Chapter 1. Introduction

Purpose

This report is intended to provide a summary of the Bureau of Reclamation's (Reclamation) recent study to determine a preferred alternative action for restoring the Salton Sea (Sea). This study was performed in fulfillment of the requirements of Public Law (P.L.) 108-361, the Water Supply Reliability and Environmental Improvement Act, November 2004.

Authority

This study is being conducted under the authority of P.L. 108-361, titled the Water Supply Reliability and Environmental Improvement Act. Specifically, the act requires that:

> "Not later than December 31, 2006, the Secretary of the Interior, in coordination with the State of California and the Salton Sea Authority, shall complete a feasibility study on a preferred alternative for Salton Sea restoration."

The costs of all alternatives presented in this report are based on very limited geologic and geotechnical data that were obtained through exploration in years 2003 and 2004. Significant design uncertainties exist as a result of the limited amount of site information. Uncertainties also exist relative to constructability, seismic performance, static performance, and construction costs. As a result of these uncertainties, the designs and costs presented in this report are at an appraisal level and not at a feasibility level. It would not be possible to develop feasibility level designs and cost estimates without conducting significant geologic and geotechnical design data collection programs.

Study Location

The Sea, a terminal hypersaline lake, is the largest inland body of water in California. It is located in the southeastern corner of the State and spans Riverside and Imperial Counties (location map). The closest cities include Palm Springs, Indio, Brawley, and El Centro.

The northern portion of the study area is drained by the Whitewater River and its tributaries, reaching the northern end of the Salton Sea within the Coachella Valley not far from the town of Mecca. Salt Creek drains the southern slope of the Orocopia Mountains and the northern end of the Chocolate Mountains, entering the northeast portion of the Sea within the Salton Sea State Park boundaries. The most important western drainage is San Felipe Creek, with headwaters near Julian, about 50 miles west of the Salton Sea. The New and Alamo Rivers drain the Imperial Valley and, to a lesser extent, the Mexicali Valley to the south.

Study Objectives

The primary purpose of this study is to identify and recommend a preferred action that attempts to provide an efficient and reasonable method for restoration of the Salton Sea ecosystem and permanent protection of wildlife dependent on that ecosystem. This objective is based on historic habitat capabilities for providing an abundant and diverse assemblage of fish and wildlife at a level sustainable (1) within the constraints of predicted future water availability and water quality, (2) at a reasonable degree of risk associated with the viability of the project (relative to environmental issues), and (3) in a cost effective manner. Although wildlife and wildlife habitat objectives were considered primary for this study, all objectives listed in the Salton Sea Reclamation Act (P.L. 105-372) were given significant consideration and adopted to the greatest extent possible. P.L. 105-372 identified the following objectives:

- Permit the continued use of the Salton Sea as a reservoir for irrigation drainage
- Reduce and stabilize the overall salinity of the Salton Sea
- Stabilize the surface elevation of the Salton Sea
- Reclaim, in the long term, healthy fish and wildlife resources and their habitats
- Enhance the potential for recreational uses and economic development of the Salton Sea

Emphasis was given to permitting the continued use of the Salton Sea for irrigation drainage and for reclaiming fish and wildlife resources and their habitats. An additional objective was considered relative to minimizing exposed areas subject to potential air quality problems. This additional objective was not included in the Salton Sea Reclamation Act. It was added for this study because of its importance to restoration feasibility and for consistency with the State of California’s Salton Sea Ecosystem Restoration Study (ERS).

Project features are designed in this study to function at current and reduced inflows, as directed by P.L. 105-372.

History and Physical Setting of the Sea

The Salton Sea lies at the northern reach of the former delta of the Colorado River (Sykes, 1937) in a large, seismically-active rift valley that was once the northernmost extent of the Gulf of California. Before 1900, the river periodically emptied northwest into the Salton Basin, forming the ancient Lake Cahuilla, which was several times the size of the current Sea. The present-day Sea formed in 1905, when Colorado River flood flows breached an irrigation control structure in Mexico and were diverted into the Salton Basin for about 18 months. Since then, agricultural drainage flows from nearby Imperial, Coachella, and Mexicali Valleys and smaller contributions from municipal effluent and storm water runoff have sustained the Sea. Over the years, the Sea has developed into a recreation area, wildlife refuge, and sport fishery.

The present-day Salton Sea occupies a below-sea-level desert basin known as the Salton Basin (or Salton Sink or Salton Trough). Historical evidence and geologic studies have shown that the Colorado River has spilled over into the Salton Basin on numerous occasions over the last thousand years, creating intermittent lakes that, in some cases, lasted decades to centuries. For example, Lake Cahuilla is believed to have formed around A.D. 700, when the Colorado River silted up its normal egress to the Gulf of California and swung northward through two overflow channels. Evidence of an ancient shoreline suggests that Lake Cahuilla occupied the basin until about 300 years ago. From 1824 to 1904, Colorado River flows flooded the Salton Basin no fewer than eight times.

The Salton Basin extends from Banning, California, on the north to near the international border of Mexico on the south. The Sea itself is about 35 miles long and 15 miles wide. Recently, the elevation of the Sea has been about -228 feet mean sea level (msl) (228 feet below sea level), with annual fluctuations of about 1 foot. At this elevation, the Sea has a maximum depth of about 50 feet, with an estimated surface area of 232,000 acres (362 square miles). The lowest Seafloor elevation is about -278 feet msl. The current Sea has a storage volume of approximately 7.2 million acre-feet.

The Salton Basin is located in a highly active tectonic region with frequent earthquakes. Tectonically, the vicinity is dominated by the San Andreas, Imperial, San Jacinto, and Elsinore fault systems. Many moderate-to-large earthquakes have occurred on faults in the Salton Basin. **Figure 1.1** displays historic earthquakes in the Salton Basin from the 1860s through the year 2005.[1]

[1] This map was obtained from Reclamation's Western United States Earthquake Database.

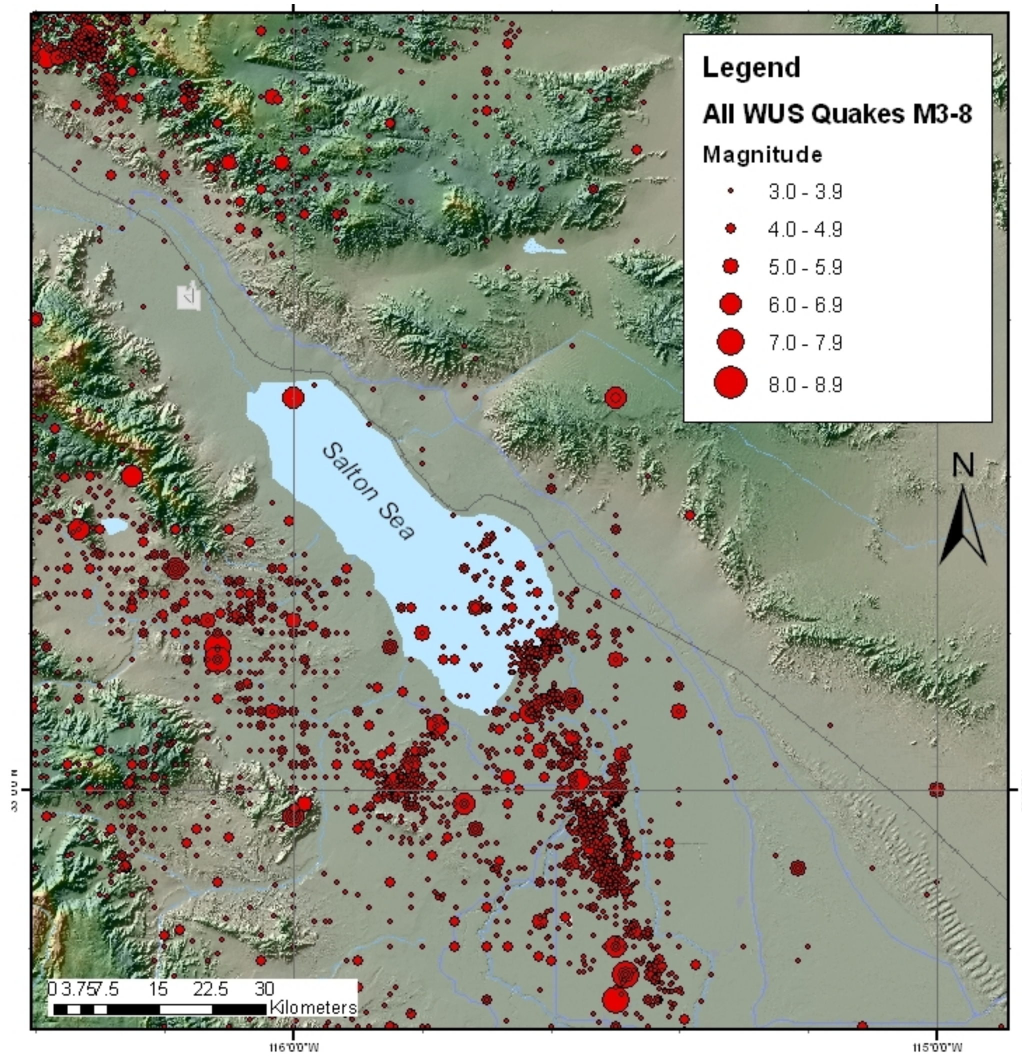

Figure 1.1 Historic earthquakes magnitude 3 to 8.

The Sea's recent salinity concentration (48,000 milligrams per liter [mg/L]) is about 37 percent saltier than ocean water. In the recent past, annual inflows to the Sea have been in balance with its annual evaporation. Inflows add about 4 million tons of salt each year. Because the Sea has no natural outlet, the salinity in the Sea continues to rise each year as salts (or total dissolved solids) are left behind when water evaporates from the Sea surface. Salton Sea salinity will increase dramatically in the near future as inflows to the Sea are reduced due to implementation of existing water transfer agreements. This accelerated increase will occur because of an imbalance between inflow and evaporation. Rising salinities have affected, and are expected to continue to affect, the once highly productive fishery of the Sea.

Important Resources

Fishery

The fishery of the Salton Sea is an important (but declining) resource for both fish-eating birds and the local economy through recreational sport fishing. Beginning in 1929, the California Department of Fish and Game introduced more than 30 marine fish species to the Salton Sea. Only three of those species, sargo (*Anisotremus davidsoni*), Gulf croaker (*Bairdiella icistia*), and orangemouth corvina (*Cynoscion xanthulus*), adapted and became established. A fourth species, tilapia (*Oreochromis mossambicus* x *O. urolepis hornurum*), was unintentionally introduced to the Sea from agricultural drains in 1964-65. By the early 1970s, tilapia dominated the fish community in the Sea. Extensive surveys in 1999–2000 (Reidel et al., 2002) indicated that growth rates of tilapia in the Salton Sea were among the highest reported anywhere in the world as a result of the high nutrient concentrations and warm temperatures. In addition to the game fish, the endangered desert pupfish (*Cyrinodon macularius*) inhabits the Sea and adjoining drains and creeks and is of concern with respect to restoration alternatives.

Increasing salinity and dissolved oxygen (DO) levels currently pose the greatest threat to the Salton Sea fishery, although temperature fluctuations may become of concern as water levels drop. Reidel et al. (2002) reported that the optimum salinity range for food consumption and conversion, growth, and respiration for sargo, croaker, and orangemouth corvina was 33-37 grams per liter. Furthermore, current salinities in the Sea appear to be nearing the upper tolerance limits for all four of the major species. In fact, recent increases in salinity may have already impaired the Salton Sea fishery. Crayon et al. (2005) recently reported that populations of sargo, Gulf croaker, and orangemouth corvina have been below detectable levels since May 2003. Tilapia populations have also been drastically reduced. Although tilapia numbers appear to be increasing, current populations are still more than 90 percent lower than the levels reported in 1999–2000.

Migratory Birds

The seasonal movements of migratory species of birds follow general, but complex, pathways that take birds from their breeding grounds to wintering areas and, subsequently, back to these breeding grounds. That journey must be supported by the availability of appropriate habitat and an adequate food base. Those essential factors must be satisfied within the limits of flight and bioenergetic considerations to provide for the return of sufficient numbers of birds in a physical condition that facilitates long-term population maintenance. The Pacific Flyway is an important migratory pathway for birds traveling between the breeding grounds in Canada, Alaska, the Pacific Northwest, and the Northern Great Plains and wintering grounds along the Gulf of California, extending into Central and South America (**Figure 1.2**).

The Salton Sea is an important link in the habitat and food chain that sustains the perpetual migratory cycles for many species of birds within Western North America. This linkage is that of a habitat for all seasons by providing an important crossroad and way station for seasonal resting and feeding needs, wintering, spring conditioning, and breeding habitat. Records of the U.S. Geological Survey's Bird Banding Laboratory disclose that birds banded at the Salton Sea have been reported from Russia and the North American Arctic to Latin America and from Hawaii to the Maritime Provinces of Eastern Canada (**Figure 1.3**). The considerable interchange evident with birds of the Pacific and Central Flyways indicates that the importance of the Sea is far greater than transient local and regional bird use.

Wood storks.

The Salton Sea ecosystem supports some of the highest avian biological diversity in North America as well as the world. The more than 400 bird species that have been reported within the Salton Sea ecosystem comprise approximately 70 percent of all the bird species recorded in California. In addition, approximately 100 species, or one-third of all species that are known to breed in California, are breeders within the Salton Sea ecosystem. This combination of avian biodiversity and importance as breeding habitat is unsurpassed by any limited geographic area within the contiguous 48 states and Latin America.

Among the birds using the Salton Sea are 19 species of waterbirds classified by the Federal government, California, or both, as species of high conservation concern because of their population status (**Table 1.1**). More than 14,000 pairs of colonial breeders, comprised of 11 species representing three families of birds, were tallied during a 1999 survey (Shuford et al., 2000) (**Table 1.2**).

The Salton Sea ecosystem is also an important area for landbirds. Investigators from the Point Reyes Bird Observatory during surveys in 1999 in areas adjacent to the Salton Sea tallied numerous neotropical migrants. More Wilson's warblers (*Wilsonia pusilla*) were caught at the Salton Sea during spring migration than at any other mist-netting site in California. The abundance of neotropical migrants recorded during spring and fall included 11 species of statewide concern in riparian habitats and is evidence that the area is used extensively by migrating passerines (Shuford et al., 2000).

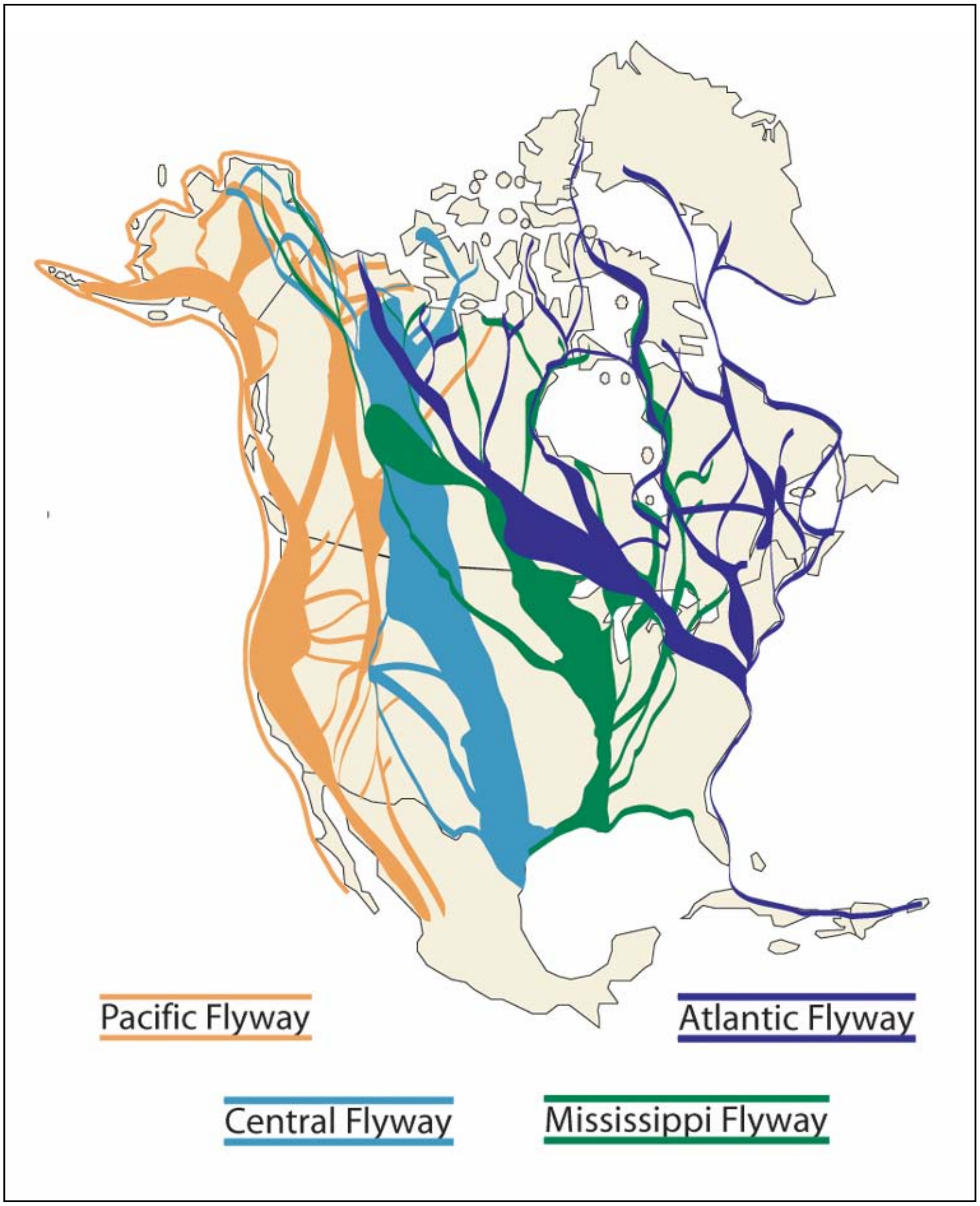

Figure 1.2 Flyways for migratory birds.

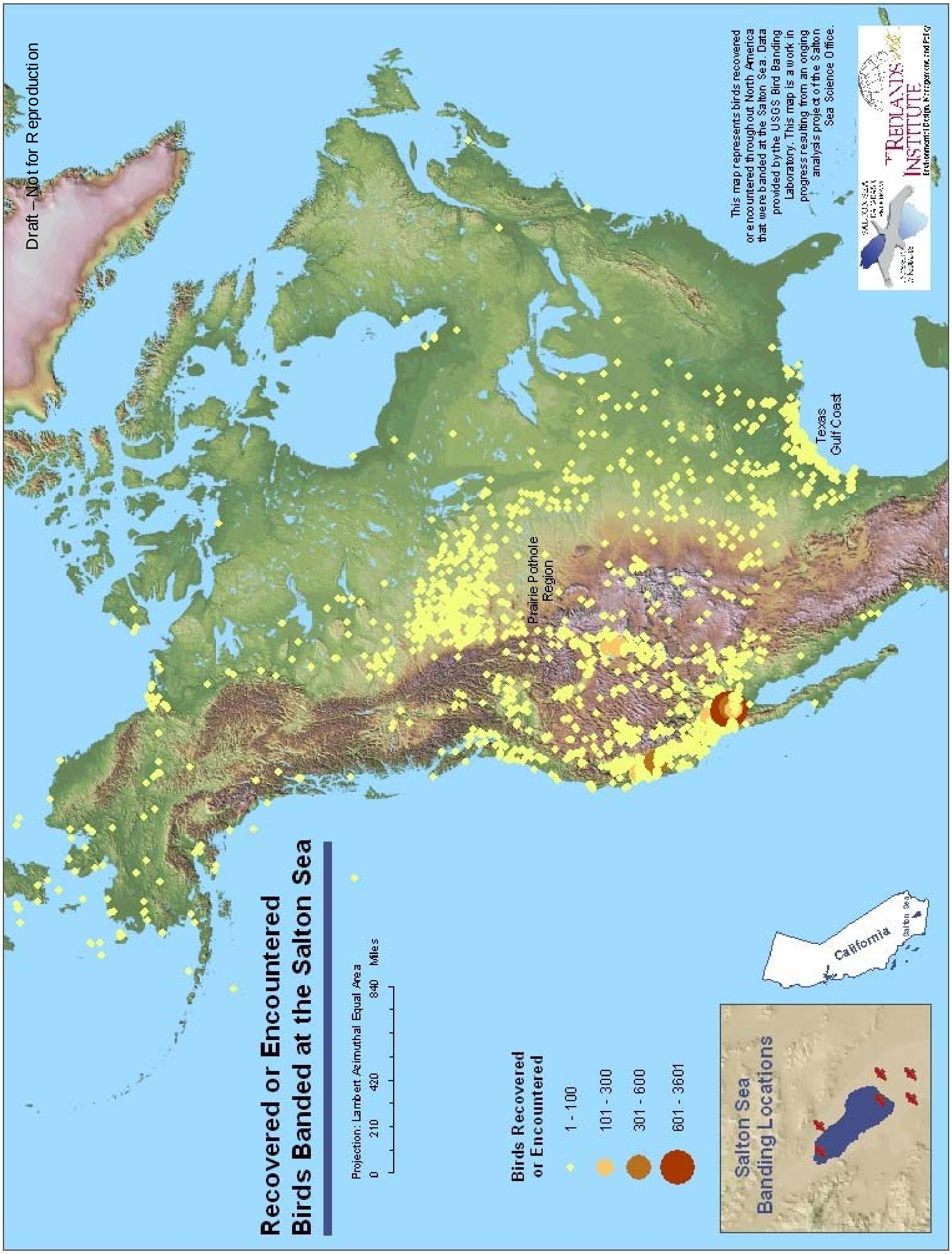

Figure 1.3 Recovered and encountered birds banded at the Salton Sea.

Table 1.1. Waterbirds of conservation concern at the Salton Sea

Status						
	Endangered		**Threatened**		**Management Concern[1]**	
Species	**Federal**	**State**	**Federal**	**State**	**FWS**	**CDFG**
Brown Pelican	x					
White Pelican					x	x
Double-Crested Cormorant						x
American Bittern					x	
Least Bittern					x	x
White-Faced Ibis					x	x
Wood Stork						x
Fulvous Whistling Duck						x
Black Rail				x	x	
Yuma Clapper Rail	x					
Greater Sandhill Crane				x		
Snowy Plover					x	x
Mountain Plover					x	x
Long-Billed Curlew					x	x
Laughing Gull						x
California Gull						x
Gull-Billed Tern						x
Black Tern					x	x
Black Skimmer						x

Adapted from Shuford et al., 2000.

[1] FWS = U.S. Fish and Wildlife Service; CDFG = California Department of Fish and Game.

Table 1.2 Colonial waterbirds nesting at the Salton Sea during 1999

Family	Species	Number of Nesting Pairs[1]
Cormorants	Double-Crested Cormorants	x
Ardeids	Great Blue Heron	+
	Great Egret	–
	Snowy Egret	–
	Black-Crowned Night Heron	–
	Cattle Egret	x
Larids	Laughing Gull	*
	California Gull	*
	Gull-Billed Tern	–
	Caspian Tern	–
	Black Skimmer	–

Adapted from Shuford et al., 2000.

[1] * = less than 100
– = 101-500
+ = 501-1,000
x = more than 5,000.

In general, the Salton Sea is of regional or national importance to various groups of birds such as pelicans and cormorants, wading birds, waterfowl, shorebirds, gulls and terns, and some passerines. The Salton Sea ecosystem is a migratory bird habitat for all seasons that serves waterbirds and landbirds alike. As a result, this ecosystem has become one of the crown jewels of avian biodiversity. If preserving the rich diversity of birds in this area is to be more than mere philosophy, then this ecosystem must be sustained in a way that preserves the current richness of species and provides for the numerous birds that use this area. Preserving this ecosystem must become a priority for the conservation community because it now serves as a critical link in the habitat chain needed to sustain migratory bird populations within western North America.

Summer: Summer use of the Salton Sea includes one of the largest populations of black skimmer (*Rynchops niger*) in Western North America. During some years, up to 40 percent of the breeding by this species in California occurs at the Salton Sea. The larger of only two breeding populations of the western subspecies of gull-billed tern (*Sterna nilotica*) occurs at the Salton Sea. Several thousand California brown pelicans (*Pelecanus occidentalis*), large numbers of the American white pelican (*P. erythrorhynchos*), and a variety of other species, including substantial numbers of breeding black-necked stilt (*Himantopus mexicanus*) and American avocet (*Recurvirostra americana*), also use the Salton Sea during summer.

Winter: Winter use includes up to 30 percent of the entire North American breeding population of the white pelican. The Sea also serves as a primary wintering area in Western North America for white-faced ibis (*Plegadis chihi*). The Salton Sea supports the largest wintering population of Western snowy plover (*Charadrius alexandrinus*) in the interior of the United States. Agricultural lands in this ecosystem support a wintering population of the mountain plover (*C. montanus*), estimated to represent about 30 percent of the species' entire population (Shuford et al., 2000). The Salton Sea is also an important wintering area for the ruddy duck (*Oxyura jamaicensis*) (Heitmeyer et al., 1989).

Spring and Fall: "The Salton Sea is one of only eight sites in the interior of Western North America that holds more than 10,000 shorebirds in fall and one of five such sites in the spring. In terms of overall shorebird numbers, the Salton Sea is the most important area in the Intermountain and Desert region of the West in spring and the second most important, after Great Salt Lake, in fall." (Shuford et al., 2000).

The seasonal highlights noted above do not include many additional species present. Among the more noteworthy occurrences reported by Shuford et al., (2000) are:

- The double-crested cormorant (*Phalacrocorax auritus*) breeding population at the Salton Sea is one of the largest in Western North America.
- The Yuma clapper rail (*Rallus longirostris yumanensis*) breeding population is about 40 percent of the entire U.S. population.
- This is one of the most important migratory stopover and wintering areas in the world for eared grebes (*Podiceps nigricollis*) (Jehl, 1988).
- The Salton Sea is one of the key migratory stopover sites in Western North America for black tern (*Chlidonias niger*).
- This ecosystem is also one of the most important areas in the interior of Western North America for wintering gulls.

Recreation

Soon after its creation, the Salton Sea became a mecca for outdoor recreation. By 1958, the North Shore Beach area had been developed with an airfield and a yacht club. The North Shore Yacht Club was touted as a $2 million marine paradise, with one of the largest marinas in Southern California. The development of Salton City also began in earnest during the 1950s on the west side of the Salton Sea.

The development included a championship golf course and the Salton Bay Yacht Club, both of which were frequented by Southern California sportsmen and Hollywood celebrities. Developers claimed that Salton City would become the most popular marine resort in all of Southern California. The Salton Sea State Park (later the Salton Sea State Recreation Area) was dedicated on February 12, 1955. It served as an important inland recreation area until the late 1970s when visitation declined markedly because of the deteriorating environmental quality of the Sea. This facility has 1,400 campsites, hundreds of day use sites, and other amenities. Current annual visitor use at the park is about 250,000 people.

Waterfowl hunting has been a popular activity at the Salton Sea since at least the 1920s. There are numerous private duck clubs along the Sea and on adjacent areas. Hunters are also provided waterfowl opportunities on portions of the Sonny Bono Salton Sea National Wildlife Refuge (NWR) and on the State's Imperial Wildlife Area Wister Unit.

The annual Salton Sea International Bird Festival attests to the popularity of the Salton Sea ecosystem as a haven for bird watching. An earlier economic analysis of bird watching at the Salton Sea reported substantial contributions to the economy of the small local communities around the Salton Sea.

A variety of other recreational activities also take place at the Salton Sea, including photography, camping, and kayaking. Because of its relative proximity to the large metropolitan areas of San Diego and Los Angeles, the Salton Sea is a valuable recreation resource.

Endangered Species

Several species listed under the Federal Endangered Species Act use habitat resources associated with the Salton Sea; however, four species are directly linked to future changes in Salton Sea water quantity and quality. For example, the desert pupfish is the only native fish inhabiting the Salton Sea. Designated critical habitat includes San Felipe Creek, Carrizo Wash, and Fish Creek Wash; however, pupfish also occur in wastewater drains discharging into the Sea, in shoreline pools of the Sea, artificial refugia, and in washes at San Felipe and Salt Creeks (Sutton, 2000). There is some indication that pupfish may use the Sea to move between sites providing habitat resources. As the Sea becomes more saline and the shoreline recedes in the future, there is concern that local pupfish populations may become isolated as they loose habitat connectivity with adjacent populations. All alternatives contain some provisions to maintain connectivity among local pupfish populations.

Three listed bird species may also be affected by future changes in the Sea. Brown pelicans use the Sea for feeding, nesting, and roosting. As the Sea becomes more saline and the shoreline recedes in the future, fish will disappear and the small islands used by pelicans will become connected to shore—thus loosing their security value. There are also concerns of selenium (Se) bioaccumulation in food chains used by fish-eating birds such as pelicans. Yuma clapper rails use freshwater marshes managed as wildlife habitat at the south end of the Sea, and some brackish sites associated with wastewater drains and river deltas. These brackish areas will likely disappear as the Sea becomes more saline and the shoreline recedes. There is also concern of Se bioaccumulation in food chains used by invertebrate-eating birds such as rails as Se concentrations in wastewater increase.

Significant Problems and Challenges

Among the problems and challenges facing the Salton Sea are increasing salinity, air quality concerns, Se, and eutrophication, as discussed in this section.

Salinity

Salinity is the more time-sensitive problem and must be dealt with so that the Sea survives long enough for the other, more complex problems to be addressed. This is not an either/or situation, as the investment in controlling salinity will be lost if the other problems are not also addressed.

As noted previously, the Sea has salinity measured recently at about 48,000 mg/L. In the absence of more definitive current information, at a salinity of 60,000 mg/L, the majority of the fishery is projected to be lost. Historically, the fishery supported species with differing levels of tolerance to salinity. In recent years, the sport fishery has declined dramatically. Sargo, croaker, and orangemouth corvina currently are not being detected in gill net samplings. Tilapia currently are rebounding from dramatic reductions that occurred over the last few years. It has been predicted that some age classes and species would likely to be lost at lower levels of salinity, thereby initiating a general decline in the fishery several years before a salinity of 60,000 mg/L is reached. This could be what has been occurring over the last few years.

The impacts of salinity on invertebrate populations also have significant biological ramifications. The pileworm (*Neanthes succinea*) is a major food source for some species of fish and birds. As salinity increases, a time will occur in the near future when pileworms will no longer be present in this ecosystem. Other invertebrates, such as brine flies (*Ephybra spp.*), will be favored by increased salinity. The shift in invertebrate populations will be beneficial for a few species of birds, but not for many others.

Air Quality Concerns

Winds in the Salton Sea basin generate large dust storms. As the Sea recedes in the future, there could be as much as 140 square miles of lake bed ("playa") exposed that could significantly increase fugitive dust in the basin. Human health is a concern related to these potential increases. Particles with a diameter of less than 10 microns (PM_{10}) are of primary concern. The Imperial Valley already suffers from the highest childhood asthma rate in the State. Furthermore, elderly people are especially susceptible to poor air quality (Cohen, 2006).

Sediment moisture, salt and sediment composition, and the extent of vegetation establishment all have major influences on the susceptibility of exposed sediments to wind erosion. Active disturbance of any exposed sediments can significantly increase the potential for wind erosion. Many major reservoirs experience significant seasonal changes in water elevation without generating serious fugitive dust problems during periods of low water levels. But serious fugitive dust problems have developed at two alkaline lakes in California—Owens Lake and Mono Lake. It is not known to what extent the Salton Sea will contribute to dust emissions, but it is assumed there is a risk that exposed playa areas would be emissive. Potential air quality mitigation projects are discussed in Chapter 3.

Selenium

Se is a naturally occurring semi-metallic trace element with biochemical properties similar to sulfur, and it is an essential trace nutrient necessary for normal metabolic functions. However, there is a narrow margin between nutritionally optimal and potentially toxic dietary exposure concentrations of Se for vertebrates. Effects of Se toxicity can range from hair/feather loss to death. Reproductive impairment—a common concern in Se studies—is exposure responsive, meaning the higher the concentration, the greater the effect. Se is a consideration in Salton Sea studies because of the potential for bioaccumulation in aquatic food chains supporting abundant and diverse bird use of the area. Bioaccumulation can occur when Se is acquired from one level of a food chain and passed on to the next higher level. For example, Se can be accumulated from water and/or sediments by bacteria and algae and passed on to macro-invertebrates that feed on them. Birds that feed on the macro-invertebrates would then accumulate larger amounts of Se. Under certain conditions, Se can accumulate to toxic levels in food chains (e.g., in birds).

Se cycling involves the interaction of physical, chemical, and biological components of aquatic systems. The processes and interactions are complex and can possess system unique characteristics. For example, Se concentrations in drainage water entering the Salton Sea are at levels that would normally cause concern for bioaccumulation within the Sea's food chains. However, the interaction of system components currently characterizing the Sea results in a sequestering of Se in bottom sediments. Se levels available for accumulation in food-chains originating in the Sea are, therefore, lower than would be expected from a different blend of system components. Se concerns for the Salton Sea focus on the uncertainties associated with the interactions of the physical, chemical, and biological components that would characterize the future under the No-Project Alternative and/or the future under the restoration alternatives. The future Salton Sea system may support Se cycling similar to the current situation, or a different system—with different Se risk to local food chains—may be supported.

Eutrophication

Eutrophication is the enrichment of lakes by nutrients, typically nitrogen and phosphorus (P). High concentrations of nutrients can lead to increased growth of algae and aquatic plants and decreased species diversity. Eutrophication is a natural aging process in some lakes, but it is frequently accelerated by nutrient loadings arising from human activity.

Nutrient loadings to the Salton Sea are very high because of the variety of both nonpoint sources (primarily agricultural runoff) and point sources (wastewater treatment plant effluent) of nutrients in the watershed. As a result, the Sea is classified as hypereutrophic, a term used for lakes with the highest nutrient and chlorophyll *a* concentrations and the lowest transparency. In hypereutrophic lakes, algae and other organic matter decompose, creating severe oxygen depletion. Oxygen depletion at the Salton Sea has caused fish kills and has contributed to other chemical changes that create odors and other nuisance conditions.

The size of the Sea would be reduced under the various alternatives, which could result in intense and persistent thermal stratification at depths greater than 10 meters (m) (33 feet). (Thermal stratification refers to the layering that occurs, particularly in the warmer months, when a warmer, less dense layer of water [the epilimnion] overlies a colder, denser layer [the hypolimnion]). As a result, the Sea would switch from a system with several mixing events per year, to a system that is mixed for a relatively brief period in the winter. This stability and the expected continuing eutrophication would make the hypolimnium of the Sea anoxic (i.e., contains no DO) for most of the year.

With this extensive anoxia, hydrogen sulfide (H_2S) and ammonia (NH_3) could build up to unprecedented levels because of the lack of mixing. When the Sea does mix, the rapid breakdown of the stratification could potentially lead to a sudden redistribution of anoxia, H_2S, and NH_3 throughout the water column and the release of gaseous NH_3 and H_2S to the air. The effect of this could be an annual die off of most fish in the Sea and serious odor problems. There are also potential human health impacts, including headache and nausea, as well as more serious problems for sensitive individuals.