate because the solubility limit of some salts may have been reached. If correct, this has major implications for any salinity-based restoration project. Further research is required.

Scientific research is needed to acquire a better understanding of a "no action" alternative, itself a necessary component required by law. This includes an objective analysis of whether a plan to reduce salinity will provide the expected ecological benefits for the ecosystem. Without a clear understanding of the current condition of the Sea and informed predictions of what conditions will be in the near and distant future, policymakers can not reasonably expect to make sound decisions. Recent discussions of the Science Subcommittee indicate a willingness to pursue a more detailed evaluation of the ecological implications of increased salinity at the Salton Sea, a research endeavor the Pacific Institute strongly encourages.

A "no action" alternative should include a credible appraisal of the costs and benefits of not addressing salinity, and would identify affected stakeholders of that outcome. The scope of work should also include an assessment of the effects of reducing nutrient and selenium loading, while allowing the concentration of salts to fluctuate naturally. See Appendix B for a more detailed description of the increased salinity alternative and its potential merits.

3. *Any restoration plan should address all the water quality factors responsible for the current problems at the Salton Sea.*

Increasing salinity at the Salton Sea is but one of a host of factors responsible for the ecological and economic problems at the Sea. The current Restoration Project's focus on salinity, to the exclusion of other factors, will not remedy the unsafe environment for resident and migratory birds and endangered species, or restore recreational uses.

The lead agencies have acknowledged the need to address nutrient and selenium loading, although not as a first-phase priority. Only after the completion of the feasibility studies and the recommendation of a preferred alternative will the full range of pollutants impacting life in the Sea be addressed. These other water quality problems are to be addressed through a multi-phase program. However, at the time of this publication, the lead agencies had not defined this phased program beyond a cursory description of the basic program objectives. These objectives themselves are a further source of concern,

[31] See Principle 6 and Appendix B for a discussion of the implications for the Salton Sea as a stopover on the Pacific Flyway.

as they would create a significant institutional obstacle, requiring that each proposed future action involve project-specific EIR/EIS documentation. This would impose a large transaction cost on future efforts to address problems such as nutrient and selenium loading. An additional consideration is that fragmenting the Restoration Project into an multi-phased approach exposes the project to additional uncertainty, due to multiple requests for additional authorization and funding. The uncertainty of future phases of restoration reduces the likelihood of broad public support.

Recommendations

A. Expand the first phase of the Restoration Project to address agricultural, industrial, and municipal pollutants.

The Restoration Project is flawed by the limited legislative authorization of the process. Selectively addressing salinity and elevation while permitting the Sea to remain eutrophic, with increasing concentrations of selenium, pesticide residues, and other contaminants, will undermine and eventually defeat efforts to reinvigorate its ecological health and improve its recreational potential. Reducing salinity without addressing all of the factors causing the current problems will prevent any restoration effort from achieving all but the first of the project's stated objectives. This is not a new observation. Of concern is the reiterative nature of the assessment process and the fact that, despite the numerous public and agency comments on previous assessments (cf. Ogden 1996), the Restoration Project continues to focus on salinity and elevation while effectively ignoring nutrient and contaminant loading and source reduction plans.

The lead agencies should expand the first phase of the restoration plan to include the full range of factors affecting water quality. Because several of these factors are related to current agricultural practices, the potential for source reduction as a means of abating pollutant inputs to the Salton Sea should be

Eutrophication is believed to be a primary factor responsible for many of the fish die-offs at the Salton Sea. (Courtesy of Ken Sturm)

explicitly addressed in the Restoration Project. It has been stated that changing on-farm management practices to reduce pollutants, such as nutrients, is not a cost-effective approach (RWQCB 1998). But in fact reduction of non-point and point source pollution may represent one of the cheapest approaches to ameliorating some of the problems at the Sea, when compared to the enormous cost of infrastructure-based alternatives, costs that can range as high as $4.7 billion. Projects to reduce the concentration of selenium entering the Sea should be included as part of the restoration process.

Reduction of non-point and point source pollution may represent one of the cheapest approaches to ameliorating some of the problems at the Sea.

B. The Regional Water Quality Control Board, Region 7, should place a higher priority on development of Total Maximum Daily Loads (TMDLs) for nutrient loading in water bodies of the Salton Sea watershed.

Region 7 has developed a Watershed Management Initiative "integrated plan" to coordinate the development and implementation of 16 TMDLs to reduce (in order of Region 7's priority) silt, insoluble pesticides, selenium, soluble pesticides, nutrients, and bacteria in the waterways of the Salton Sea watershed.

The TMDLs for nutrient loading are not scheduled for development until 2002, but should be given a higher priority to reflect the ecological problems associated with nutrient inputs into the Salton Sea.

4. *Parties responsible for the current problems facing the Salton Sea and beneficiaries of its restoration should bear an equitable share of the costs.*

The distribution of benefits and costs to be generated by each restoration alternative must be considered. There is a legitimate concern that U.S. taxpayers will subsidize a massive redevelopment program that benefits a small number of landowners. A fundamental premise of any restoration plan must be that the beneficiaries of the Sea's designation as a repository for agricultural waste, as well as those property owners who stand to gain from improving the Sea, should contribute to the costs of restoration. An equitable solution is one in which those responsible for the current problem assume some of the costs of addressing it.

Relying upon large-scale development of the Salton Sea to fund its restoration could ultimately destroy the very environment restoration was meant to save.

Much of the current predicament at the Salton Sea can be attributed to human action, particularly the intensive use of water and fertilizers in the Imperial Valley. To a great extent, these actions have been encouraged by the heavily-subsidized price of water and by the ability to externalize the costs of excessive fertilizer and pesticide use, costs that are subsequently borne by the environment in general and the Sea in particular. It is not cost-effective or in the best interests of U.S. taxpayers to finance symptomatic, end-of-pipe fixes when source reduction efforts offer the potential for greater efficiency and efficacy and long-term sustainability.

Bazdarich (1998) suggests levying various forms of transfer taxes as a means of funding the restoration of the Sea. Such an approach is appealing because those benefiting from restoration share in its costs. However, such a property tax-based funding scheme requires a significant increase in the quantity and desirability of developed real estate, which in turn could generate significant environmental impacts. Relying upon large-scale development of the Salton Sea to fund its restoration could ultimately destroy the very environment restoration was meant to save.

Recommendations

A. Federal funding for the restoration plan should be contingent upon demonstrable benefit to the national interest.

Despite the fact that Salton Sea restoration cannot be justified solely on economic terms, society may deem the ecological importance of the Sea worthy of the expenditure of funds. Benefits to the public interest include, but are not limited to, protection of endangered species, restoration of the National Wildlife Refuge, and meeting international obligations under treaties and multilateral environmental agreements, as well as improving the quality of life of people in the region.

A first step in assessing the degree of federal involvement would be to determine the short and long-term economic benefits of stabilizing the Sea's elevation and improving aesthetics, and who will benefit from this. Bazdarich (1998) predicts tremendous economic growth around the Salton Sea, driven primarily by increasing property values as the Salton Sea becomes a more attractive locale.

Although the report makes several questionable assumptions,[32] it does identify landowners around the Sea as a class of potential beneficiaries of restoration. The scope of the economic assessment of the restoration project should be sufficiently broad to capture the potential environmental impacts of increased development around the Salton Sea.

[32] Assumptions of the report include stabilizing the Sea at its current elevation, addressing eutrophication, and that land values around the Sea will approach or exceed those of other waterfront desert areas in the region.

B. Beneficiaries of transfers of Imperial Irrigation District water to the metropolitan areas of Southern California should internalize some of the costs associated with restoring the Sea.

Current and proposed water transfer agreements involving IID could exacerbate the concentration of salinity and other constituents in the Sea by reducing inflows. Parties to these transfer agreements should contribute an equitable share of the costs associated with restoring the Sea.

5. Any restoration plan must be compatible with region-wide water conservation and voluntary reallocation programs.

To make valid engineering and restoration recommendations, an estimate of future inflows to the Salton Sea will be necessary, which requires a comprehensive water balance for the Salton Sea. Arbitrarily determined annual inflows and concomitant lake levels should not undermine potential conservation measures in the region. The restoration of the Salton Sea should not hinder more efficient use of water in the region, nor should it necessitate augmenting inflows to the Sea with Colorado River water in order to maintain an arbitrarily selected elevation. At a minimum, it is essential that water conservation efforts in the basin not be held hostage to a restoration plan that requires current inputs be maintained. Such a course of action could negatively impact water and ecological issues in the Colorado River basin for decades to come.

Current inflows to the Salton Sea average approximately 1.35 million acre-feet per year, but several factors indicate that this figure will decrease significantly in the future (see Section II), a likelihood that should be better integrated into the assessment process. The Salton Sea Reclamation Act of 1998 (PL 105-372) states that the restoration appraisal should recognize that inflows to the Salton Sea could decrease to 800,000 acre-feet or less per year. The timing of these flow reductions is difficult to predict accurately, adding additional uncertainty to the planning process. However, to date, the lead agencies have not appropriately integrated expectations of more efficient agricultural water use rates into the Restoration Project. This failure is evidenced by the continued base assumption (used for modeling proposed alternatives) that 1.35 maf will remain flowing to the Sea on an annual basis (cf. USBR 1998b).

It is essential that water conservation efforts in the basin not be held hostage to a restoration plan that requires current inputs be maintained.

Recommendations

A. Address the likelihood that inflows to the Salton Sea will decrease substantially in the future.

The likelihood of significant reductions in the quantity of inflows to the Sea suggests that the chosen restoration plan must be sufficiently flexible to incorporate markedly different inflows and lake levels. Any restoration plan must account for and integrate planned and projected water conservation efforts within the basin, as well as future urban transfers.

6. Any restoration plan for the Salton Sea must be compatible with protection and restoration of the Colorado River delta, Upper Gulf of California, and other ecosystems in the region.

The Salton Sea should be addressed from a regional perspective that includes analyzing potential impacts on interrelated ecosystems. Its restoration should not be accomplished by compromising the ecological and/or human health of other areas, such as the Colorado delta and upper Gulf. Externalizing the problems of the Salton Sea by pumping brine and pollutants out of the basin would inappropriately remove the burden from those responsible for the current problems and redirect it to others. Furthermore, pump-out alternatives currently under consideration will create additional problems

Like the Salton Sea, wetland areas in the Colorado River delta, such as the Rio Hardy system (top) and the newly formed El Indio marshland provide vital habitat for migrating birds on the Pacific Flyway. (Photos by J. Morrison)

elsewhere. Improving one ecosystem by destroying another is not a sustainable solution, and will likely only lead to future expenditures to remedy future problems.

A benefit of taking a regional approach is added flexibility. Within the broader context, it is possible to preserve the region's integrity as a stopover on the Pacific Flyway, even if the Salton Sea were to continue to increase in salinity. Freshwater habitats for some fish-eating birds currently exist in the delta region and could be expanded, at a fraction of the cost estimated for the Salton Sea restoration alternatives. Unlike the closed Salton basin, the delta system is a natural flow-through system, reducing concerns about the accumulation of toxics in the system.

Within the broader context, it is possible to preserve the region's integrity as a stopover on the Pacific Flyway, even if the Salton Sea were to continue to increase in salinity.

Recommendations

A. Exporting brine and contaminants to protected international ecological reserves in Mexico is not an acceptable solution.

The majority of the restoration alternatives currently under consideration would export concentrated brine to sites outside the Salton basin, including Mexico's Colorado River Delta–Upper Gulf of California Biosphere Reserve. Brine and other contaminants should not be discharged into the delta or upper Gulf of California. Such pump-out schemes would not only have negative ecological effects, but most likely economic ones as well, potentially compromising the local shrimping and tourism industries in the region. Beyond the very real questions of environmental justice, any plan that would include international conveyance of brine or seawater would encounter enormous institutional obstacles, and should be avoided.

In general, restoration alternatives that would pump out brine to outlying areas must include a comprehensive strategy for properly managing and disposing of brine and other contaminants. The problems of the Salton Sea should not be simply exported out of sight. Any such pump-out plan should carefully manage the resultant brine and contaminant residues to ensure that they do not harm the site or surrounding area. Forcing other regions to bear the costs of the Salton Sea's problems is neither sustainable nor equitable.

B. Colorado River surplus flows should not be diverted from the Colorado River delta to restore the Salton Sea.

Historically, the Colorado River delta contained expansive wetlands characterized by extremely high biological diversity and productivity (Leopold 1966). Vestiges of this wetland have re-emerged in response to flood releases during and since the 1980s. Today, the delta provides vital habitat for a broad array of flora and fauna, requiring little management and limited inputs beyond sporadic flood flows of Colorado River water. Proposals to divert Colorado River water into the Salton Sea could desiccate remaining high-quality habitat in the Colorado River delta region and should be avoided.[33]

The relative value of the freshwater inflow must be assessed, as diversions to the Salton Sea would maintain a pseudo-marine ecosystem, much like the upper Gulf. Yet the same quantity of water routed through the delta would sustain freshwater wetlands and riparian habitat, in addition to ecological benefits to the upper Gulf.

7. The Restoration Project must be transparent, inclusive, and fully integrated with other actions impacting the Salton Sea.

The scope and potential magnitude of the Salton Sea Restoration Project require an inclusive process that actively seeks input from a broad array of interests and integrates that input into the project. A comparable initiative, the CALFED Bay-Delta Program, has structured a consensus-based approach with representatives from federal, state, and local agencies, as well as the environmental community and other stakeholders. However, unlike this other major regional issue with a formal role for a broad array of stakeholders, the Salton Sea restoration process is relatively closed and is being run by only two agencies.

The Salton Sea restoration effort to date has been characterized by limited public participation and no formal role for public interest groups. There has been no formalized effort to include public or environmental representation within the Technical Advisory Committees that advise the lead agencies. Part of this failure lies with environmental groups and local communities themselves, both of which have yet to articulate a cohesive position on restoration.

Likewise, numerous public agencies are being left out, or are only participating in an advisory fashion. Not surprisingly, as a result, there has been a lack of integration with the activities of those agencies in the basin. An open, inclusive process would provide legitimacy to a project that potentially could cost federal taxpayers more than a billion dollars. An inclusive process would seek consensus from all stakeholders for the concurrent and planned actions in the basin.

Recommendations

A. Identify and fully integrate ongoing and planned efforts in the Salton basin that could impact the restoration of the Sea.

Numerous public agencies are conducting activities in the basin that have implications for the Salton Sea, but these efforts have yet to be fully integrated into the restoration process. In recent years, the Regional Water Quality Control Board, Region 7 has expanded its pollution abatement program to reduce sediments, pesticides, nutrients, salt, and selenium in the waterways of the Salton Sea watershed. The lead agencies should work with Region 7 to implement their existing Watershed Management Initiative and integrated basin plan. Yet, to date, Region 7's efforts to improve water quality in the basin have not been formally incorporated into the first phase of the Restoration Project. In fact, two primary arguments given by the lead agencies for focusing on salinity alone have been a lack of information regarding the effects of other water quality parameters and the inability to address them adequately. This ignores the Region 7's recent identification of non-point source pollution from agricultural practices in the Imperial Valley as a major threat to water quality in the Salton Sea watershed (RWQCB 1998), as well as existing efforts of state and federal regulatory bodies to ameliorate this problem.

Also, the Bureau of Reclamation's efforts to reduce wasteful water use practices in the Imperial Valley should be formally integrated into the Salton Sea restoration process. To date, Reclamation has segregated its role as lead agency for the Restoration Project from

[33] Even without additional diversions of Colorado River water from the river to the Salton Sea, the future of the vital delta habitat is by no means secure. Coordinating the permanent protection of existing delta habitat should be a priority for both the U.S. and Mexican governments.

its regulatory responsibilities to curtail inefficient agricultural water use in the basin. The lack of integration is evidenced by the current base assumption (used for modeling proposed alternatives) that 1.35 maf will continue to flow to the Sea on an annual basis. In effect, one office of the Bureau of Reclamation is working actively to encourage IID to reduce its water consumption, while another office is ignoring these efforts and continues to assume that water use in the basin will continue at historical levels.

Outreach efforts in Mexico and elsewhere that emphasize collaboration, rather than mere dissemination of information, will strengthen the restoration process and expand possible solutions.

B. Include all the affected stakeholders in and around the Salton basin.

The Imperial Valley currently suffers from an unemployment rate in excess of 30 percent, a rate likely to increase in the face of recently signed water conservation agreements (Gomez and Steding 1998). The restoration of the Salton Sea offers the promise of economic growth for the area, growth that if planned and managed appropriately could markedly improve the lives of people in the basin. To ensure that the needs and expectations of currently marginalized communities are addressed, the restoration process should include outreach to local communities to gauge the level of local support for restoration of the Sea and to determine the willingness of such communities to invest in such efforts. The lead agencies should also engage local communities and public interest organizations in Mexico that are potentially affected by restoration alternatives that involve Mexico.

Outstanding claims by the Native American communities in the Salton Sea basin must be resolved as a component of the restoration plan. The Administration and Congress should commit to a process whereby the settlement of the long-standing property claims of the Torres-Martinez communities is given priority and resolved in the next Congress. No solution to the Salton Sea problem is equitable or can be considered comprehensive without a just settlement of the Tribe's long-standing loss of the beneficial use of their trust lands.

Recent discussions of the Science Subcommittee suggest that the Subcommittee is interested in working with scientists and federal agencies in Mexico. This is a welcome step and should be pursued actively. Outreach efforts in Mexico and elsewhere that emphasize collaboration, rather than mere dissemination of information, will strengthen the restoration process and expand possible solutions.

C. Incorporate successes of similar regional restoration initiatives.

The CALFED Program provides a useful model for the Salton Sea Restoration Project, particularly in terms of its relatively transparent, inclusive process. Many of the same federal and state agencies are active in both the Bay-Delta and the Salton Sea, both efforts seek to balance ecological and agricultural interests in a large-scale, potentially multi-billion dollar restoration effort, and both seek to implement long-term strategies. Please refer to Appendix C for a discussion of the pertinent aspects of the CALFED process.

The CALFED program invests agricultural, environmental, and urban interests in the process—the Salton Sea Restoration Project should follow this example. An important first step would be to appoint representatives from the public at large and from the environmental community to the Research Management Committee.

Conclusion

The Salton Sea, dependent on human-generated inflows, provides valuable habitat for tremendous numbers of birds. The complex array of natural and human factors impacting the Salton Sea challenges efforts both to identify the causes of current problems at the Sea and plans to ameliorate these problems. The current federal and state interest in restoring the Sea affords an opportunity to improve the ecological conditions in the region and enhance and diversify the local economy, while preserving agriculture in the region. Yet this opportunity could be squandered by the current efforts of the lead agencies leading the restoration effort. The selection of restoration alternatives based on a limited understanding of the physical and biological processes at the Sea impairs the current restoration effort and will likely not achieve the project's stated objectives. The Pacific Institute believes that the principles and recommendations described above can help improve the current process and ensure the long-term efficacy of any resultant restoration plan.

Early this year, the lead agencies of the Salton Sea Restoration Project began incorporating several of the recommendations suggested by the Pacific Institute and other interested parties during and since the Scoping Phase of the restoration process. The Pacific Institute applauds these developments and encourages further changes that can lead to a more sustainable and equitable outcome for the region. We look forward to continuing to participate productively in the restoration process as it evolves. ■

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Legal Framework for Water Quality: Federal to Local

Federal and state water quality legislation and regulations apply to the Salton Sea and potentially could affect the selection and implementation of a plan to restore the Sea. The federal Clean Water Act, discussed below, is the most salient of these and provides for many of the state enforcement actions. Until recently, inflows to the Salton Sea largely escaped federal and state regulation due to exemptions for non-point source pollution. As described in the following, current efforts by California's Regional Water Quality Control Board to address such pollution could improve the quality of inflows to the Sea.

Applicable Provisions of the Clean Water Act

Exemption of agricultural return flows from regulation

The Clean Water Act (CWA) exempts all agricultural return flow discharges from regulation as a "point source" discharge to waters of the United States. Thus, pollutants from agricultural operations (such as pesticides and nitrates and other chemicals from fertilizers) that enter streams, lakes or other water bodies as run off are not regulated under the permitting requirements of the CWA. This exemption for "non-point source pollution" (NPS) has continued for agriculture despite the fact that agricultural discharges are responsible for as much as two-thirds of the water pollution in the country (Adler et al. 1993), and despite a finding that 37 percent of the 436 species listed under the Endangered Species Act are endangered due to the effects of irrigation and pesticide use (Adler et al. 1993).

Congress was aware of the extent that agriculture contributed to water pollution in 1972 when the CWA was strengthened, but chose not to regulate this source because of the difficulty in designing a regulatory program that could determine causation for these diffuse sources of pollution. Nevertheless, the statutory goal of the CWA is to assure that the nation's water bodies are "fishable and drinkable" and clean enough for recreation and fish & wildlife (33 USC 1251(a)(7)).

Section 208 of the 1972 amendments to the Clean Water Act established a voluntary program for states, providing some financial incentives to develop area-wide water quality plans. Under the plans, states were required only to identify sources of NPS and set forth methods to control these sources "to the extent feasible." The 208 program resulted in many watershed planning efforts but had no regulatory requirements to address NPS. The 208 program was widely viewed as a dismal failure and funding was discontinued in the 1980s.

Section 319

In 1977, amendments to the CWA were adopted that provided farmers with up to 50 percent funding for implementing "best management practices" (BMPs) to reduce NPS pollution. Section 319 (33 USC 1329) was added in 1987, which also continued the voluntary approach to NPS, but did require states to formulate programs to reduce NPS "to the maximum extent practicable" and to report to the EPA on their progress. States are required to develop water quality standards, define the water quality goals for water bodies and river segments, designate the uses for those waters and establish programs to reduce non-point sources of pollution as much as possible in order to protect those uses. Without federal enforcement mechanisms or a requirement that states enact enforcement programs, however, the state NPS programs have had little success. EPA's reports to Congress on NPS, in the annual National Water Quality Inventory, reflect this lack of progress (US EPA 1994 [1]).

Total Maximum Daily Load (TMDL) Requirements under Section 303(d).

Section 303(d) of the CWA (33 USC 1313(d) 1994) added a requirement for states to establish "total maximum daily loads" (TMDLs) for pollutants in rivers and other waters that were not meeting water quality standards after the implementation of technology-based requirements (point-source controls), regardless of the source of pollution. TMDLs are the greatest amount of pollutant loading that water can receive without violating state water quality standards. States must compile a list of waters not meeting these standards, rank them by priority based on the severity of impairment, establish TMDLs for these waters, and institute and implement monitoring procedures. These actions must be submitted to EPA for approval. TMDLs also must specify the amount by which a particular pollutant must be reduced and allocate load reductions among polluters in the watershed. In addition, states must describe regulatory and non-regulatory BMPs to control NPS.

If a state fails to submit the lists, priorities, and TMDLs, or EPA disapproves the state program as inadequate, EPA is required to identify waters requiring TMDLs and establish the loads for those waters (33 USC 1313(d)(2)). So far, no state has achieved the standards for all its waters and most have been extremely slow to implement TMDL

[1] See also, 28 ELR 10320-21, "Pfiesteria Piscicada: A Regional Symptom of a National Problem."

programs at all. Lawsuits in more than half the states for failure to implement these programs in a timely manner have been successful (28 ELR 10317 (1998)). Environmentalists have recognized that TMDLs can be a powerful tool for addressing NPS.

Section 401 Requirements

Section 401 of the CWA provides states with the authority to certify whether any federal license or permitted activity that may potentially result in a discharge into navigable waters complies with state water quality standards. In a landmark case decided by the U.S. Supreme Case in 1994, PUD No. 1 of Jefferson County v. Washington Department of Ecology (114 S. Ct. 1900), the Court upheld the State of Washington's authority to place conditions on a Federal Energy Regulatory Commission (FERC)-licensed dam because of water quality impacts. In the facts of that case, operation of the hydropower dam resulted in decreased instream flows, adversely affecting anadromous fish. The decision is significant for the control of non-point source pollution, as the reduced instream flows were considered to be non-point source.

The decision upheld states' authority to deny or place conditions on a federally permitted activity, if that activity would adversely impact water quality. In its broadest context, this could conceivably require state certification of contracts to use federal Reclamation water, and will clearly provide states with a powerful tool for regulating federal projects that adversely impact water quality, if they choose to exercise it.[2] At a national level, many of the sources of NPS are from activities on federal lands and federal projects, such as timber sales and roads in national forests, Bureau of Land Management grazing leases, and FERC-licensed dams. States could also take a stronger role in controlling non-point source pollution at the local and watershed level. Since it seems unlikely that the CWA will be amended to strengthen the federal government's regulatory powers, it will be left primarily to the states to address NPS.

California's Water Quality Protection Program

Water quality in California is under the jurisdiction of the State Water Resources Control Board (SWRCB) (California Water Code, Sec. 13100, et. seq.). The SWRCB has broad powers to regulate discharges of waste affecting water quality in the state, including point and non-point sources of pollution. Regional Water Quality Control Boards (RWQCB) were established for each region of the state; the members are appointed by the Governor and include representatives from various water interests and the public. Each Regional Board is required to "establish such water quality objectives in water quality control plans as in its judgment will ensure the reasonable protection of beneficial uses and the prevention of nuisance" (Section 13241). The SWRCB retains the authority to act if the RWQCB does not control pollution or adopt an adequate water quality plan. The Salton Sea drainage basin is part of the Colorado River Basin Region (Region 7).

Section 13260 of the California Water Code provides that any discharge of "waste," other than to a municipal sewer system, that could affect water quality must be reported to the RWQCB, unless a waiver has been granted. A waste discharge report (WDR) "can be waived as to a specific discharge or a specific type of discharge where the waiver is not against the public interest." Waivers are conditional and may be terminated at any time by the RWQCB (Section 13269). The statute also provides that no discharge shall create a vested right to continue the discharge (Section 13262(g)).

The Drain Water Quality Improvement Program

In 1994, Region 7 and IID began developing a Drain Water Quality Improvement Program (DWQIP) to address the non-point source problems in Imperial Valley drains (RWQCB 1994b). The objective of the program is to reduce the amount of pollution in tail water and drainage discharges in order to protect the beneficial uses of the various water bodies in the basin - the New River, the Alamo, the drainage canals themselves, and the Salton Sea. The pollutants (in order of Region 7's concern) are: suspended solids, insoluble pesticides, selenium, soluble pesticides, nutrients, and bacteria. As a component of the DWQIP, IID prepared a list of Best Management Practices (BMPs) to control agricultural pollutants and a plan to evaluate whether these BMPs are successful in pollution prevention and cost effectiveness. The program is to continue until there are sufficient BMPs to control discharges and meet the above criteria.

The Watershed Management Initiative and TMDLs

By May 1998, the State Board and Region 7 developed the Watershed Management Initiative "integrated plan" to address water quality issues in the Salton basin. The overall objective of the Initiative is to coordinate the development and implementation of 16 TMDLs for waterways of the Salton Sea watershed and to provide technical assistance for on-farm BMPs. The Initiative is also soliciting grant proposals for demonstration projects, such as constructed wetlands projects. In a May 1998 report, Region 7 acknowledges that "it is not possible to develop and implement the required TMDL Schedule for the 1998 updated Clean Water Act

[2] See Donahue, 1996, The Untapped Power of the Clean Water Act, Section 401, 23 Ecology Law Quarterly 201.

303(d) list of impaired water bodies without significant increases in funding" (RWQCB 1998). The report also stated that the combination of conservation and water transfers from the IID could have a "profound effect on water quality and the ecosystem of the Salton Sea" (RWQCB 1998).

Region 7 will be working with IID and others to develop monitoring plans to determine if TMDLs are effective in reducing pollutant loading of silt, selenium, pesticides, and nutrients. While Region 7 will continue to implement and improve its regulatory compliance permit program for point source discharges, the NPS program is based on "regulatory-encouraged" BMPs with stakeholder cooperation. The development of TMDLs and BMPs will be a phased process with interim goals and objectives for reduction of pollutants, including monitoring and evaluation of pollutant loading from all sources (see Table 10). The majority of these TMDLs are directed at agricultural practices in the Imperial Valley.

Bacteria

The current water quality objectives for bacteria in the New River are based on the standard agreed to in Minute 264 of the 1944 US-Mexico Treaty, which is not deemed adequate to ensure compliance with water quality objectives and needs to be reviewed with Mexico. However, due to inadequate funding for Region 7, no bacteria monitoring data exists for the New River north of the border (from Calexico) since 1993. Region 7 has also detected elevated bacteria levels in the Coachella Stormwater Channel (Whitewater River), but TMDLs for this waterway has been given a low priority and will not be developed until 2004.

Volatile Organic Compounds (VOCs)

Data indicates that VOCs detected in the New River, some of which are suspected human carcinogens (benzene, chloroform, dichlorbenzene), originate in Mexico. Since Treaty Minute 264 does not address this class of substances, setting standards for these pollutants and developing enforcement capacity will also have to be the subject of binational discussions.

Silt and Pesticides

The interim TMDL target levels adopted by Region 7 are to reduce the silt load (and insoluble pesticides) by 10 percent. IID's Drain Water Quality Improvement Plan includes demonstration sedimentation basins and wetland projects as BMPs to remove silt and insoluble pesticides. The projects have received $3 million in federal funding.

Nutrients

Region 7's May 1998 report stated that strong regulatory controls on agriculture to address the nutrient problem in the Salton Sea and the New River may not be technically or economically practical (RWQCB 1998). Despite the link between eutrophication at the Sea and massive fish die-offs, the Regional Board has given TMDLs for nutrient loading a low priority. Not starting until 2002, the TMDL goal is to reduce nutrient loading by 10 percent by 2010.

Selenium

The proposed demonstration projects and IID's Drain Water Quality Improvement Plan are currently the only programs to meet TMDL goals of reducing selenium loading by ten percent. Region 7 has restricted increases in selenium levels above current levels unless IID can show that increases do not cause additional water quality impacts.

Table 10
Timeline for Development of TMDLs in the Salton Sea Watershed

Water Body	Pollutant	Start Date	Complete Date
New River	Silt	1998	2002
	Bacteria	1998	2005
	Nutrients	2002	2010
	Pesticides	2002	2013
	VOCs	2007	2013
Alamo River	Silt	1998	2000
	Selenium	2000	2010
	Pesticides	2002	2011
Imperial Valley Drains	Silt	1998	2000
	Selenium	2000	2010
	Pesticides	2005	2011
Salton Sea	Salt	1998	2001
	Selenium	2002	2007
	Nutrients	2002	2010
Coachella Valley Stormwater Channel	Bacteria	2004	2009

Source: RWQCB 1999

Appendix B

Potential Consequences and Merits of Allowing Salinity at the Salton Sea to Increase Unimpeded

The proposals to restore the Salton Sea call for stabilizing or reducing the lake's salinity, based on the premise that the biological hazards at the Sea will increase if salinity increases. The salinity of the Salton Sea is now approximately 44 ppt (for comparison, the northern Gulf of California is 36 ppt), and over the past 15 years has increased at a rate of about 0.35 ppt per year. Allowing the salinity of the Sea to increase could offer several potential benefits, including breaking the existing food chain that concentrates selenium in birds and reducing the incidence of avian morbidity and mortality. The following discussion describes the existing Salton Sea food chain and the biohazards associated with it, as well as a preliminary discussion of how the ecology might evolve under an "increasing-salinity" scenario.

Although the Pacific Institute at this time does not endorse any proposal that allows the salinity of the Salton Sea to continue to increase unimpeded, we believe this alternative must be thoroughly investigated to serve as a baseline for comparison. Consideration of the "no project" alternative is required by the NEPA process. The extremely high potential economic costs and the uncertain ecological benefits and impacts associated with all of the current restoration alternatives underscore the importance of an objective analysis of the cost effectiveness and expected benefits of a plan to reduce salinity. To date, the lead agencies for the Restoration Project have not given serious attention to allowing salinity at the Sea to increase unimpeded. A credible appraisal of this alternative may reveal that it is much easier to manage the Salton Sea as an ecologically stable salt lake than as an artificial, quasi-marine ecosystem that cannot be sustained without extensive and costly human intervention. Such an appraisal will ultimately help determine whether the Salton Sea or some other location would be best served by such ecosystem restoration efforts.

The Current Food Chain in the Salton Sea

In less than 100 years the Salton Sea has changed from a fresh water lake to a pseudo-marine ecosystem dominated by introduced species. The ecology of the Sea has been described in several reports and publications (Walker 1961; Kim 1973; Setmire et al. 1993); the following account is simplified to illustrate the problematic aspects. Just two diatoms (*Nitzchia* and *Cyclotella spp.*) reportedly account for most of the primary productivity in the lake (Setmire et al. 1993). Their activity is augmented by near-shore, winter blooms of two dinoflagellates (*Glenodinium* and *Exuviaella*), and by the growth of a narrow fringe of attached, filamentous and tubular green algae (e.g. *Enteromorpha*) along the shoreline. This low algal diversity contrasts with the hundreds of algal species in the nearest true marine ecosystem, the upper Gulf of California. The diatom blooms are intense due to enrichment, mostly from agricultural runoff, but also from sewage effluent entering the lake. Due to the turbidity of the water, the photic zone is usually no more than one meter deep; below this level there is insufficient light to support photosynthesis.

Within the photic zone, diatoms are consumed mainly by two zooplankton, a rotifer (*Brachionus plicatilis*) and a copepod (*Apocyclops dengizicus*) which are most active in Summer. Pileworm (*Nereis succinea*) and barnacle larvae, released in spring and autumn, also eat the diatoms (Setmire et al. 1993). As the plankton die, most of them sink to the bottom of the lake and enter the detrital food chain. Adult pileworms living in the bottom sediments, along with bacteria and amphipods, recycle the detritus. Pileworms were introduced into the Salton Sea in 1930. Pileworms are high in fat and protein and form the base of the food chain of fish and fish-eating birds (Kuhl and Oglesby 1979). They are eaten by four species of forage fish in the lake: bairdiella or gulf croaker (*Bairdiella icistia*), Tilapia (*Tilapia mossambica*), longjaw mudsucker (*Gillichthys mirabilis*) and sargo (*Anisotremus davidsoni*), which are eaten in turn by orangemouth corvina (*Cynoscion xanthulus*), introduced in the 1950's as a sport fish. *T. mossambica* is now by far the most numerous fish in the Salton Sea (Costa-Pierce 1997). Tilapia and the other species are prey for a large number of fish-eating birds including black terns, herring gulls, snowy egrets, great blue herons, brown pelicans, white pelicans, osprey, and double-crested cormorants (Setmire et al. 1993). Other birds feed directly on copepods, rotifers, and algae in the planktonic community or on attached algae along the shore. These include black necked stilts, ruddy ducks, lesser scaups, eared grebes, marbled godwits, American avocets, and western sandpipers.

Figure 12 shows simplified food chain relations at the Salton Sea (from Setmire et al. 1993). Sunlight and nutrients drive the planktonic food chain. Most primary productivity is recycled in the detrital food chain. Pileworms, amphipods, and bacteria consume the detritus. Pileworms, which accumulate selenium from the sediments, are at the base of the food chain leading to fish and birds in which selenium undergoes biomagnification.

Wildlife Hazards Posed by the Existing Food Chain

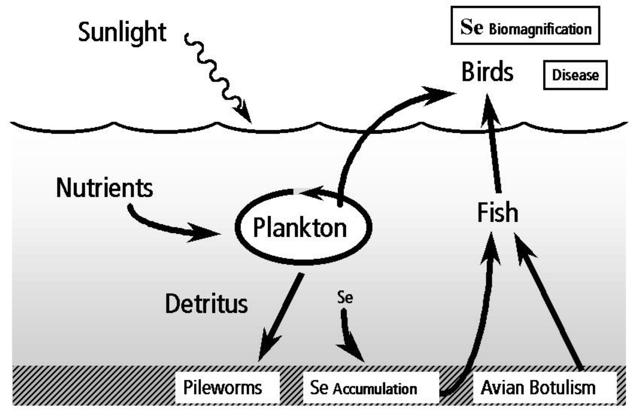
Two biological hazards have been linked to the detritus-fish-bird food chain. The first is potential selenium toxicity (Saiki 1990; Setmire et al. 1993). Water in the Salton Sea contains low levels of selenium which can biomagnify in the food chain to levels hazardous to wildlife (Ohlendorf et al. 1990; Presser et al. 1994). A detailed study (Setmire et al. 1993) concluded that the most hazardous selenium food-chain pathway in the Salton Sea begins with accumulation of selenium by pileworms, followed by uptake by fish feeding on the worms, and then by fish-eating birds. In that study, conducted 1988-1990, pileworms were the only invertebrates in whose tissue the critical concentration of 5 µg/g for food chain organisms was exceeded. Their high selenium content was attributed to the levels of selenium detected in the sediments in which they live, which is more than 3,000 times higher than in the water column. Fish feeding on pileworms had whole-body selenium contents that exceeded the critical level of 12 µg /g for reproduction of sensitive species. It would be expected that birds feeding on the fish would have even higher levels. In fact, it was found that 40 percent of the bird species evaluated in the Imperial Valley surrounding the Salton Sea exceeded the 30 µg/g threshold associated with high biological risk, with the highest levels found in species utilizing the Salton Sea as a feeding station.

The second hazard related to the detritus-fish-bird food chain is bird kills due to infectious and toxic diseases spread by fish, massive fish kills, or bottom sediments (Boyle 1996; Costa-Pierce 1997; USGS 1996; USFWS 1996, 1997). Large-scale fish die-offs are a frequent occurrence at the Salton Sea. As noted in Section II, there appears to be a correlation between fish kills at the Salton Sea and the transmission of type C avian botulism (which is rare among fish-eating birds elsewhere) to fish-eating birds at the Sea. More than 8,500 white pelicans, 1,200 brown pelicans and 4,000 other fish-eating birds have died at the Salton Sea since 1992 due to outbreaks of avian botulism. Altogether, over 200,000 birds have died at the Salton Sea since 1992. Large-scale bird die-offs do occur elsewhere on the Pacific Flyway, and the Salton Sea food chain may not be directly responsible for all the bird deaths. Nevertheless, the massive fish die-offs and the anoxic bottom conditions are considered contributory factors in making the Sea an attractive, but hazardous site for birds on the Pacific Flyway.

Increasing Salinity May Reduce Biological Hazards By Reducing Pileworm And Fish Populations

There is no way to predict the biological effects of rising salinity with certainty without detailed research. However, a review of the existing literature on the organisms making up the Salton Sea food chain, and of the type of food chains that exist in other saline lakes, suggests that rising salinity may actually reduce the biological hazards in the Salton Sea by reducing the reproductive fitness of pileworms, amphipods and fish that accumulate selenium and attract fish-eating birds.

Figure 12
Salton Sea Food Chain and Biological Hazards



Adapted from Setmire et al. 1993

Adult pileworms, for example, survive well up to 68 ppt, but eggs and larvae are sensitive to 45-50 ppt (Kuhl and Oglesby 1979). Tilapia adults also survive well beyond 60 ppt, but reproduction is optimal at 10 ppt, slows above 30 ppt, and may not be effective above 49 ppt (Stickney 1986). The other fish species in the Salton Sea have difficulty reproducing above 40 ppt and are already in decline (Setmire et al. 1993; Costa-Pierce 1997). Adults of Salton Sea copepods survived above 90 ppt, but their reproduction was seriously impaired at 68 ppt (Dexter 1993). The amphipod *Gammarus mucronatus* had reduced reproduction above 39 ppt (Simpson et al. 1995). Thus, the Salton Sea is approaching salinity levels at which the population size of the main faunal species will be reduced by impaired reproduction.

As the key elements of the food chain (detritus-feeding invertebrates and tilapia) diminish, the attraction of the main body of the Salton Sea to fish-eating birds should diminish as well, and the incidence of massive fish and birds kills may diminish.

It can be argued that the loss of fish from the Salton Sea will decrease biodiversity among visiting birds that feed on fish. However, the lower Colorado River and delta need to be viewed as a single, regional ecosystem. Loss of fish from the Salton Sea does not necessarily mean there will be a net loss of fish-eating birds from the lower Colorado River ecosystem. The fish-eating birds that presently use the Salton Sea can be expected to move into the nearby Colorado River delta habitats in Mexico as the fish populations in the Salton Sea decline. The Colorado delta contains vast marine resources protected in a Biosphere Reserve, as well as wetland and riparian habitats. The delta habitats have been partially reestablished by flood releases and agricultural drainage from the United States over the last two decades (Glenn et al. 1996). Corvina stocks are presently at record levels (J. Barrera, director of the Colorado River Delta-Upper Gulf of California Biosphere Reserve, personal communication, 1998). Regional biodiversity might be best preserved by paying attention to the restoration needs of the delta habitats in Mexico, as well as the Salton Sea.

A Scenario for the Salton Sea as a Hypersaline Lake

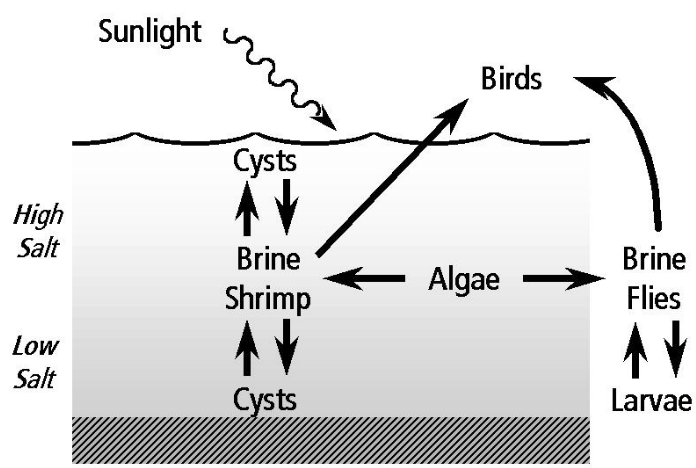
If agricultural inputs diminish and are not replaced by ocean water, the water level in the Salton Sea will decrease. One consequence is likely to be an increase in the areas of marsh habitat where the Alamo River, New River and Whitewater River enter the lake. When the Salton Sea National Wildlife Refuge was established in 1930, it contained over 24,700 acres (10,000 ha) of marshes, formed at the points of entry of agricultural drain water into the Salton Sea. Currently only 2,000 acres (800 ha) of marshes remain due to rising lake-levels. However, a contraction in Sea volume will also expose many square kilometers of bare shoreline that may need to be artificially vegetated to prevent blowing dust. Although salinity will continue to increase indefinitely, the volume of the Salton Sea will stabilize at a new size at which evaporation from the exposed surface area matches inputs. As long as agricultural drainage flows, the Salton Sea will remain an aquatic habitat.

The present food chain organisms will most likely be replaced by the algae-brine shrimp-brine fly community, or a variation of this food chain. These organisms are not just found in Mono Lake and the Great Salt Lake; they occur in natural and manmade salt lakes around the world (Persoone and Sorgeloos 1980). They are stable over a very wide range of salinities and salt mixtures. For example, the salinity of Mono Lake ranged from 42-99 ppt from 1913-1998, and it is composed of a highly alkaline mix of sulfate, carbonate and chloride salts, yet the basic diatom-brine shrimp-brine fly food chain has been preserved in the lake (Mono Basin Ecosystem Study Committee 1987; Hart 1996). Productivity of the food chain decreased at higher salinities, and water inputs are now regulated so that a salinity no higher than 69.3 ppt will be achieved within 20 years (the present salinity is 80.8 ppt)(Hart 1996). Salinity in the Great Salt Lake, composed mainly of sodium chloride, has varied even more widely, from 55 ppt in the south part of the lake during record floods in 1983-1987, to over 180 ppt in the north part due to construction of a railroad causeway across the lake in 1957 that reduced water exchange between north and south (USGS 1998). The basic food chain has persisted, although the commercial brine shrimp harvest was negatively affected at the lowest and highest salinities.

Figure 13 depicts simplified food chain relationships for the Great Salt Lake, Mono Lake or other salt lakes. Planktivorous algae and cyanobacteria are grazed by brine shrimp and brine flies, which are food for birds. Brine shrimp cysts float in water more than 60 ppt and sink in less saline water. Brine fly larvae are bottom feeders but most primary productivity is recycled in the planktonic food chain where selenium accumulation is not a problem.

The present diatom species, particularly *Nitzchia*, are likely to remain dominant in the Salton Sea well beyond 60 ppt (Tanner et al. 1999). At higher salinities, single celled cyanobacteria and the single-celled halotolerant algae, *Dunaliella*, can be expected to become prominent (Ginzberg 1987). When fish disappear, brine shrimp (*Artemia* spp.) can be expected to thrive and the detrital food chain will diminish in importance (Persoone and Sorgeloos 1980). A small, commercial brine shrimp industry based on pond culture has already been established using Salton Sea water near Salton City (authors' unpublished observation). Brine shrimp are slow-swimming, filter-feeding crustaceans which graze planktonic algae from the water column. Brine shrimp in turn are easily harvested from the water column by waterfowl and aquatic insects such as water boatmen (*Corixidae*). Hence, most of the primary production is recycled within the planktonic food chain or removed by birds. The planktonic food chain is not reported to accumulate selenium or other elements to harmful levels. Hence, unlike the Salton Sea, the Great Salt Lake and Mono Lake are not regarded as selenium haz-

Figure 13
Salt Lake Food Chain



Adapted from Setmire et al. 1993

ards at present, even though vast quantities of selenium and other elements may accumulate in their bottom sediments (Mono Basin Ecosystem Study Committee 1987; USGS 1998). The benthic habitat in these lakes is occupied by larval stages of brine flies which graze on algae and detritus and by the cysts of brine shrimp which may sink to the bottom of the lakes when salinities are below approximately 60 ppt. Brine flies are harvested by birds when they hatch out along the shoreline.

Both Mono Lake and the Great Salt Lake are highly productive and valuable lakes for birds. Mono Lake provides critical habitat for nesting California gulls and snowy plovers, and migrating Wilson's phalaropes, red-necked phalaropes and great numbers of eared grebes (Hart 1996; Mono Lake Committee 1998). The Great Salt Lake supports millions of breeding and migrating shorebirds and waterfowl, including 17,000 breeding adult white pelicans (USGS 1998). Though the lakes are fishless, fish are found in their tributaries and adjacent marshlands. In addition to supporting birds, brine shrimp in the Great Salt Lake produce vast quantities of floating cysts which are harvested for the aquaculture industry around the world (Sorgeloos 1980). The harvest from the Great Salt Lake alone is worth as much as $200 million per year, depending on the size of the harvest (USGS 1998). The basic, ecological similarity among salt lakes despite differences in salt composition and climate, argues that the Salton Sea will also develop into a stable salt lake.

Managing the Transition to a Salt Lake

Allowing the Salton Sea to become hypersaline has been labeled the "no-action" scenario, but this is a mischaracterization. As mentioned earlier in this report, a reduction in agricultural drain inputs will reduce lake-size and expose areas of shoreline, which will need immediate management attention. The rate of salinity increase would have to be managed by controlling the volume of drain water entering the Salton Sea. Research would be required to determine whether a fast or slow transition is best. In either case, intensive monitoring of the aquatic ecosystem would be needed during the transition period to a fishless water body. If fish kills continue, methods to reduce their hazard to wildlife and humans would also be needed.

The fate of fish-eating birds using the Salton Sea would need to be determined. Salinity tolerance among birds differs from fish most notably in that birds can generally avoid or escape an area with high salinity. Typically, healthy birds will not fly into a hypersaline environment and die from salt toxicity, though such environments may reduce reproductive success (Dan Anderson, UC Davis, personal communication, 1998). Allowing the salinity of the Salton Sea to increase would likely decrease the numbers of fish-eating birds that visit the Sea, while numbers of birds that eat brine flies and brine shrimp would likely increase. Fish-eating birds would continue to visit the Sea's brackish estuaries and tributaries. Replacement habitat might be needed in the upper Gulf of California, requiring binational cooperation. Co-management and monitoring of bird populations between U.S. agencies and the management team of the Biosphere Reserve of the Upper Gulf of California and Delta of the Colorado River may be desirable. Intensive water quality monitoring in both the Colorado River delta and the Salton Sea would be required to determine the safety of the altered habitats for wildlife.

If the Salton Sea were to evolve into a true salt lake, new economic opportunities such as the harvest of brine shrimp cysts or the development of a chemical extraction industry may become feasible. This would require cleanup and monitoring of polluted input sources, such as sewage effluent from Mexicali. The Great Salt Lake, Mono Lake and even the seasonally-flooded Owens Lake. All have ongoing management issues, and the Salton Sea would be no exception.

The speed of ecosystem turnover will be determined by the rate of water input, which is within human control. The natural evaporation loss of water from the Salton Sea is 5-6 feet per year, or 18 percent of the average depth (Setmire et al. 1993). Without water inputs, the Sea would go dry in under 10 years. However, present water inputs roughly match evaporation, so salinity only increases by the amount of salts present in the incoming water. If the volume of input water to the Salton Sea was reduced by 25 percent, the salinity could reach 60 ppt within ten years, at which salinity reproduction of fish and pileworms should be impaired and the ecosystem should be in transition. The point at which brine shrimp will become important in the Sea is unknown, and requires study. Certainly they will not thrive as long as forage fish are present. Just as at the Great Salt Lake and Mono Lake, the brackish ecosystems will persist as refugia at points where water enters the lake.

Appendix C

The CALFED Bay-Delta Program

The CALFED Bay-Delta Program is a cooperative effort involving 15 state and federal agencies working toward the development of long-term solutions for fish and wildlife protection, water supply reliability, flood control, and water quality problems in the San Francisco Bay/Sacramento-San Joaquin River Delta Estuary (Bay-Delta). There are numerous similarities between the Bay-Delta and the Salton Sea: many of the same federal and state agencies are active in both, each effort seeks to balance ecological and agricultural interests in a large-scale potentially multi-billion dollar restoration effort, and each seeks to implement long-term strategies.

For decades, the Bay-Delta has been the focus of competing economic, ecological, urban, and agricultural interests. These conflicting demands have resulted in declining wildlife habitat and species threatened by extinction; the degradation of the Delta as a reliable source of high quality water; and a Delta levee system faced with a high risk of failure. After years of conflict between federal and state agencies trying to regulate and manage the Bay-Delta, a framework agreement was signed in June 1994, which formalized a cooperative effort called the CALFED Bay-Delta Program.

The CALFED Program depends upon the participation of a broad array of stakeholders and pertinent state and federal agencies. Bay-Delta stakeholders contribute to the CALFED Program design and to the problem-solving/decision-making process. Public participation and input into the process have come through the Bay-Delta Advisory Council (BDAC), public participation in workshops, scoping meetings, comment letters, and other public outreach efforts. BDAC is comprised of stakeholders, including water districts and utilities, environmental organizations, the California Farm Bureau, and sport fishing organizations from throughout California. The group of public advisors helps define problems in the Bay-Delta, helps to assure broad public participation, comments on environmental analysis and reports, and offers advice on proposed solutions.

BDAC played an instrumental role in the negotiation and approval of the December 1994 Bay-Delta Accord. The Delta Accord marked a radical departure from the legal confrontations of the past, representing the first time in California water history that environmental, agricultural, and urban interests were able to reach a consensus on such major issues. Underlying the success of the Bay-Delta Accord was the fact that all stakeholders were present at the bargaining table.

The CALFED Program has made some effort to reach out to poor communities and communities of color, with efforts to carry out public involvement activities tailored to meet the needs of California's diverse communities and populations, though this has often taken the form of dissemination of information, rather than an effort to engage these communities in the process.

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecological health and improve water management for beneficial uses of the Bay-Delta. There are four Primary Objectives of the CALFED Program: improve ecosystem quality; maximize the reliability of the water supply; provide good water quality for all beneficial uses; and reduce risk from breaching of levees. The program mission and primary objectives are guided by a set of solution principles, which provide an overall measure of the acceptability of alternatives and guide the design of the institutional part of each alternative. These principles are:

- Reduce conflicts in the system (among beneficial users of water)
- Be Equitable
- Be Affordable
- Be Durable
- Be Implementable
- Have No Significant Redirected Impacts

The foundation of every CALFED alternative is the common Program elements:

- the ecosystem restoration program,
- water quality program,
- water use efficiency program,
- levee protection plan,
- water transfer policy framework, and
- watershed management coordination program.

These common Program elements differ only slightly between alternatives. Each of the individual common Program elements is a major program on its own, and each represents a significant investment in and improvement to the Bay-Delta system. For example, the ecosystem restoration plan is the largest, most complex ecosystem rehabilitation effort ever undertaken anywhere (CALFED 1998).

"The common or foundational Program elements resulted from a realization during Phase I that some categories of actions were so basic in addressing Bay-Delta system problems that they should not be optional nor be made to arbitrarily vary in level of implementation. These common Program elements are also distin-

guished from the variable storage and conveyance elements in that each consists of hundreds of individual actions, which can be implemented over a twenty to thirty year period. They will be guided by specific policy direction and an ongoing adaptive management framework and require local partnerships, coordination and cooperation" (CALFED 1998).

Appendix D

Abbreviations and Conversions

Abbreviations

Authority	Salton Sea Authority
BMP	Best Management Practice
CVWD	Coachella Valley Water District
CWA	Clean Water Act
DWQIP	Drain Water Quality Improvement Program
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
FWS	U.S. Fish and Wildlife Service
IID	Imperial Irrigation District
NEPA	National Environmental Protection Act
CEQA	California Environmental Quality Act
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
maf	million acre-feet
NPS	Non-Point Source pollution
PL 102-575	Reclamation Projects Authorization and Adjustment Act of 1992
PL 105-372	Salton Sea Reclamation Act of 1998
ppm	parts per million
ppt	parts per thousand
Reclamation	U.S. Bureau of Reclamation
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
VOC	Volatile Organic Compounds

Conversions

Length

1 foot	30.48 cm
1 foot	0.3048 m
1 mile	1.609 km

Area

1 square inch	6.452 cm^2
1 square foot	929.0 cm^2
1 square foot	0.0929 m^2
1 acre	4046.9 m^2
1 acre	0.40469 ha
1 square mile	640 acres
1 square mile	259.0 ha
1 square mile	2.590 km^2

Volume

1 gallon	3.785 liters
1 acre-foot	325,851 gallons
1 acre-foot	1233.48 m^3
1 million acre-feet	1.233 km^3