Saving *the* Salton Sea

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A RESEARCH NEEDS ASSESSMENT

prepared by:
U.S. Department of the Interior
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in cooperation with:
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and U.S. Geological Survey - Biological Resources Division and Water Resources Division

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Forward

"Ecosystem management" has become the new paradigm for the conservation and management of natural resources in the 1990's. This shift from traditional conservation and management of individual species is driven in part by our greater appreciation of the impacts of environmental change on the sustainability of biological systems and the diversity of species within those systems. In the 20 years between the first major global conference on the environment held in 1972 and the 1992 United National Conference on Environment and Development, several prominent scientists noted that "marked degradation and dysfunction had occurred in most of the earth's ecosystems". As evidenced in the following document, the Salton Sea is clearly one of the systems that has markedly degraded during this period. This proceeding from a recent workshop on the Salton Sea summarizes the perspectives of approximately 100 scientists, managers, and others regarding approaches that must be taken if the Sea is to serve as a functional ecosystem in support of the surrounding human population.

Ecosystem degradation is intimately associated with human economic, social, cultural, and physiological well-being. In this context, it is critical, as noted by others, that we identify processes that have led to degradation of ecosystems like the Salton Sea, recognize the early signs of ecosystem dysfunction, and understand the consequences of ecological change for the human community, both in terms of utilitarian values and existence values. These needs have resulted in the emergence of a new area of focus called "ecosystem health" which has been defined as "a systemic approach to the preventative, diagnostic, and prognostic aspects of ecosystem management, and to the understanding of relationships between ecosystem health and human health. It encompasses the role of social values and attitudes in shaping our conception of health at human and ecosystem scales. ... Its focus [has] preventive, as well as curative and rehabilitative aspects." An ecosystem health perspective was pursued at the Saving The Salton Sea workshop.

Stakeholders, scientists, and managers all agree that rehabilitation of the Sea <u>is essential</u> and requires that current ills be rectified in a manner that allows the Sea to sustain social values of importance to the human populations of the Imperial and Coachella Valleys, as well as society in general. The complexity of saving the Salton Sea is reflected in the multi disciplinary organization of the workshop, consisting of 5 teams which considered the physical environment, biological environment, cultural resources, pathogens and disease, and contaminants. Nothing less than a fully integrated and collaborative effort by individuals from the physical, biological, and engineering sciences, in conjunction with the many stakeholders involved, can provide the information and understanding required to assure that the most appropriate engineering approaches are taken to stop further deterioration of the Sea and return this ecosystem to a desired level of quality. Key questions previously identified by others addressing ecosystem degradation must include: What are the

critical ecosystem functions that must be maintained for economic and societal well-being? What are the impacts of transformation on the health of fish and birds, as well as humans? How are societal values influenced by changes in the landscape in which they arise, and how do these values in turn impact the landscape?

Success in saving the Salton Sea requires that physical and biological scientists work together to describe system properties such as nutrient flows, energy transformation, community structure and other aspects of the ecosystem and how these components will be affected by various engineering approaches to reduce salinity and water levels; health specialists will need to assess fish, wildlife, and human disease implications; social and cultural interests must be fully considered to assure that engineering alternatives provide for the enhancement of human community values; and the sustain ability of agriculture and other economic investments of the area must be fully supported by the actions to be taken. This challenge is of Herculean proportions but not beyond successful accomplishment. The importance of the Salton Sea to the economic, social, and biological values of the region and the costs associated with any technological efforts to save the Sea demand success. The continued deterioration of the Sea despite more than a decade of various response actions clearly illustrates the need for a more holistic and integrated effort. A blue print for constructing this coalition has emerged from the latest Salton Sea workshop. Investments must now be made to provide the working capital and expertise required to produce the information and knowledge that will lead to successful rehabilitation of the Sea.

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Executive Summary

The Salton Sea is California's largest inland water body and an important resource for people and wildlife in the Imperial and Coachella valleys. It is a major stop over for millions of migratory water birds along the Pacific Flyway, supports 5 endangered species, and once was widely known and visited for its highly productive sport fishery. The abundance and diversity of birds has become known and a tremendous following has developed of avid birders from all over the world. A study by Paul Kerlinger conducted 1993 - 1994 found that 54,000 people spent $3.1 million in the area while watching birds. Dedicated lands in the Sea's environs include the Salton Sea National Wildlife Refuge, the California Department of Fish and Game's Wister Wildlife Management Area, the Salton Sea State Recreational Area, and the Torres Martinez Indian Reservation. The Sea was originally created as a result of flood events in the lower Colorado River. Today, its major source of water replenishment is agricultural drainage. The Salton Sea is designated as a repository for surface and subsurface agricultural drainage in support of the $1 billion agricultural industry in Imperial and Coachella Valleys. The only outflow from the Sea is evaporation. Consequently, over time, water quality in the Sea has changed from a freshwater environment to a saline environment that is now saltier than seawater and becoming saltier. Environmental contaminants such as selenium, pesticides, and fertilizer compounds are also at concentrations that may threaten the viability of fish and wildlife populations. Although fish kills have been observed for more than four decades, their frequency and magnitude have caused alarm in recent years. In addition, several previously abundant recreational fishes have declined in abundance, and other species are known to harbor potentially virulent forms of disease organisms. Human public health advisories warn of the dangers of eating fish caught in the Sea. The end-result is that the sport fishery may be on the verge of collapse, and other beneficial uses of the Salton Sea that contribute significantly to the local economy have been reduced in value.

Recent disease outbreaks in fish and birds at the Salton Sea have focused local and national attention on the status of this ecosystem as degraded and in dire trouble. The deaths of more than 150,000 eared grebes in 1992 from an undiagnosed cause; a severe botulism outbreak killing over 15,000 birds in 1996, including 1,400 endangered brown pelicans; the appearance of Newcastle disease in 1997 that decimated an entire nesting colony of double-crested cormorants, and numerous other die-offs documented since the 1970s, attests to the severity of the disease problems. In addition, literally millions of fish have died in continuous as well as epidemic events. Substantial public health concerns exist with regard to disease-causing agents present in the Salton Sea ecosystem. For example, several pathogenic microorganisms have been identified in the New River and efforts are ongoing to stop the flow of raw sewage from Mexico. However, critical baseline scientific data to facilitate focused epidemiological studies do not exist. This limits the capability of public health agencies to evaluate and respond to local public health concerns of people residing near the Salton Sea or utilizing its environs.

Proposals for major engineering projects have been developed to deal with the ongoing deterioration of the Salton Sea. Recognizing the need to address multiple, complex problems for wildlife and people in participating in the planning of a Salton Sea project, the Fish and Wildlife Service and Bureau of Reclamation convened a workshop to examine scientific information needs efficiently. The workshop scientists were to collaboratively design a research proposal document, that when implemented and completed would yield the foundational understanding for intelligent decision making within the time frame mandated by the 1997 Congressional Action Plan for the Sea, prepared by the Salton Sea Congressional Task Force. The Action Plan was presented on behalf of the Inland Empire Congressional Delegation by Congressmen Sonny Bono and Duncan Hunter. It provides for three years of data gathering through a collaborative effort, eventually leading to a recommended solution for the Sea.

"Saving The Salton Sea" was a needs-assessment workshop held in Palm Springs, California, August 4 - 8, 1997. The workshop brought together nearly 100 scientists, managers, agency and university representatives, and other interested parties. It was conducted in cooperation among the Fish and Wildlife Service, Bureau of Reclamation, California Department of Fish and Game, and others to develop a process to address the natural and cultural resource issues, and research and investigation needs for any proposed engineering solution to repair the Salton Sea Ecosystem. Twenty-one Federal, State and local agencies, universities and government offices participated (Appendix A).

The workshop focused on determining those tactical investigations and research initiatives of 1 - 3 year duration that should be completed, and what data and information needed to be synthesized to assess proposed engineering solutions for the troubled Salton Sea ecosystem. The natural resource and human values are so inextricably linked in this ecosystem, that a clear understanding must be reached of how this systems works in order to repair the problems for wildlife and people. It is recognized that the Sea will require a rigorous and comprehensive approach to understand and address the numerous problems preventing it from functioning as a healthy ecosystem. Furthermore, without enhanced knowledgeable and intensive management, the Salton Sea will not fulfill the needs of society and will continue to deteriorate. The end result will be the loss of regionally significant natural resources and severe economic losses for the human population.

To aid the workshop participants in framing their research needs within the context of proposed engineering solutions for the Sea, presentations were made of the three proposals being considered by Congress, the Salton Sea Authority, and private consultants to address the problems. The scientists were given full exposure to the gamut of robust initiatives under serious consideration. The three proposals presented to them included the diking alternative; the Congressional Action Plan which considers pumping water through Mexico, out of the Sea to the Sea of Cortez and returning gulf water to the Salton Sea; and pumping water out of the Sea through a "Riparian Corridor" extending from the Salton Sea to the Sea of Cortez.

The workshop topics included the natural and cultural resources, contaminants, and disease on an ecosystem level. Workshop participants were placed on teams to develop proposals that, when funded and completed, would provide data layers. The collection of those data layers would be coordinated to maximize collaboration, avoid unproductive duplication, and render the data available as quickly as possible to the many cooperators. A protocol would be developed to ensure the comparability and scientific validity of techniques and results. The data would be spatially referenced, so that all information could be incorporated into a model of the Salton Sea ecosystem in a Geographic Information System (GIS). This would allow synthesis of the individual data layers into an interactive model that could simulate the synergistic complexities of the ecosystem in predicting changes, given differently engineered projects and managed scenarios.

The teams of scientists covered the physical environment, biological environment, cultural resources, pathogens and diseases, and contaminants. The proposals developed by these teams were to address various aspects of the following 3 goals: (1) Develop an understanding of the Salton Sea ecosystem; (2) Develop an understanding of the factors driving massive fish and wildlife die-offs in the Salton Sea and environs, methods for interrupting this mortality, and the potential risks to human health; (3) Develop methodology for managing the Salton Sea ecosystem for maximum sustainability of cultural and biological resources which can later be used to address sustaining economic resources of the area. A great wealth of collective expertise and local knowledge were successfully melded through intense discussion into 39 proposals and over 44 accompanying recommendations. Budgets were developed for 31 of the proposals.

The entire package of 31 proposals, as drafted, would require $36,097,600 to implement and complete, or $12 million per year over a 3-year period. With maximum coordination of the studies and collaboration among the researchers, major overlap among the studies would be eliminated and costs would be reduced. The studies would provide a broad spectrum, in-depth examination of the physical and chemical attributes of the Sea's environment, the habits and roles of many key species, and how the living and non-living interact to cycle life and perturbations in the Salton Sea ecosystem. In understanding the interactions of salts, nutrients, and other key components of the water with current, wind, and wave, with organisms that produce and store food and accompanying chemicals, and species that consume, the cycling of problematic contaminants, toxins, and diseases could also be traced and counter-managed.

The data layers resulting from the studies drafted by the workshop scientists, when linked and analyzed, would comprise an ecosystem model with predictive capabilities. With such a tool, the engineered project for the Salton Sea and any subsequent management scheme could be implemented in accord with well-founded scientific strategies for maximizing success. Without this tool, the effects of a major project or management cannot be adequately predicted.

Introduction

This report presents the results of a workshop, “Saving The Salton Sea - A needs assessment workshop”, held in Palm Springs on August 4 - 8, 1997. The workshop brought together the scientific expertise, Salton Sea experience, and agency representation needed to document the information required to assess any proposed technological fix for the deteriorating Salton Sea. The major products of the workshop were study proposals and management recommendations, which are included herein in sections F and G.

The Salton Sea is 35 miles long, 9 to 15 miles wide with about 115 miles of shoreline, and California’s largest inland body of water. The Sea has been a recurring phenomenon for millennia, associated with flooding from the Colorado River. Located in the Sonoran desert of Imperial and Riverside Counties, it came into recent existence when the entire flow of the lower Colorado River was accidentally diverted into the Salton Sink for 16 months, beginning in 1905. Since then, the Sea has been maintained by agricultural runoff and local drainage, mostly via the New, Alamo, and Whitewater Rivers. Unfortunately, inflows from the New River, reported to be one of the most polluted rivers in the U. S., include industrial and domestic wastes and pollutants from Mexico. The Salton Sea is designated as a repository for surface and subsurface agricultural drainage waters in support of the $1 billion agricultural industry in Imperial and Coachella Valleys. The only outflow from the Sea is evaporation of about 5.5 feet per year.

The annual evaporative loss of so much fresh water has led to the concentration of salts, nutrients, and perhaps other chemicals in the Sea’s water, sediments, and/or inhabitants. The salt concentration in the Salton Sea, for example, is about 44 parts per thousand, or 25% higher than that in ocean water. This concentration has come about in spite of additional inflow into the Sea that has resulted in a problematic rise in the surface elevation. At a current elevation of approximately -227 feet MSL (Mean Sea Level), many hundreds of acres that formerly supported agriculture, recreation, businesses and human dwellings, or wildlife habitat are now under water. For example, of the 35,000 acres originally designated as the Salton Sea National Wildlife Refuge in 1930, only 2,200 manageable acres remain unflooded.

The Salton Sea Ecosystem includes 5 endangered species, many other sensitive species, and millions of migratory water birds. The bird diversity in the Sea’s environs has given rise to ecotourism. With 380 species of birds identified on the NWR, it is one of the country’s refuge hot spots for the emerging past time of birding. A recent world-class sport fishery, waterfowl hunting, and other recreational opportunities contribute significant revenue to the local economy but have declined with the environmental deterioration over the past decade.

Public perception strongly linked the Salton Sea with major recreational opportunities, thereby drawing urban residents from all over southern California. As recently as in 1987, 154,600 households spent $76 million on recreational pursuits in the Sea's environs. Just as recreational usage has declined with reductions in introduced sport fish populations and other manifestations of the deterioration of the Sea's ecosystem, these uses should increase with improved conditions in the ecosystem.

The Salton Sea has become an ecosystem out of balance as evidenced by frequent fish and bird die-offs, fish consumption warnings, and other human health alerts. Some of the major events and actions taken in chronicling and dealing with the deterioration of the Salton Sea ecosystem over the past 10 years are found in Appendix B.

Public health, economic, and natural resource values are also inextricably linked to overall conditions of the Sea's ecosystem. Some of the pathogens infecting fish and birds could also affect humans under certain conditions. Contaminants in fish, notably selenium, also pose human health risks and human consumption advisories have been posted. Land speculation and development went from boom to bust with increasing salinity, fluctuating water levels, offensive odors, lack of sport fish, and perception of increasing human health concerns. Lastly, if the deterioration of the Salton Sea is leading to an overall collapse of the ecosystem, nationally significant natural resource values are at great risk. Given the linkage between the health of this ecosystem and human values, including economic, recreation, human health, and natural resources, understanding and repairing this ecosystem appears warranted. Completion of the workshop was a major step in this process.

The mission of the workshop was to produce a document that identifies the priority tactical natural and cultural resources investigation needs of the Salton Sea ecosystem and the cost to complete them. The maximum study time frame of 3 years was adopted to be synchronous with the Congressional action plan for the Salton Sea.

This document is intended to aid scientists, natural resources agencies, Congress, and other policy makers in making informed decisions with regard to engineering solutions and management options for reversing the deterioration of this ecosystem. Neither the workshop, nor this report were intended to deal substantively with recreational or economic issues. The information herein should be useful in helping to fulfill mandates under the National Environmental Policy Act, California Environmental Quality Act, Fish and Wildlife Coordination Act, Endangered Species Act, Archeological Resources Protection Act of 1979, National Historic Preservation Act, and related applicable legislation.

Techniques and Organization

The workshop focused on the Sea's natural and cultural resources, contaminants and disease on an ecosystem level. Workshop participants were placed on teams to develop proposals that, when funded and completed, would provide data layers. The collection of those data layers would be coordinated to maximize collaboration, avoid unproductive duplication, and render the data available as quickly as possible to the many cooperators. A protocol would be developed to ensure the comparability and scientific validity of techniques and results. The data would be spatially referenced, so that all information could be incorporated into a model of the Salton Sea ecosystem in a Geographic Information System (GIS). This would allow synthesis of the individual data layers into an interactive model that could simulate the synergistic complexities of the ecosystem in predicting changes, given differently engineered projects and managed scenarios.

The collective expertise, local knowledge, agency and other affiliate representation was successfully melded in a collaborative process at the workshop. The respectful cooperation of the many participants resulted in the most meaningful portion of this document, the proposals and recommendations. The workshop teams, participants, and their affiliations can be found in Appendix C.

An inter-agency group had previously developed the topics to be addressed by the teams in their deliberations and final products, although additional categories of investigation were to be pursued, if warranted. The Biological Environment Team was requested to address fish and wildlife distribution; food chain dynamics, including microbial ecology of the algae, phytoplankton, and zooplankton; seasonal habitat changes including quality and distribution; migratory birds; threatened and endangered species; and benthic and other invertebrates. The Physical Environment Team was directed to explore the topics of water chemistry, sedimentary and geologic history, toxicology, hydrology, meteorology, bathymetry, air quality, and salinity. The Contaminants Team was given the topics of salinity; selenium; other inorganics; biomagnification and other phenomenon of accumulation; ammonia; pesticides; other agricultural chemicals; sewage and industrial effluent; transmission pathways for contaminants; and water quality and degradation. The Pathogens and Disease Team were asked to explore known causes of mortality including Vibrio infections in fish and botulism in birds; other infectious diseases and potential pathogens; microbial toxins including algal toxins; microbial ecology; undetermined causes of fish kills; undetermined causes of grebe mortality; disease/contaminant interactions; and sublethal and immunological effect. The Cultural Resources Team's topics included Archaeology and prehistory; traditional use sites; Native American issues; and Native American sites.

In developing these topics, the teams were to create proposals that would help attain goals that were largely derived from the Salton Sea Ecosystem Initiative: Salton Sea Workshop, hosted by the National Wildlife Health Center in Madison, Wisconsin, October 22 - 23, 1996 in response to the massive bird die-offs. The current workshop goals were as follows:

Goal I. Develop an understanding of the Salton Sea ecosystem.

A. Compile, catalog, and evaluate existing data including GIS and identify areas where information is lacking on the current biological, physical, and political realities of the ecosystem.

B. Develop a conceptual model of ecosystem function to help identify critical physical and biological information needs.

C. Develop a strategy for methodical inventory and monitoring of the physical, chemical, and biological attributes of the Salton Sea ecosystem. Monitoring should include the Salton Sea, its major inflows, including the New, Alamo, and Whitewater Rivers, and agricultural drainage systems. Data collection and interpretation must be linked to hydrologic models currently under development for the Salton Sea.

Goal II. Develop an understanding of the factors driving massive fish and wildlife die-offs in the Salton Sea and environs, methods for interrupting this mortality, and the potential risks to human health.

A. Conduct surveys to document microbial flora and fauna, and to identify potential pathogens in the Salton Sea.

B. Develop a strategy for data collection and observations during fish and wildlife die-offs.

C. Initiate field research to examine causes of, and factors related to fish and wildlife mortality.

D. Test hypotheses generated from field data through controlled laboratory experiments.

E. Devise and test management methods to control or prevent fish and wildlife mortality.

Goal III. Develop methodology for managing the Salton Sea ecosystem for maximum sustain ability of cultural and biological resources which can later be used to address sustaining economic resources of the area.

A. Design biological, physical, and cultural resources studies to provide the data needed to answer questions about the relations between human actions, water quality, sediment chemistry, pesticide applications and effects, microbial ecology, land use characteristics, and fish and wildlife mortality.

B. Develop adaptive management strategies to mitigate or resolve problems.

C. Implement, test, and monitor management strategies.

D. Develop an interagency coalition as a forum for interactive dialogue, information exchange, and resolution of biological problems within the Salton Sea ecosystem.

Results

The workshop teams produced 31 study proposals that included budgets, most of 3-year duration and 8 short-form studies without budget submittals. These studies were designed to provide information on all aspects of the Salton Sea ecosystem, the past human environment, and major problems in the Sea. The complete proposals are in section F of this report and a list of proposal titles is in Appendix D.

Each team ranked the proposals they produced, with number 1 being of the highest priority. No attempt was made to rank, or prioritize all 39 proposals. Neither the managers, nor scientists at the workshop felt qualified, for example, to determine if understanding the cycle leading to massive grebe die-offs is of higher priority than understanding nutrient flow, or food web dynamics in this ecosystem. Consequently, the proposals are only ranked within their particular team subject, and the order that the teams are dealt with herein is arbitrary. Proposals deemed of equal ranking within a team were designated with the same number and a letter or number suffix.

The proposals emphasize beginning investigations from our current base of knowledge. Pertinent literature would first be reviewed, evaluated, and incorporated where appropriate, based upon contemporaneous relevance, scientific rigor and validity. Furthermore, the teams recognized the priority of studies with the greatest management implications in order to transition through these studies to adaptive management and monitoring. Consequently, maximum advantage would be taken of existing knowledge, practical application of all useful information would be made quickly, and the Sea's progress would be tracked efficiently over time.

A brief summary of the proposal titles follows.

The Physical Environment Team produced dual priority 1 projects, one on sediment transport that takes advantage of a study in-progress (PE1A); the other on constituents and characteristics of the Sea's water, including plankton (PE1B). Additional proposals deal with a nutrient budget for the Sea, and developing an understanding of the effects of an over-abundance of nutrients (eutrophication) (PE3), phenomena that undoubtedly play a role in fish kills; a water and salt model (PE4A); a profile of water quality (PE4B) and use of remote sensing to monitor water quality (PE7); a characterization of sediments and evaluation of geologic hazards (PE5); studies of sediment transport with regard to resuspension (PE6); a characterization of dissolved organic carbon in the Sea and inflows (PE8); and the potential for dust problems with a receded Sea (PE9).

The Biological Environment Team's first priority was also an understanding of water chemistry and other properties in relation to selected aquatic biota, the algae and inverte-

brates (BE1). Additional priority studies were on fish ecology (BE2) which has changed dramatically in recent years; bird distribution, abundance, and ecology in the context of its importance in the Pacific flyway (BE3); wetland type, abundance, distribution, function, and potential for restoration (BE4); developing common, rigorous protocols for data collection methodologies, storage, access and retrieval, analyses, and geologic referencing (BE5); and habitat base mapping and support for the Geographic Information System (GIS) that will allow interactive analyses of all these data in an ecosystem model (BE6).

The Cultural Resources Team's proposals call for an examination of existing information on the Archaeology and human history in the watershed (CR1); exploration of the unwritten record of cultural values and history of the area through interviews with native Americans (CR2); GIS layering and modeling of past human ecology and current cultural resource distribution (CR3); field inventory of the cultural resources (CR4); and a reconstruction of the Holocene environment, particularly over the past 12,000 years, with an overlay model of the associated cultural environment (CR5).

The first priority of the Pathogens and Diseases Team was an understanding of disease-causing agents for fish, wildlife, and humans in the Sea's environment, including a health assessment monitoring program (PD1). The second priority focused upon avian botulism, the role of fish and other environmental factors in cycling the toxins (PD2). The third proposal dealt with algal biotoxins and their role in fish and wildlife mortality (PD3). Additional priority studies covered salinity, contaminants, and disease interactions in fish and birds, a joint proposal with the Contaminants Team (PD4 and C3); understanding and reducing mortality in eared grebes (PD5); and Newcastles disease relative to bird die-offs and the potential risk of spread to other wild birds, domestic poultry, and humans (PD5.5).

The top dual priorities of the Contaminants Team were the interaction of water quality variables and environmental contaminants in fish kills, assessed in the field and lab (C1A); and selenium and DDE distribution and toxicity in total organic carbon of bottom sediments (C1B). Their second priority was a study of immune response capabilities relative to contaminant levels in fish and birds (C3 and PD4). Additional proposals in priority order included a model of past, present, and future inputs and fates of contaminants in the Sea (C4); toxicity assessment of salt precipitates in the Sea and its inflows (C5A); validated response curves for selenium toxicity in avian reproduction (C5B); monitoring nutrient and contaminant containment in constructed wetlands (C6); effects of contaminants on reproduction in fish-eating birds (C7); human exposure to contaminants from waterfowl consumption (C8); human exposure to, and risks from selenium and other contaminants consumed with fish caught in the Sea (C9); accumulation of organochlorine pesticides and selenium through the food chain to higher trophic levels in birds (C10); and characterization of the constituents in the extremely high levels of dissolved organic carbon in the Sea and its inflows (C11).

Please refer to the full text of the proposals herein for the background and discussion needed to appreciate the detail of each.

Study costs are summarized by team, study, and year in Table 1. The entire package of 31 proposals would require $36,097,600 to complete over 3 years (Table 2). This cost would be reduced by minimizing overlap among studies. However, this is a reasonable estimate of the cost for a broad spectrum, in-depth examination of the physical and chemical attributes of the Sea's environment, the habits and roles of many key species, and how the living and non-living interact to cycle life and perturbations in the Salton Sea ecosystem. In understanding the interactions of salts, nutrients, and other key components of the water with current, wind, and wave, with organisms that produce and store food and accompanying chemicals, and species that consume, the cycling of problematic contaminants, toxins, and diseases could also be traced and counter-managed.

It is only with the type of examination of the Sea's ecosystem outlined herein that we will have enough understanding to successfully evaluate the various engineering alternatives, participate in implementation, and manage the Sea. Our goal must be the understanding needed to maximize the Sea's health and productivity for wildlife, since, as the past has shown, that is the way to maximize the Sea's value for people too.

Table 1. STUDY PROPOSAL FUNDING (in $1,000s)

Physical Environment Proposals		Year 1	Year 2	Year 3	Totals
PE 1A	Circulation/Sedimentation	275.00	230.00	230.00	735.00
PE 1B	Limnology	115.00	110.00	85.00	310.00
PE 3	Nutrients/Eutrophication	155.00	160.00	85.00	400.00
PE 4A	Hydrology/Salt	50.00	50.00	65.00	165.00
PE 4B	Water Quality	95.00	165.00	180.00	440.00
PE 5	Sediment/Geology	500.00	765.00	225.00	1,490.00
PE 8	Organic Carbon	135.00	84.00	–	219.00
	TOTALS	1,325.00	1,564.00	870.00	3,759.00

Biological Environment Proposals		Year 1	Year 2	Year 3	Totals
BE 1	Algae/Invertebrates/ Chemical Limnology	1,000.00	700.00	700.00	2,400.00
BE 2	Fish	600.00	350.00	350.00	1,300.00
BE 3	Birds	497.00	447.00	447.00	1,391.00
BE 4	Wetlands	170.00	–	–	170.00
BE 5	Research Protocols	150.00	–	–	150.00
BE 6	GIS	200.00	150.00	150.00	500.00
	TOTALS	2,617.00	1,647.00	1,647.00	5,911.00

Cultural Resources Proposals		Year 1	Year 2	Year 3	Totals
CR 1	Resources Overview	160.00	115.00	–	275.00
CR 2	Native American Consultation	280.00	170.00	110.00	560.00
CR 3	GIS	200.00	190.00	–	390.00
CR 4	Field Inventory	740.00	790.00	370.00	1,900.00
CR 5	Holocene Reconstruction	160.00	260.00	70.00	490.00
	TOTALS	1,540.00	1,525.00	550.00	3,615.00

Pathogens and Disease Proposals		Year 1	Year 2	Year 3	Totals
PD 1	Fish, Bird, Human Health	3,400.00	3,300.00	3,300.00	10,000.00
PD 2	Botulism	1,000.00	700.00	700.00	2,400.00
PD 3	Biotoxins	393.00	543.00	544.00	1,480.00
PD 4	Disease/Contaminant Interact	400.00	450.00	460.00	1,310.00
PD 5	Grebes	450.00	450.00	100.00	1,000.00
PD 5.5	Newcastles Disease	300.00	300.00	195.00	795.00
	TOTALS	5,943.00	5,743.00	5,299.00	16,985.00

Contaminants Proposals		Year 1	Year 2	Year 3	Totals
C 1A	Fish deaths	975.00	940.00	217.50	2,132.50
C 1B	Selenium and DDE	343.00	316.00	97.00	756.00
C 3	Immune Competence	See PD 4			
C 4	Contaminants Model	370.00	355.00	275.00	1,000.00
C 5A	Salt Precipitate Toxicity	452.50	–	–	452.50
C 5B	Toxicity Validation	182.20	182.20	182.20	546.60
C 6	Wetland Water Polishing	480.00	230.00	230.00	940.00
	TOTALS	2,802.70	2,023.20	1,001.70	5,827.60

Table 2. SUMMARY OF STUDY PROPOSAL FUNDING (in $1,000s)

Team	Year 1	Year 2	Year 3	Totals
Physical Environment	1,325.00	1,564.00	870.00	3,759.00
Biological Environment	2,617.00	1,647.00	1,647.00	5,911.00
Cultural Resources	1,540.00	1,525.00	550.00	3,615.00
Pathogens and Disease	5,943.00	5,743.00	5,299.00	16,985.00
Contaminants	2802.70	2023.20	1001.70	5827.60
TOTALS	14,227.70	12,502.20	9,367.70	36,097.60

Summary of Recommendations

The 5 teams of scientists made over 44 recommendations to accompany, qualify, and compliment their study proposals. The recommendations can be found verbatim in section G of this report. Some of the common themes are summarized below.

1. The full coordination of study and management efforts would be greatly expedited by, and may only be possible with a secure on-site facility with sleeping quarters, wet and dry labs, a full complement of all equipment needed for data collection and analysis to be used in common by all researchers, separate offices for writing and meetings, and a visitors center. The available equipment should include ample computer hardware, software, and support, state-of-the-art global positioning units, and a boat large enough to be useful under most conditions.

2. Foremost in team discussions was the overriding need to understand the Salton Sea ecosystem, preferably before, but at a minimum, while we attempt to fix it through human intervention. Otherwise the technical solution for the Sea's problems is liable to be too narrowly focused and a unique opportunity to greatly benefit people and wildlife might not achieve success. The knowledge imparted through these studies would be the minimum required for well-founded decision making with respect to both a technical project and subsequent management.

3. The scientists strongly recommended that protocols be established and strictly followed governing data collection techniques, sites, frequency, geographic referencing, analysis, security, availability, and integration in a GIS ecosystem model. The protocols should be developed by a team representing those who will perform the investigations in collaboration with a science coordinator who will oversee study coordination including constant adherence to the protocols. The scientific validity and reproducibility of methods and resultant data must be carefully assured and monitored.

4. Information from the proposed studies should be available in an understandable and consistent format, as quickly as possible and as appropriate to all participants. There should be regularly scheduled coordination meetings to review progress, adjust schedules, and disseminate information. Progress reports and updates, including news releases, would be provided in newsletter format to all participants and interested parties, as appropriate. Information would be presented to the public at 3 annual conferences and in published conference proceedings.

5. An oversight team should be formed to help monitor, coordinate, and support the study efforts. Team composition should be representative of the researchers, involved agencies, and others with vested interests. However, the team should be small enough to be operative, and work cooperatively with the science coordinator.

6. An event-response team should be formed and funded to allow immediate tactical response to major events in the Sea. Natural disasters, such as large fish kills at the Sea should be the future forum for immediate, multi-disciplinary scientific action including study, monitoring, and management trials. Currently, all of the available resources are being swallowed up in crisis management. However, the key to answers and fixes may lie with an adequately funded strike force of scientists and wildlife managers with an immediate response capability.

7. Successful modeling of the Salton Sea ecosystem and the needed predictive capabilities of the data set, given any technical fix and management scheme for the Sea, will be heavily reliant on data integration in a GIS. Information must flow freely from the scientists, through the science coordinator, to the GIS center and back. Data must be collected and recorded in a manner and format that can be immediately assimilated into the master GIS data base. The University of Redlands was appropriated funds and may take on the role of the ecosystem modeling center for the Salton Sea project.

8. The proposal submitted by the Corps of Engineers to streamline and meld their processes into one action in dealing with the Salton Sea project should be supported by all participants and implemented. (see Appendix G)

9. The numerous additional recommendations of the science teams should also be implemented in conjunction with the studies proposed herein.

The Proposals

Physical Environment Team Proposals

PE1A. Extension of Circulation Model Applied by UC Davis to Estimate Sediment Transport in the Salton Sea.

Introduction: Degradation of avian and aquatic life in and around the Salton Sea may be linked to the presence of a number of contaminants. Several of these contaminants, such as selenium, pesticides, and phosphorus, are associated with sediment and particulate matter. Any toxicological effects of these particulate contaminants may be localized and transient due to the accumulation of these sediments in certain areas of the Sea. Therefore, it is important to have an understanding of the transport and fate of these contaminated sediments under a variety of conditions, as well as the capability to predict and understand the potential redistribution that may occur when engineered remediation solutions are implemented.

A three-dimensional hydrodynamic model of the Sea has been developed by the University of California, Davis to simulate alternative management scenarios. This model incorporates temperature, salinity, and dynamic wind forcing; however, the sediment transport algorithms already present in the model have not been applied to the Salton Sea. This study will incorporate the transport and deposition of sediment originating from riverine sources and resuspension of bottom material associated with various engineering alternatives.

Justification: Sediment loads from the New and Alamo Rivers are quite large and a definitive sedimentation zone stretches out into the Salton Sea. At this time, very little is known about the deposition of sediments which enter the Sea or how their redistribution could be affected by future proposed remediation projects. Understanding the transport and fate of contaminated sediments is important, especially if a link is found to exist between contaminated sediments and recurring environmental problems in the Sea. An important tool for understanding the dynamics of sediment deposition and transport within the Sea is a sedimentation model. This model can be derived by extending the capabilities of the circulation model being developed for the Salton Sea Authority by the University of California, Davis to include sedimentation and resuspension processes. The adapted model will not only have utility for understanding existing conditions, but also provide probabilistic insights into changes in sedimentation patterns that may result when engineered remediation solutions are implemented. Understanding these processes and the mechanisms by which sediment transport, deposition and resuspension occur are critical to the health of the Sea, especially if the Sea's bathymetry is altered in the future.

Objectives:

1. To collect suspended sediment concentration and particle size distribution data for the Alamo, New, and Whitewater Rivers at gaging stations near their inflows to the Sea.
2. To apply existing sediment transport algorithms to the Salton Sea circulation model developed by UC Davis.
3. To collect appropriate data for parameter estimation, calibration, and verification, including water temperature, current velocity, suspended sediment concentration, and particle-size distribution.
4. To apply the model to describe the deposition, resuspension, and transport of sediments into and within the Salton Sea.
5. To apply the calibrated and verified model in predicting changes in the deposition, resuspension and transport patterns of sediments that will result from proposed remediation scenarios.

Products:

Year 1: Construct an uncalibrated, unverified sedimentation model for the Salton Sea and estimate model parameters from collected data.

Year 2: Complete collection of data for calibration and verification of the sedimentation algorithms; calibrate and verify sedimentation algorithms in the model.

Year 3: Evaluate the changes in sedimentation patterns likely to be caused by various engineered remediation scenarios and prepare a final report.

Anticipated Focus of Recommendations: This project is directed toward gaining a better understanding of sediment distribution patterns in the Salton Sea and the factors that affect them. Results from this project may provide important insights into factors that cause aquatic and avian die-offs in the Salton Sea. In addition, the calibrated and verified model will be useful as a decision-making tool for predicting benefits or degradations associated with proposed remediation solutions, and could provide insight into the movement of dissolved and suspended toxins within the Sea. This project will satisfy all three goals, especially Goal III to develop methodology for managing the Salton Sea.

Budget/Duration:

	Year 1	Year 2	Year 3
Labor (2 FTE)	200,000	200,000	200,000
Equipment	50,000	10,000	10,000
Supplies	10,000	10,000	10,000
Miscellaneous	15,000	10,000	10,000
Total	$275,000	$230,000	$230,000

Principal Contacts: Jerry Orlob, Geoff Schladow, Chris Cook, Roy Schroeder, and Mark Matsumoto.

PE 1B. Limnological Characterization of the Salton Sea.

Introduction: The Salton Sea is the largest inland body of water in California. Its formation in 1905-07 was followed by a rapid increase in salinity and decline in water level, then by a more gradual increase in salinity and water level with some annual fluctuations that continue today. Water quality in the Sea is thought to have continually degraded since its formation; however, very limited historical data other than salinity and major ion concentrations are available for the Sea. The Sea is a very important stop over for migratory birds on the Pacific Flyway. In recent years, its degraded water quality appears to be the proximate cause of extensive fish kills and to have resulted in major die-offs of brown pelicans and grebes using the flyway. Consequently, it is important to characterize the physical, chemical, and biological conditions that exist within the Sea, how these conditions vary seasonally and spatially, and how they will respond to implementation of any management alternatives.

Justification: All other investigations will require basic limnological data from the Salton Sea. The extent of existing data and its quality are currently not known. By assembling and evaluating existing information, and by determining the needs of all researchers involved in the Salton Sea program, it will be possible to maximize the data value for all studies and to provide a baseline for future evaluation of remediation alternatives. The implementation of rigorous and standardized protocols for sample collection by trained technicians, laboratory analyses, and assurances [followed by rapid electronic dissemination of the data stored in a national database] will yield results of multiple utility in understanding the Sea and the possible factors influencing conditions leading to wildlife die-offs, and for managing the basin to prevent hazardous conditions.

Objectives:

1. To assemble existing water-quality, phytoplankton, zooplankton, and fisheries data into a standardized database. (Note that all technical and fiscal aspects of the biological components of this study are addressed in other proposals, such as BE 1)

2. To document the water quality and plankton and fish distributions (species and density) throughout the Salton Sea with respect to time and depth using standard protocols. Final decisions on establishment of sites and sampling frequency will be made after consultation with biologists to maximize value of the limnological data to plankton and fish studies. Collections will tentatively be made from 5 sites; 3 in deep areas of the Sea, and 2 in shallower areas nearer riverine inflows. Sampling frequency will be monthly from Oct-Mar, and bi-weekly from Apr-Sep when stratification will be most intense. Profiles in the water column will be produced from temperature, pH, conductivity, dissolved oxygen, and light intensity (LiCor meter) or secchi depth recorded from one-meter intervals. In addition, samples from selected depths (the top and bottom of the epilimnion and hypolimnion at deep sites, and the top and bottom of the water column at shallow sites) will be analyzed for nitrate plus nitrate, dissolved Kjeldahl nitrogen, ammonium, total and dissolved phosphorus, dissolved silica, dissolved iron and manganese, alkalinity, dissolved

organic carbon, and chlorophylla. Samples from the top and bottom of the water column at each site will be analyzed for a broad suite of trace elements annually when non-stratified conditions prevail in winter. Algal samples will be taken from the euphotic zone at each sampling for taxonomic identification and enumeration.

3. To describe the extent to which unusual or hazardous water-quality or planktonic conditions occur.

4. To disseminate data rapidly and in a format useful to all researchers.

Products:

Year 1: Compile and make available relevant existing data in electronic format. Establish integrated objectives for monitoring selected sites at an appropriate frequency.

Year 2: Continue monitoring. Analyze temporal and spatial variation in first year's data and compare to any relevant historical data that exist. Compare current water-quality data with biological data for the occurrence and distribution of algal blooms, fish production, and fish and waterfowl die-offs (or lack thereof).

Year 3: Prepare a summary report describing all data. Meet with all other teams and interested parties to determine the need for continued limnological monitoring.

Anticipated Focus of Recommendations: Compilation of existing data will provide all investigators with ready access to historic studies and provide guidance to the establishment of sampling sites and frequency of collection. The systematic collection of data will provide the basis for a variety of activities that satisfy Goal II such as: development of nutrient budgets; contaminant characterization; development and evaluation of circulation models; determination of algal succession and density, and any relation to fish and wildlife diseases; and provide the basis for evaluating trends in lake chemistry and biology under any management alternative that is selected.

Budget/Duration: Labor, Equipment and supplies, Transportation, Miscellaneous.

	Year 1	Year 2	Year 3
Labor	50,000	50,000	50,000
Equipment (boat, profiler)	35,000	5,000	5,000
Analytical	25,000	50,000	25,000
Supplies	5,000	5,000	5,000
Total	$115,000	$110,000	$85,000

Principle Contacts: Roy Schroeder, Stuart Hurlbert, Dale Robertson, and Doyle Stephens.

PE3. Development of a Nutrient Budget and Eutrophication Evaluation for the Salton Sea.

Introduction: High nutrient (nitrogen and phosphorus) inputs from external sources and recycling from bottom sediment have resulted in high concentrations in the Salton Sea and extreme eutrophication. After periods when the Sea is stratified, winds or lake turnover cause the anaerobic bottom water and accompanying nutrients to be redistributed throughout the water column in the Sea. In addition, winds resuspend bottom sediment and nutrients into the water column. These nutrients, along with those introduced from riverine sources, can drive algal blooms. Decomposition of the dying algae causes oxygen depletion that can cause fish kills. In addition, the presence of anaerobic bottom water and resuspension of anaerobic sediments is associated with the release of hydrogen sulfide that impairs the recreational use of the Sea.

Justification: Mixing of anaerobic bottom water from the decomposition of organic matter which results from high algal production in the Salton Sea cause not only the odors (from the release of hydrogen sulfide gas) that reduce the recreational value of the Sea, but also appear to be the direct and indirect cause of fish kills. The harsh conditions (high temperature, increasing salinity, and low dissolved oxygen concentrations) result in conditions favorable to growth of pathogenic bacteria, and possibly production of phytotoxins, that are responsible for fish kills and bird die-offs. A quantitative nutrient budget for the Salton Sea is necessary to determine which remedial efforts will be most beneficial in reducing nutrient concentrations in the Sea, and thereby lead to a reduction in algal and organic matter production. Once a nutrient budget is established, the magnitude of external loading (predominantly from riverine sources) and internal recycling (from bottom sediments) can be compared to that removed by birds and other biota. Possible anthropogenic intervention can then be considered, such as massive harvest of tilapia and construction of wetlands along rivers. The nutrient budgets will permit determination of the impacts of these various alternatives on the Sea's water quality.

Objectives:

1. To determine daily and annual nutrient loading from external sources, primarily gaged streams, using biweekly sampling for nitrogen and phosphorus and daily flow data. Diurnal variations also will be measured at least twice, in winter and in summer, at each site. The sites are: New River near the outlet to the Salton Sea; New River at the international boundary; Alamo River near the outlet to the Salton Sea; and Whitewater River near the outlet to the Salton Sea.

2. To estimate atmospheric inputs from precipitation-quality data at network stations. If no stations are nearby, suitable instrumentation to collect local data will be co-located at 3 meteorological stations that exist in the CIMIS network near the Sea.

3. To measure nutrient fluxes from internal sources, primarily from the bottom sediment to the overlying water, using laboratory microcosms in conjunction with measured ambient conditions in the Sea.

4. To evaluate suitability of existing limnological monitoring to provide sufficient definition of nutrient concentration and distribution. Add constituents to the list of analytes in year 2, if data from basic limnological monitoring (separate proposal) indicate the need.

5. To estimate potential changes in nutrient concentrations and trophic status of the Sea in response to various management alternatives and climatic scenarios.

Products:

Year 1: Provide all data in tabular form. Calculate annual load of nutrients to the Salton Sea (and portion generated in Mexico), and amount recycled within the Sea.

Year 2: Compare and confirm results from Year 1. Compare loads and internal fluxes to scenarios, such as constructed wetlands and fish harvesting, to assess effectiveness of potential remediation. Estimate potential changes in nutrient concentrations and trophic status of the Sea in response to various management alternatives and climatic scenarios.

Year 3: Evaluate data, link nutrient budget to Salton Sea circulation model (if appropriate), prepare final report, and make recommendations.

Anticipated Focus of Recommendations: The results of the monitoring component of this study will address Goal IC, to compile an inventory of nutrient attributes in the Salton Sea Basin. They also will indirectly satisfy Goal IIB, and the modeling component will provide a framework for Goal II, to assess and develop methods for interrupting fish and wildlife mortality.

Budget/Duration: Labor, Equipment and Supplies, Transportation, Miscell.

	Year 1	Year 2	Year 3
Labor	100,000	125,000	50,000
Equipment and Supplies	10,000	5,000	5,000
Miscellaneous and Analytical	30,000	20,000	20,000
Transportation, per diem, shipping	15,000	10,000	10,000
Total	$155,000	$160,000	$85,000

Principal Contact: Roy Schroeder.

PE4A. Development of Hydrologic and Salt Model for Salton Sea.

Introduction: Water elevations have remained high in the Salton Sea since 1985 and were recently responsible for major flooding of agricultural land and urban areas. The salinity of the Sea is presently about 30% higher than ocean water and is projected to increase rapidly with increased water conservation. Hydrologic and salinity models have been developed and used by the Coachella Valley Water District and the Imperial Irriga-

tion District to predict changes in water level and salinity of the Salton Sea. Historically, they have matched the observed changes rather poorly; in part because of inadequacies in physical and geochemical information, but mostly because of greater than anticipated water use. These models will provide the framework for developing complete hydrologic and salt models for the Sea. Refined models will then be used to determine how the projected flow and salt inputs will affect the elevation and salinity of the Salton Sea under various remediation scenarios.

Justification: Many factors affect the elevation and salinity of the Salton Sea, including geochemical processes. Geochemical processes, such as precipitation of insoluble salts, may be important in controlling major-ion composition of the Sea. As a result, modifications to the input and output of water and salt likely will not lead to a linear response between them in the Sea. Therefore, a detailed model which includes the processes is needed to determine what changes in water level and salinity can be expected from various management alternatives.

Objectives:

1. To determine historical loading of water and salt to the Salton Sea from all major sources.
2. To construct a complete hydrologic and salt budget for the Sea, with all major sources and sinks quantified, and geochemical processes described.
3. To determine how various management alternatives (such as, diking, construction of an ocean connection, and "enhancement" of riparian corridors to the Sea) under various scenarios of water supply (reduced Colorado availability of Riverwater; water recycling in Mexico, etc.) affect the water level and salinity of the Salton Sea.
4. To apply the hydrologic and salt-balance models to determine the most cost-effective and environmentally acceptable alternatives for reducing the salinity and maintaining a stable water level for the Sea.

Products:

Year 1: Historical loading of water and salt to the Salton Sea are obtained.

Year 2: Refined hydrologic and salt models are constructed and current budgets are obtained. Projected changes in land and water management are obtained.

Year 3: Report describing the hydrologic and salt model, and the relative importance of various hydrologic and salt inputs is prepared. The report also will describe how various management alternatives will affect the water level and salinity of the Sea.

Anticipated Focus of Recommendations: This project will satisfy Goal I to provide the basic understanding at the most fundamental level of the Salton Sea ecosystem: water and salt balance. All other management alternatives for Goal III will rely on forecasted changes in water level and salinity.

Budget Duration: Labor, Equipment and Supplies, Transportation, Miscell.
Year 1 - Labor 50K; Year 2 - Labor 50K; Year 3 - Labor 50K; Printing 15K
Total $165K

Principle Contact: Dale M. Robertson.

PE4B. Development of Water-Quality Models for the Salton Sea.

Introduction: Water quality in the Salton Sea has significantly degraded over the past 100 years, as a result of external loading of nutrients, salts, and contaminants from the watershed. This loading has led to high nutrient and contaminant concentrations in the Sea and in its sediments. Nutrient input from external sources and recycling from bottom sediment have resulted in high concentrations and frequent development of large algal and bacterial blooms in the Sea. Algal respiration and decomposition causes suppressed oxygen levels that often stress and/or kill fish. Degradation of water quality has been accompanied by aquatic and avian die-offs in and around the Salton Sea.

Justification: Various management alternatives are being developed to reduce the input of nutrients, salts, and contaminants to the Sea; however, it is not known how these reductions will affect the water quality. To determine the potential impact and cost effectiveness of the various management alternatives, water-quality models need to be developed and applied to the Salton Sea.

Objectives:

1. To determine how various management alternatives will alter the Salton Sea using one-dimensional water-quality eutrophication models. By applying these models to representative segments of the Sea, relevant chemical and biological processes and the relation between water-quality constituents in the water column and bottom sediment or atmosphere will be quantified.
2. Adapt a laterally averaged water-quality model to describe longitudinal variations in water-quality associated with various management alternatives.
3. Depending on spatial variability in water-quality measured in the Sea, calibrate and verify a three-dimensional model capable of assessing impacts on water-quality resulting from implementation of proposed remediation alternatives.

Products:

Year 1: Describe process dynamics and dominant interactions between a fully mixed water column and the bottom sediments and atmosphere for representative locations in the Sea. Estimate relevant reaction rates and coefficients governing key processes.

Year 2: Apply preliminary two-dimensional models and initial simulations of spatial variability in water-quality to model tests of alternative management options.

Year 3: Calibrate and verify a three-dimensional model. Prepare a report describing the models and their use in assessing the impact on water-quality of various management alternatives.

Anticipated Focus of Recommendations: This project is directed toward gaining an improved understanding of water-quality dynamics in the Sea, and how various management alternatives may affect the water quality thereby satisfying Goal III. Models developed for proposals PE1A and PE4A, and closely related monitoring activities in other proposals, will provide a comprehensive capability to assess consequences of management actions affecting the hydrodynamics, water-quality, and ecology of the Sea.

Budget/Duration: Labor, Equipment and Supplies, Transportation, Misc.

	Year 1		Year 2	Year 3
Labor (0.75 FTE)	75,000	(1.5 FTE)	150,000	150,000
Equipment	0		0	0
Supplies	10,000		5,000	20,000
Miscellaneous	10,000		10,000	10,000
Total	$95,000		$165,000	$180,000

Principal Contacts: Geoff Schladow, Chris Cook, Dale Robertson, and Mark Matsumoto.

PE5. Salton Sea Sediment Characterization and Geologic Hazards Evaluation.

Introduction: The Salton Sea was flooded in 1905, and has subsequently been maintained mostly by agricultural run-off that has resulted in long-term changes in water level and water quality. The bottom sediments contain the most complete record of the changing Sea. They also comprise the substrate on which any dikes and levees must be constructed. Furthermore, the Sea lies astride a complex of active faults feeding from the San Andreas fault and extending to the Sea of Cortez. Any engineering solution for water-quality and wildlife-mortality remediation requires physical characterization of the bottom sediment and locating active faults to evaluate potential hazards from earthquakes, including likelihood of rupture and probability of failure from strong shaking and liquefaction. This study will characterize the sediment by performing reflection profiles, followed by coring and analysis of the cores. Active faults in the Sea will be mapped by geophysical profiling, and by mapping their extensions on land near the Sea, to identify the most stable areas for constructing dikes and pipelines. Engineering properties must be evaluated in cores to provide guidelines for subsequent geotechnical analyses. All data should then be compiled in GIS formats for integration with other data sets and supplemented as needed to complete the understanding of the geologic and seismic framework of the Salton Sea.

Justification: Engineering properties of bottom sediments and geologic hazards associated with active faults are essential elements of an environmental impact study for developing dikes, levees, and pipelines that will be used to remediate water-quality (Goal III). The sediment characterization will provide a foundation for geotechnical studies. In addition, GIS data bases for sediments in the Sea bottom and immediately surrounding lands will be a valuable part of the ecosystem description (Goal I), especially relevant for understanding contaminant dispersal.

Objectives: This study will provide key data for designing engineering solutions for the Salton Sea, and is described with three elements.

Element 1. To *characterize bottom sediments*. Bottom sediments will be evaluated first by vertical incidence seismic reflection profiling. This will provide a record of lateral and vertical distribution of sedimentary units deposited after 1905, as well as locate faults by offset in older sedimentary units. The seismic record will serve to guide coring for biologic, contaminant, and physical data. Physical data to be analyzed from cores include seismic velocity (to allow direct comparison with other seismic information), density, engineering properties, sedimentology, and magnetic susceptibility. Dating of the sediment (by Cs, Pb, C, and Sr isotopes or pollen) will be completed in several cores (Proposal C4). Deeper cores can be taken to analyze the Holocene record if needed for cultural resource evaluations (Proposal CR5). All data will be collected the first year, with analysis and follow up studies as necessary in the second year. Collaboration is planned and costs shared with contaminant and biological coring investigations, development of circulation models, and with any coring done to reconstruct the Holocene environment.

Element 2. To *characterize surficial sediments and identify active faults adjacent to the lake*. The best way to evaluate faults in the lake is to trace them from on-land exposures where their records, such as recurrence intervals, can be used to estimate the likelihood of rupture in the near future. Most of the data are already complete, and will be inventoried, placed in a GIS, and updated where necessary. Geophysical studies such as shallow seismic reflection may be needed to supplement the mapping where land disturbance makes surface studies difficult. Trenching studies will be conducted along active faults that do not have established recurrence intervals. Final maps and reports will describe active faults and locations of the most stable areas for levee construction.

Element 3. To *characterize surficial sediments and identify active faults southward into Mexico*. This element will evaluate hazards for pipelines to be built between the Sea of Cortez and Salton Sea. Existing data will be inventoried and placed in a GIS. Data gaps then will be filled, supplemented as needed by subsurface geophysical studies. Final maps and reports will describe active faults and locations of the most stable areas.

Products: The results of this work will be released as 1:24,000 scale maps showing bottom sediments, surficial geology, and active faults, as well as reports describing the physical aspects of the sediments, active faults and times of their recent ruptures, and reports of all geophysical data.

Element 1	Element 2	Element 3
Year 1		
Reflection data from lake	Data base of adjacent geology	Inventory of geology to Mexico
Description of cores	Data base of active faults	Data base of active faults
Year 2		
Final reports on profiles	New geologic maps (if needed*)	New geologic maps
Map of active faults	Geophysical survey results	Geophysical survey results
Year 3		
	Final reports and maps	Completed mapping and geophysics
		Final reports and maps

[*If database is complete, final reports are issued in year 2]

Anticipated Focus of Recommendations: The results of this work will address Goal III (*Develop methodology for managing the Salton Sea ecosystem*) by providing recommendations on areas most suitable for constructing dikes, pipelines, or other engineered structures to minimize geologic hazards, and will address Goal I (*Develop an understanding of the ecosystem*) by providing baseline data on sediment characteristics for the ecosystem.

Budget/Duration:

Element 1		Element 2		Element 3	
Year 1					
Salary 1.6 FTE	$160K	Salary 0.75 FTE	$ 75K	Salary 1.5 FTE	$150K
Travel	15	Travel	5	Travel	10
Contract coring	15	Misc. Expenses	5	Misc. Expenses	5
Boat & operators	10	GIS lab	15	GIS lab	35
	$200K		$100K		$200K
Year 2 (estimated)					
Salary 0.5 FTE*	$ 50K	Salary 1.5 FTE**	$150K	Salary 3.5 FTE	$350K
		Travel	25	Travel	30
		Seismic reflection	50	Seismic reflection	50
		Trenching	10	Trenching	10
	.	GIS lab	15	GIS lab	25
	$ 50K		$250K		$465K
Year 3 (estimated)					
		Salary 0.5 FTE**	$ 50K	Salary 1.0 FTE	$100K
		Travel	10	Travel	15
		GIS lab	10	GIS lab	40
			$ 70K		$155K

*If no follow-up studies in Element 1 are needed, year 2 FTE will be reduced.
**If no new studies in Element 2 are needed, year 2 is funded at year 3 level ($70K) and project is completed in year 2.

Principle Contact: David M. Miller.

PE6. Resuspension and Transport of Sediment in the Shallows Areas of the Salton Sea.

Developing an understanding of the movement of many contaminants in the Salton Sea requires an understanding of the movement of fine sediment. Wind-generated waves probably play an important role in resuspension of fine sediments in the shallows and thus in the exchange of sediments and contaminants between shallows and the deep portions of the Sea. Resuspension processes could be quantified by collection and analysis of wind-wave and suspended-sediment time series in shallow areas. The knowledge derived therefrom could then be used to construct a wind-wave model that would predict wind waves and resuspension using wind data. Resuspension data could then be used with the hydrodynamic model to predict movement of fine sediment between the shallow and deep portions of the Sea.

Principle Contact: Larry H. Smith

PE7. Use of Remote Sensing to Identify and or Track Water-Quality Changes in the Salton Sea.

Multi-spectral (TM, IR, etc.) satellite imagery and fixed-wing imagery (AVIRIS) of the Salton Sea Basin clearly show features such as irrigated crops, fallow fields, dispersion of suspended sediment to the Salton Sea (at the mouths of the New and Alamo Rivers), surface chlorophyll distributions and many other physical and geomorphic features. Also, remote sensing provides the capability of providing a total system "snapshot" as compared to point measurements made on the ground. This suggests the possibility that remote sensing technology might be able to identify and track changes in water quality in the Salton Sea.

Of greatest value could be the identification and tracking of algal blooms and fish school migration within the Salton Sea. Perhaps timing and intensity of fish and bird die-offs could be tracked and correlated to the presence or absence of algal blooms. It is recommended that coastal marine biologists and terrestrial ecologists who have applied remote sensing in their studies be contacted to ascertain viability of proposed applications at the Salton Sea. An accurate accounting of cost should also be obtained from them.

PE8. Comparative Characterization of Dissolved Organic Carbon in the Salton Sea, its Major Tributaries, and Drain water.

Introduction: Dissolved organic carbon (DOC) concentration in the Salton Sea is very high at about 50 mg/L, yet virtually none of this DOC has been characterized at the physicochemical or molecular level. A variety of possible sources exist for the Sea's DOC including: (1) within-lake production in the Sea's highly eutrophic environment, and (2)

production outside the lake, followed by transport to the Sea. The buildup to such high DOC levels in the Salton Sea suggests that some component of this DOC may be rather recalcitrant to biological or chemical degradation. Can this property lead to buildup of potentially hazardous levels in the Sea, or in any impounded portion of the Sea, over time? Depending on the physical and chemical properties of the DOC in the Salton Sea, the DOC may itself be important in complexing trace elements and pesticides, and thereby lower their bioavailability in the water column.

Justification: One of the most prominent long-term features of the New River is the appearance of foam, presumed to be from detergents, every morning at the international boundary. Although most of the additives to detergents, such as optical brighteners and ionic surfactants, exhibit low toxicities and are photo degradable, neutral surfactants are suspected of being endocrine disruptors. Are these compounds present in the Salton Sea and are their levels increasing as they continue to be delivered by the New River? And if so, do they pose an environmental hazard that should be remediated either by halting wastewater discharges to the New River or by encouraging use of detergents with different formulations.

Objectives:

1. To obtain water samples from 5 sites: the Alamo River; New River at the international boundary and at the Salton Sea outlet; a drainwater sump; and the Salton Sea itself for use in DOC characterization.
2. To use established resin sorption and pH adjustment techniques, to isolate six fractions based on differing physiochemical properties of the macromolecules in each fraction.
3. To characterize these fractions and the raw water itself by nuclear magnetic resonance, ultraviolet- and infrared-absorption spectroscopy, fluorescence, size-exclusion (molecular weight) chromatography, and other appropriate instrumental methods.
4. To use selected instrumental techniques listed above to determine whether detergent additives thought to be present in the New River, but believed not to be present in the Alamo River or in drainwater, have the potential to accumulate to high levels by comparing results between sites.
5. To infer the potential ability of DOC in the Salton Sea, based on its determined physicochemical properties, to sequester complex trace metals and hydrophobic pesticides.

Products:

Year 1: Results from simple analyses, such as absorption and fluorescence spectroscopy, will be available soon after collection of the samples.

Year 2: Complete complex and time-consuming analyses that require use of resin-isolation techniques several months after sample collection. Interpret and report all results.

Year 3: If substantial neutral surfactants are present, examine fish (or other species) for levels of vitellogenin, estrogen/testosterone ratios, or other diagnostic bioassays. This effort would be undertaken in collaboration with related studies proposed by the Contaminants and Disease and Pathogens Teams.

Anticipated Focus of Recommendations: The results of this work will address Goal IC to develop an inventory of chemical attributes, and Goal IIC to assess potential for buildup of toxins. If the results indicate the likelihood that detergents in wastewater are accumulating to high levels, it is recommended that this study be followed by laboratory bioassays for endocrine disruptor activity.

Budget/Duration:	Year 1	Year 2
Labor	100,000	75,000
Equipment and Supplies	20,000	5,000
Transportation, shipping, per diem	7,000	3,000
Miscellaneous	3,000	1,000
Total	$135,000	$84,000

Principle Contact: Roy Schroeder.

PE 9. Atmospheric Entrainment of Salt and Dust from the Dry Lakebed Exposed by a Receding Salton Sea Shoreline.

Episodic extreme degradation of air quality from windblown dust and salt at the dry Owens Lake in California and at the Aral Sea in Central Asia has led to concerns that a similar fate awaits the Salton Sea if water conservation and remediation practices expose formerly submerged bottom sediment. However, it seems more likely that the much more gradual, and less extensive changes proposed for the Salton Sea will cause most salt to simply “wash down” with the receding lake, and that the cohesive nature of the soil sediment will not allow soils to be readily picked up by winds. Furthermore, the Coachella and Imperial Valleys already experience dust storms during high wind events. No communities exist immediately adjacent to the south side of the Salton Sea where prevailing northwesterly winds would carry overland after crossing the exposed lake bottom.

Wind speed and direction from three meteorological stations operated by the state on the shores of the Salton Sea could be plugged into an existing model that couples surface roughness and grain-size distribution to wind speed to calculate the frequency with which conditions producing erosion exist. It is recommended that the South Coast Air Quality Management District or California State Air Resources Board in Sacramento be contacted to determine individuals qualified to undertake such an assessment. The estimated cost is less than $100,000 if existing data and existing models are adequate to assess the problem.

Refer to Appendix G for full text of a Corps of Engineers process proposal.

Biological Environment Team Proposals

BE 1. Algal and Invertebrate Populations of the Salton Sea in Relation to Physical and Chemical Limnology.

Introduction: A survey of the basic physical, chemical, and biological limnology of the Salton Sea is required to evaluate proposed solutions to prevent and eliminate ongoing fish and wildlife die-offs in the Sea. Fish and wildlife mortalities have been associated with physical stresses (high and low temperatures), chemical stresses (low dissolved oxygen, hydrogen sulfide, ammonia), and biological stresses (toxic algae, pathogenic bacteria and fungi). There has been no systematic survey of these limnological components since the 1960's.

The Salton Sea is truly a unique system. Often compared to the ocean and to other salt lakes, its inherent physical, chemical and biological components are different, and information from other systems has little direct relevance. For example, temperature / salinity relationships which determine water density are extremely volatile as the shallow lake occupies an arid desert basin (110+ days/ yr with temperatures > 100 degrees). Similarly, high nutrient loading has resulted in a hyper eutrophic water-body which acts as a fertile substrate for many pathogens and toxic algae. Populations of introduced fishes, such as tilapia, amass tremendous biomass in short time intervals. This sets the stage for massive die-offs upon physical, chemical or biological changes.

Increasing salinity has been a problem since the Sea's recent formation (initial fish community mostly extirpated and new fisheries established due to increased salinity). Scientists projected a continued rise in salinity and numerous engineering solutions have been proposed to halt the rise. Recent fish and wildlife die-offs have spawned increased interest in these solutions, however, salinity may not be the causative agent for these die-offs. The work proposed herein will define the context in which these die-offs occur and will aid in finding proper long-term solutions.

Justification: These data are needed to understand the basic processes of the Salton Sea ecosystem. The fish and wildlife of the Salton Sea represent "end-products" of a series of complex processes within the Salton Sea ecosystem. Problems within the fish and wildlife communities may originate at any point along these extended chains of cause and effect relations. Solutions to-date have been of a "band-aid" nature (e.g. removing carcasses of dead fish and birds), focusing more on the effect of the problem, not the cause. Effective, long-term solutions must be based on an understanding of those processes in order to focus on the earliest stage (causative agent).

Objectives: Major objectives of this program fall into three categories. One deals with the communities living within the water column and how they function in relation to the basic physical and chemical environments. A second area focuses on the animals associated with the Sea's bottom and their functions of transferring food, energy, pathogens, contaminants, etc up into the food chain. A third and final area, concerns the fact that many of these organisms have never been identified and a few are suspected to be extremely noxious organisms. Specific objectives for each of these categories are as follows:

1. Seasonal and spatial dynamics of plankton, nutrients and mixing regimes.

a) Conduct vertical profiles of dissolved oxygen, pH, temperature and salinity along the major and minor axes of the Sea and at major source points of water inflow.

b) Quantitative samples of phytoplankton and zooplankton sufficient to determine horizontal and vertical distributions.

c) Assess macro distribution of plankton through large scale observations of chlorophyll, temperature and turbidity through satellite imagery, aerial photography, towed spectrophotometers, etc.

d) Quantitative analyses of major nutrients (N, P, Si) sufficient to characterize primary production and eutrophication potential.

e) Assessment of tilapia grazing on plankton dynamics and composition. (ie. What happens if tilapia dies off or increases? Does grazing increase or decrease abundance of toxic algae?)

2. Spatial and temporal distribution of benthic organisms.

a) Density and diversity of organisms living within the mud/water interface.

b) Density and diversity of macro invertebrates in shallow inshore areas. (eg. corixids)

3. Biodiversity inventory of algae and invertebrates.

a) Taxonomic analysis of algal species with annotated listings regarding toxic potential, public health threats, etc.

b) Taxonomic analysis of invertebrates. (esp. arthropods, nematodes, rotifers, and protozoa)

c) Catalogs with electron micrographs, light microphotographs, and/or line drawings of all known algal and invertebrate taxa, as foundation for later studies.

Products:

Year 1: Preliminary assessment of composition and distribution of major limnological components of Salton Sea.

Year 2: Preliminary identification of new or previously unrecorded plankton and invertebrates.

Year 3: Baseline report on dynamics of algal and invertebrate populations in relation to physical and chemical processes of the Salton Sea.

Anticipated Focus: This study will provide information relevant to all three goals and all subgoals.

Budget/Duration:

Personnel	(19.5 person years)	1.95 M
Equipment	(boat/computer/sampling equip)	0.15 M
Other	(travel, data mgt, report prep)	0.30 M
Total Budget for 3 Years		$2.4 million

Principal Contacts: Stuart Hurlbert and Tom Burke.

BE 2. Fish Ecology of the Salton Sea.

Introduction: The Salton Sea was the most productive inland recreational fishery in California from the 1960s through the 1980s. During this period, it was a significant contributor to the southern California economy. The Salton Sea fishery is still highly productive but there have been changes, including changes in the species composition of the fish community, which have caused a decline in its recreational popularity. The productive fishery that remains is a key factor in the importance of the Sea to piscivorous resident and migratory birds of the Pacific Flyway. The Salton Sea Basin is also home to the federally and state endangered desert pupfish.

Justification: The last reasonably comprehensive study of Salton Sea fishes was published in 1961. Since then a new species has become important in the Sea's fish fauna: tilapia. The previous work is therefore, largely obsolete. Scientific work on Salton Sea fishes since 1961 has largely been confined to creel surveys and salinity tolerance work on a few species. A knowledge of present day fish population dynamics, spawning requirements, and food webs, relative to salinity levels, potential project sites, and pathogen transfers to birds, is an essential component of any proposal to rehabilitate the Salton Sea. Because of their positions at the top of the aquatic food web, an understanding of fish ecology will be a critical building block on which to base any management plan.

Objectives:

1. Abundance and distribution - General abundance surveys will be performed by netting (gill, seine, or trawl) or trapping (especially for desert pupfish). This will provide baseline data relative to bird distribution. Since corvina and bairdiella (members of the drum family) produce audible sounds, sonic surveys may also be useful indicators of abundance for these species.

Scale or otolith samples will be collected to allow calculation of past growth dynamics. This will compensate slightly for the lack of historical data. Size-frequency analysis during the course of this study will allow calculation of current population dynamics.

2. Condition and feeding habits - Samples of various-sized fish from both deep and shallow water stations will be a) weighed and measured to allow calculation of condition factors, and b) sacrificed for stomach content analysis.

3. Spawning habitats and requirements - Although the body of the Sea is hyper saline, freshwater channels may provide important spawning grounds for corvina and bairdiella. This must be determined by surveys for planktonic eggs (may be combined with zooplankton sampling in limnology proposal) or tracking tagged fish. Additional laboratory work on the salinity tolerance of eggs and larvae may also be necessary.

4. Fish kill response program - A contact phone number for reporting fish kills will be set up and local residents notified of its availability. A response team will be on call and a standard response protocol developed to assess the severity of all reported fish kills and collect specimens for contaminant and pathogen analysis.

5. Synergistic tolerance studies - Although many factors (temperature, dissolved oxygen, ammonia, sulfide, algal toxins, etc.) have been implicated in fish kills, there is little work on the interaction among these factors. By changing one or more factors, a Salton Sea management plan might profoundly alter the toxic effect of a different factor. This needs detailed study.

6. Tilapia feeding studies - Tilapia in the Salton Sea are apparently largely herbivorous (Stuart Hurlbert, San Diego State University, personal communication). A detailed knowledge of their feeding selectivity might be important in explaining the occurrence of phytoplankton blooms.

Products:

Year 1: Species composition, distribution and population dynamics; food habits

Year 2: Species distribution and population dynamics; identification of spawning habitat; tilapia feeding studies; synergistic toxicity studies

Year 3: Species distribution and population dynamics; spawning requirements; synergistic toxicity studies

Anticipated Focus: This research supports goals IA, B, C, IIB, C, D, E, IIIA, B, C, D.

Budget/Duration: Assuming availability of boat with one man crew funded by other means:
$1,100,000 = field work: 9 person years with fisheries-specific equipment and supplies
$ 200,000 = laboratory work: tolerance and feeding selectivity studies
$1,300,000 = total

Principal Contacts: Richard Thiery and Dwayne Maxwell.

BE 3. Trends and Ecology of Birds on the Salton Sea

Introduction: The Salton Sea has become the center of avian biodiversity in the American Southwest, supporting over 1.5 million birds annually--it is a world-renowned site. The Sea is an integral part of the Pacific Flyway, providing essential habitat for both resident and migrant species. In addition, numerous species of migratory waterfowl,

including four federally-listed Endangered Species, depend upon Salton Sea habitats. Continued habitat degradation would create an ecological catastrophe to migrant and resident birds. Avian die-offs coupled with continued habitat degradation have become critical management problems on the lake. Recently, three large dieoffs involved almost 200,000 birds representing about 66 species. The most recent event included more than 1,400 endangered California brown pelicans and approximately 10-12% of the western population of American white pelicans. Many of the disease processes involved in these mortality events remain to be explained; yet, even without this issue, a basic understanding of avian ecology will be required to further protect and enhance avian biodiversity at the Salton Sea. Since approximately 95% of California's wetlands have already been destroyed, including the loss of suitable habitat in the Rio Colorado Delta area, the Salton Sea has become increasingly important.

Justification: An understanding of the causes of recent mortalities, as well as basic ecology and population dynamics, requires detailed data on trends and variations. Also, an understanding of ecological interactions in the avian community utilizing the Salton Sea is necessary. Without this information, management considerations for improvement of the Salton Sea for birds may not be effective and deterioration of the ecosystem will continue.

Objectives:

1. To determine past and present conditions and trends of the avifauna and its relationships to the area.

2. To provide data to assist in decisions concerning future attempts to improve the system to include both breeding and non-breeding elements of the avifauna.

a) Conduct systematic avian surveys (including rare, threatened and endangered species.
- review and summarize all available literature.
- conduct avian population surveys, including local movements and habitat use patterns.
- identify the uses of sensitive feeding and nesting areas and define temporal changes.

b) Conduct detailed ecological studies of selected key indicator species.
- document reproductive success of local breeders.
- determine condition factors and food-web relationships in key fish-eating species and waterfowl.
- determine activity and habitat use patterns through radio-telemetry.

c) Determine sources of migrant bird species and interconnections between avifauna of the Salton Sea and other areas.
- summarize existing band recovery data.
- collaborate with researchers in Mexico and other parts of the Pacific Flyway.
- establish monitoring program with collaborators.
- conduct an analysis to determine the overall importance of the Salton Sea and associated habitats to birds of the Pacific Flyway.

d) Implement a systematic reporting and response protocol for bird die-offs.
- standardize data collection.
- participate in recovery efforts.
- maintain reporting network.

e) Coordinate and relate all these findings to other elements of the Salton Sea research effort.

Products:

Year 1: A report summarizing the historical population trends
A report summarizing band recovery patterns from banding on and off the Sea
A report summarizing the first year of detailed data and its relationship to the historical data base
A detailed summary of reproductive performance of colonial birds in Year I
The establishment of a radio-telemetry monitoring system for the Salton Sea and summary of the first year's movement and habitat-use data from selected species

Year 2: A report summarizing the continuing data collection effort on items listed above
An evaluation of new data needs
Initial management recommendations based on available data summary
A summary of first two year's data on condition factors and food webs and an evaluation of year-to-year variations

Year 3: Final, internal reports to the management agencies summarizing all findings and detailed final management recommendations (including further needs for research on specific hypotheses derived from this work)

Anticipated Focus of Recommendations: Specifically sensitive habitat-use areas on the Salton Sea will be identified and described to managers; a flyway perspective will be provided to further justify the ecosystem as a critical resource; a list of new habitat-acquisition and protection areas for avifauna will be provided managers and funders. This research supports goals IA, B, C, IIB, E, IIIA, B, C, D.

Budget/Duration:

	Year 1	Year 2	Year 3
Personnel	300,000	350,000	350,000
Equipment/Supplies	140,000	40,000	40,000
Transportation	42,000	42,000	42,000
Miscellaneous	15,000	15,000	15,000
Subtotal	$497,000	$447,000	$447,000

Project Total: $1.8 million

Principal Contacts: Dan Anderson and Ken Sturm.

BE4. Determination of Wetland Habitat Types, Functions, Importance and Value to the Salton Sea Ecosystem and Potential for Restoration and Enhancement.

Introduction: The Salton Sea ecosystem includes wetlands and other habitat types that are used by a variety of wildlife including migratory waterfowl, endangered species, a variety of fish species as well as mammalian, amphibian and other species. The location, composition, and functions of the wetland component of the ecosystem are critical. The importance of the wetland component of the ecosystem includes habitat for fish spawning, food sources, bird foraging and nesting sites, and bio-filtration. Wetlands within and peripheral to the ecosystem are important to ecosystem health and cannot be overemphasized.

Justification: Historical identification and evaluation of wetland habitat within the Salton Sea ecosystem is limited. Accurate identification and delineation of wetlands is required for investigation of the overall health of the Salton Sea ecosystem. Areas identified as potential wetlands on the National Wetland Inventory (NWI) maps, developed by the US Fish and Wildlife Service, must be field verified with extents and boundaries accurately delineated. Information on the importance of wildlife usage and habitat value to the ecosystem is vital to determining existing conditions and potential restoration and enhancement of the resource.

Objectives:

1. Definition, delineation and field verification of wetland habitats as they currently exist.
2. Determination of plant species composition.
3. Estimation of nutrient uptake and contaminant concentrations in these wetland habitats.
4. Investigation of wildlife utilization (e.g. breeding sites and food source) and biological condition of wetland and riparian habitats.
5. Evaluation of potentials for wetland expansion, enhancement, and restoration as well as the potential for wetland creation as bio-filters at tributary inlets to the Salton Sea.
6. Determination of the current and potential functions of wetlands as:
   a) sediment traps for determination of sedimentation rates;
   b) erosion control of wave action impacts to sea shoreline;
   c) recharge and discharge areas for groundwater.
7. Evaluation of the utilization of satellite wetlands by migratory waterfowl and their importance to the Salton Sea ecosystem.
8. Evaluation of the changes of wetland functions, extent, and species composition due to changes in the elevation of the Salton Sea for both increasing elevation due to storm events as well as potential elevation reduction due to water conservation efforts.

Products:

- Low-level color infrared photography of wetland/riparian habitats.
- Mapped (GIS) locations of wetland and riparian habitats and their respective wildlife uses.
- Mapped (GIS) locations of proposed sites for wetland enhancement, restoration, or creation.
- Baseline map of wetlands with nutrients/contaminants load.

Anticipated Focus: This research supports goals IA, B, C, IIB, C, IIIA, B, C.

Budget/Duration:

Low-level color infrared aerial photography	$20,000
Habitat delineation and verification (assumes computer hardware and software available)	$50,000
Quantitative vegetation analyses	$20,000
Investigation of wetland biological functions	$15,000
Nutrient/contaminant analysis (collection of sediment samples done in conjunction with quantitative vegetation analyses)	$75,000
Determination of potential wetlands enhancement, restoration, and creation opportunities	$15,000
Total Budget for 1 year:	$170,000

Principal Contacts: Michael Remington and Tim Krantz.

BE5. Research Protocols:

1. Quality assurance/quality control
2. Establish written volume of peer reviewed protocols relative to collection, storage retrieval, access (or controlling access - e.g. cultural resources locations), georeferencing.
3. Explore use of remote sensing (e.g LANDSAT) as a means of detecting environmental changes e.g algal blooms, wetland availability on a seasonal basis, wetland delineation, habitat quality
4. Low level aerial photography -infrared images

$150,000 for one year

BE6. Habitat Base Mapping /GIS:

1. Georeferencing of all data and monitoring stations
2. Establish GIS base station at the Salton Sea
3. Delineate various upland and marsh habitats surround the Salton Sea
4. All data must be compatible with and accepted as input as layers of all other sampling formats - all use the same GIS format
5. Incorporate historical mapping of habitat types

$500,000 for 1 year.

Cultural Resources Team Proposals

CR1. Cultural Resources Overview of Existing Information on the Archaeology, Prehistory, and History of the Salton Sea Watershed.

Introduction: Freshwater lakes have existed intermittently in the Salton Basin for the last 50,000 years. These lakes, in turn, have supported human populations since at least as early as 5,000 years ago. Numerous archaeological sites and features are found today throughout the Salton Sea watershed (see Appendix E), many in association with the remains of the ancient lake shores. These resources provide an important link to the past, reflecting past human adaptation to fluctuating shorelines and environmental change. Numerous studies of these cultural resources have been conducted within the Salton Sea watershed; however, these must be synthesized before management can make informed decisions about engineering solutions designed to fix the sea.

Justification: A cultural resources overview would compile and synthesize the existing baseline data on the archaeology, ethnography, prehistory, and history of the Salton Sea and surrounding region; identify the kinds of data that contribute to National Register of Historic Places significance; provide a context for evaluating significance of archaeological sites; identify cultural resource themes around which management can focus research effort and limited funds; and help managers make decisions on the selection and placement of engineering solutions to the problems of the Salton Sea. Furthermore, a cultural resources overview is the essential first step in meeting the legal mandates of Section 106 of the National Historic Preservation Act (NHPA).

Objectives:

1. Conduct a record search at the California State Office of Historic Preservation's Eastern and Southeastern Information Centers to identify where previous archaeological surveys and excavations have been conducted and what archaeological sites have been recorded.
2. Conduct a search of the grey literature on the cultural resources of the Salton Sea watershed. This search can be accomplished through contact with federal, state, and local agencies, universities and colleges, and museums and historical societies.
3. Conduct a search of collections and field notes from archaeological investigations in the Salton Sea watershed. This search can be accomplished through contact with the entities mentioned above.
4. Conduct a bibliographic search to identify existing published information on the archaeology and ethnography of the Salton Sea watershed.
5. Conduct an archival search, focussing on county and city archives, Bureau of Indian Affairs archives, railroad surveys, and GLO maps, and newspapers.
6. Identify gaps in the existing data and determine current research needs and issues.
7. Utilize the information gathered to identify criteria for determining significance of archaeological sites identified in the study area.

Products:

Year 1: Collection of data will be completed. A bibliography of existing published and unpublished information on the archaeology, ethnography, prehistory and history of the Salton Sea watershed will be produced.

Year 2: A report, synthesizing the existing data on the archaeology, ethnography, prehistory and history of the Salton Sea watershed, and discussing current research needs and issues and criteria for determining significance of archaeological sites in the region, will be completed.

Focus of Recommendations: Through compiling existing data and identifying where information is lacking on the historical and cultural aspects of the ecosystem, the proposed project helps to meet Goal IA of the Salton Sea Workshop. A cultural overview will also provide a valuable management tool, satisfying Goal III and supplying the foundation for meeting the legal mandates of Section 106 of NHPA.

Budget/Duration:

	Year 1	Year 2
Labor	100,000	100,000
Equipment & Supplies	5,000	0
Transportation	45,000	10,000
Miscellaneous	10,000	5,000
Subtotal	$160,000	$115,000

Project Total: $275,000

Principal Contact: Anan Raymond.

CR2. Native American Consultation

Introduction: The Salton Sea watershed (including nearby Mexico) is home to 56 Native American Tribes, bands, or communities (see Appendix F). These groups currently (and historically) share in the water, wildlife, agriculture, trade and commerce, environmental, natural and cultural resources of the area. The United States Federal government has a unique relationship with Native American tribes and indigenous peoples as set forth in the Constitution, treaties, statutes, and court decisions. This legislation requires that Federal, State, and municipal agencies (agencies) establish protocols to consider and protect Tribal interests in a manner respectful of Tribal sovereignty.

Justification: Various legislation requires the Federal, State, and municipal agencies to work with Native American organizations and Tribes to promote the conservation of sensitive areas, species, and the health of ecosystems upon which they both depend. It is

imperative that these agencies consult with Tribes, bands and other indigenous organizations of the Salton Sea watershed prior to implementing any activities that may impact resources of concern to them.

Objectives:

1. Contact all Tribes and indigenous organizations in the Salton Sea watershed.
2. Determine which Tribes in the Salton Sea Watershed are interested in establishing a consultation/protocol process.
3. Maintain sensitivity of Indian cultures, religions, spirituality. Promote atmosphere that allows all Tribal members to evaluate the potential impact of a proposal for the Salton Sea.
4. Identify key issues for each Tribe, including water rights, ground water protection, cultural and sacred sites, wildlife, vegetation, traditional use areas and threats to human health.
5. Facilitate information sharing between Tribes and agencies.
6. Design solutions or alternatives to address specific or unique needs of each tribe.
7. Gather cultural, historical, and other data to add to the Salton Sea watershed archives.

Products:

Year 1: Identify and physically contact all Tribes in the Salton Sea Watershed. Establish primary and secondary contacts. Determine the key Tribes necessary for consultation including all Tribes which express a specific interest in participating. Develop consultation processes, and protocols to establish working relationships between Tribes and agencies. Identify Tribal issues, develop adaptive management strategies to resolve problems. Develop a forum for dialogue i.e., "Government to Tribe, Tribe to Tribe" information exchange and natural/cultural management. Issue a report of this work.

Year 2: Compile data into GIS with tribal cooperation on sensitive or sacred areas. Monitor field for Salton Sea restoration projects. Conduct ethnographic research on water rights, land ownership, impacts of proposed projects to Tribes, and long range impact to Tribes.

Year 3: Prepare report synthesizing Year 2. Provide recommendations on sensitive locations, issues of concern, and coordination needs between agencies and Tribes. Sign and implement protocols for consultation between agencies and Tribes.

Focus of Recommendations: This proposal contributes to Goal IIID by filling data gaps and cultivating ecosystem management partners. This proposal provides for a structure that is essential for compliance with federal laws and executive orders to establish "government to government" relationships with tribes, and meeting Trust responsibilities.

Budget/Duration:

	Year 1	Year 2	Year 3
Labor	200,000	100,000	50,000
Equipment and supplies	40,000	30,000	20,000
Transportation	40,000	40,000	40,000
Subtotal	$280,000	$170,000	$110,000

Project Total: $560,000

Principal Contact: Anan Raymond.

CR3. Geographic Information Systems (GIS) Layer and Model of Prehistoric Human Ecology and Cultural Resource Site Distributions in the Salton Sea Region.

Introduction: Cultural resources are those tangible places on the landscape that contain evidence of human use and occupation. In addition, cultural resources include sacred sites and traditional use areas. Over thousands of years ancient Lake Cahuilla drew indigenous peoples to hunt, fish, and live. Likewise, the historic Salton Sea was the scene of early enterprises significant to the growth of the Coachella and Imperial Valleys. Hundreds of cultural resource sites ring the Salton Basin and dot the surrounding uplands. Efficient management of cultural resources and full characterization of the Salton basin ecosystem requires a GIS generated model of prehistoric human ecology and corresponding predictions of archaeological site types and locations. This information is an essential management tool for recognizing areas of cultural sensitivity and those areas that should be avoided and/or mitigated, in compliance with Section 106 of the National Historic Preservation Act. This proposal logically follows production of a cultural resource overview on the Salton Sea Study Area.

Justification: A host of laws require land mangers to consider the impacts of their projects on cultural resources before they implement such projects. A readily accessible database of cultural resources is essential to efficiently plan projects that will address the environmental problems of the Salton Sea. Unfortunately, the information on cultural resources is not compiled in an accessible format. We propose to input cultural resource information into a GIS model of prehistoric human ecology of the Salton Sea area.

Objectives:

1. Provide GIS coverage for the Salton Sea Study Area (defined in Appendix E) of existing cultural resource information including: surveyed areas, site locations, site types, survey “era,” site contents, references, distance to water, soil type, habitat type, and Endangered Species overlays.
2. Identify proprietary information and provide for appropriate safeguards and access.
3. Coordinate with others preparing GIS layers for cultural resources in/near the area.
4. Provide a GIS layer of the various level of Lake Cahuilla during the Holocene.

5. Identify, condense, and reconcile maps of the project area into an appropriate GIS format.

6. Provide all information in an amendable format and ensure capability for ongoing data maintenance and/or hardware requirements.

7. Prepare a GIS based model of aboriginal human ecology of the Salton Sea Study area that predicts archaeological site type and location using habitat, soil type, water etc, as variables.

Products:

Year 1: Coordinate with agencies that have current cultural resources GIS products. Identify and establish protocols for proprietary information. Compile and convert existing cultural resources data into GIS format.

Year 2: Input GIS data on the rise and fall of levels on Lake Cahuilla through the Holocene.
Convert existing maps into GIS coverages, and produce maps. Ensure information is amendable. Provide instruction for data maintenance and hardware requirements. Produce prehistoric human ecological model and site predictions as a report and computer GIS database.

Focus of Recommendations: The project will satisfy Goal IA by modeling prehistoric human ecology at the Salton Sea in a GIS format It will also contribute to Goal IIIA of the workshop by facilitating decisions on engineering solutions designed to address the biological problems of the Salton Sea.

Budget / Duration:

	Year 1	Year 1
Labor	160,000	150,000
Equipment	10,000	5,000
Supplies	20,000	20,000
Transportation	10,000	10,000
Miscellaneous	10,000	5,000
Subtotal	$200,000	$190,000

Project Total: $390,000

Principal Contact: Anan W. Raymond.

CR4. Cultural Resource Field Inventory for the Salton Sea Study Area.

Introduction: Although many archaeological sites are recorded in the Salton Sea watershed, the Salton Sea Test Base is the only area adjacent to the Sea that has received an in-depth cultural resource inventory. Virtually nothing is known about cultural resources in the Mexican portions of the Salton Sea watershed.

The "Salton Sea watershed" includes that area from Whitewater River east and south, including the Coachella, Imperial and Mexicali Valleys, along with the lands adjacent to the Laguna Salada. (Appendix E contains a detailed description of the "Salton Sea Watershed" and "Salton Sea Study Area" for the purposes of all the Cultural Resource proposals)

The Salton Sea Study Area is divided into two regions. The first study area is located between Highway 86 on the west, Highway 111 on the east, Avenue 70 on the north, and the southern boundary, which includes Obsidian Butte. The south boundary is a strip one mile wide extending from the southwest corner of the Salton Sea at Highway 86, just west of the FWS Refuge, T.13S., R.12E., Section 3 and extending east to Highway 111 in T.10S., R.14E., Section 31.

The second study area includes strips of land at key geographic features, including: Alamo River, New River, Laguna Salada, Whitewater, San Sabastian/San Felipe, Wonderstone, and Mammoth Washes, Kane Springs, other washes and springs, main canals, drains, and roads.

Justification: This proposal will enable cultural resource experts to evaluate potential staging and construction areas as to sensitivity to cultural resources in compliance with 106. Cultural resources are non-renewable. The knowledge of the location of cultural resources is essential to the preparation of GIS cultural resource levels.

Objectives:

1. Develop model of prehistoric human ecology and archaeological site locations. Conduct inventories of a sample of the study area.
2. Identify areas containing cultural resources significant to the history of the area.
3. Identify areas which do not contain cultural resources.
4. Identify cultural resources which have been severely impacted and continual impacts.
5. Identify cultural resources that coincide with the proposed project.
6. Prepare management sensitivity maps/overlays. Fill in data gaps in the final archaeological GIS layers. Collected data will generate research models such as: dating chronologies, walk in well placement and usage, life type compared to horticulture, and fish trap placement and usage.
7. Develop criteria for determining significance of sites to the NRHP. Conduct preliminary in-field evaluation of cultural sites to NRHP.

Products:

Year 1: Identify and produce a model for the location of cultural resource sites in the study area. Obtain permits. Conduct field work adjacent to the Sea. Document cultural resources.

Year 2: Conduct field work for other areas and the underwater, if necessary at the Sea. Define and generate research models. Identify areas for clearing and evaluations.

Year 3: Final analysis, prepare report, management recommendations maintenance proposals, and living interpretive site proposals.

Focus of Recommendations: This proposal contributes to Goal IA by providing the essential background on the ecology of the Salton Sea over time. This proposal is also necessary to evaluate Goal III of the workshop to assess the context and significance of cultural resources in the project area of any engineering fixes proposed for the Salton Sea.

Budget/Duration:

	Year 1	Year 2	Year 3
Labor	450,000	450,000	250,000
Equipment and supplies	120,000	175,000	50,000
Transportation	80,000	85,000	20,000
Miscellaneous	90,000	80,000	50,000
Subtotal	$740,000	$790,000	$370,000

Project Total: $1,900,00

Principal Contact: Anan Raymond.

CR5. Reconstruction of the Holocene Environmental Record of the Salton Basin and Implications for Prehistoric Human Ecology.

Introduction: Much has been made of the fortuitous engineering mistake in 1905 that diverted the entire flow of the Colorado River into the Salton Basin and thus formed the Salton Sea. However, this has happened repeatedly in the past without the involvement of human engineering. Over the last 50,000 years, huge bodies of water have periodically come and gone in the Salton Basin. Known as ancient Lake Cahuilla, these waters and the environmental change associated with them, have nourished and challenged humans for the last 12,000 years. In order to fully understand the ecology of the present Salton Sea we must know something of the ecology of the ancient sea and surrounding uplands. Baseline information on environment of the Salton Basin over the last 25,000 years, particularly the last 12,000 years will provide an essential context for archeological sites located in the Salton Sea watershed, as well as a much needed perspective for modern studies of the Sea's ecology.

Justification: We cannot fully appreciate the ecology of the Salton Sea today without some understanding of the environment of the Salton Sea watershed in the past, particularly the last 12,000 years. There are many repositories of environmental data in the Salton Sea watershed, including archaeological sites, packrat middens and sediment sumps. To understand the prehistoric changes in plants, animals, and human ecology, we must sample these environmental deposits and reconstruct the past climate and rise and fall of the Sea.

Objectives:

1. Identify the type and location of the various paleoenvironmental sumps in the Salton Sea watershed. That is, locate those places in the basin that are repositories for environmental data about the past. Such places include certain archaeological sites such as caves and midden deposits, ponds, marshes and lakes, and packrat middens.

2. Obtain samples of deposits from paleoenviromental locales, and conduct analyses of data using techniques of palynology, paleobotany, sedimentology, archaeology and allied disciplines.

3. Reconstruct the paleoenvironment of the Salton Basin, particularly the last 12,000 years, focusing on wet/dry warm/cool cycles, lake transgression/regression, and corresponding plant and animal distributions and fluctuations.

4. Model prehistoric human ecology and predict its archaeological expression over time and space during the Holocene.

Products:

Year 1: Identification of, and sampling from, paleoenvironmental sumps in the Salton Sea watershed.

Year 2: Laboratory analyses of collected samples.

Year 3: Report completion describing the paleoenvironmental record including climate, vegetation, and fauna and implications for human ecology and archaeological site location and types.

Focus of Recommendations: This proposal contributes to Goal IA by providing the essential background on the ecology of the Salton Sea over time. This proposal is also necessary to evaluate Goal III of the workshop to assess the context and significance of cultural resources in the project area of any engineering fixes proposed for the Salton Sea.

Budget/Duration:

	Year 1	Year 2	Year 3
Labor	100,000	180,000	50,000
Equipment and supplies	25,000	50,000	5,000
Transportation	25,000	0	0
Miscellaneous	10,000	30,000	5,000
Subtotal	$160,000	$260,000	$70,000

Project Total: $490,000

Principal Contact: Anan W. Raymond.

Pathogens and Diseases Team Proposals

PD1. Disease-causing Agents for Fish, Wildlife, and Humans in the Salton Sea Ecosystem: a Systematic Monitoring and Health Assessment Program.

Introduction: Recent disease outbreaks in fish and birds at the Salton Sea have focused national attention on the status of this ecosystem as degraded and in dire trouble. The death of over 150,000 eared grebes in 1992 from an undiagnosed cause, a severe botulism outbreak killing over 15,000 birds in 1996, including endangered brown pelicans, an outbreak of Newcastle disease in 1997 which decimated an entire nesting colony of double-crested cormorants, and numerous other die-offs documented since the 1970s, attests to the severity of the disease problems. In addition, literally millions of fish have died in continuous as well as epidemic events. Substantial concern also exists over public health from disease-causing agents present in the Salton Sea Ecosystem, including the New River. Scientific studies and empirical data have identified the presence of agents in the Salton Sea which could result in episodes of human disease, including polio, typhoid, cholera, and tuberculosis. Viruses which cause encephalitis have also been reported in the Salton Sea vicinity. Despite these reports, critical baseline scientific data to facilitate focused epidemiological studies does not exist. This limits the capability of public health agencies to evaluate and respond to concerns of people residing near or utilizing the Salton Sea and its environs.

Justification: Major knowledge gaps exist as to the causes of many of the disease problems in fish and wildlife in the Salton Sea, their magnitude and impact on fish and wildlife resources, the environmental factors contributing to these diseases, and the role of ecosystem degradation in the recent increase in magnitude and diversity of disease problems. Furthermore, contemporary public health protection dictates that attention is given to any potential health threat to the community. These critical information gaps must be addressed to develop sound and cost effective management alternatives for improving fish and wildlife health, protecting human health, restoring the integrity of the Salton Sea ecosystem, and for predicting and evaluating proposed changes in the Salton Sea. Establishment of baselines for these factors will enable evaluation of temporal and spatial changes in disease and disease risk in response to changes in the Salton Sea ecosystem.

Objectives:

1. Establish baseline data for the occurrence and distribution of selected wildlife and human pathogens, algal blooms, and other significant microbial populations through surveys of biotic (fish, birds, etc.) and abiotic components (water, sediments, etc.) of the Salton Sea and its environs, including important wildlife habitat and areas of high human use.
2. Develop a systematic monitoring system to detect, document, and diagnose fish and wildlife mortality, their temporal and spatial distribution, methods for estimating magnitude of mortality and for assessing population impacts of disease.

3. Use sentinel animals (fish, birds, crayfish) to evaluate site-specific factors such as localized microbial flora, biotoxins, and contaminants that may contribute to the occurrence of disease.

4. Analyze environmental/limnological/sedimentological conditions in relation to patterns of fish and wildlife mortality and changes in pathogenic microbial populations to develop disease-specific risk assessment models.

5. Coordinate public health interdiction efforts with research conducted by other agencies.

6. Identify target human populations, including local Indian tribes and other ethnic groups that may be at elevated risk of exposure to human pathogens.

7. Conduct epidemiological investigations to quantify exposure risks among people who may be engaged in activities associated with the Salton Sea and surrounding area.

8. Evaluate impact of potential engineering solutions on disease and pathogens through surveys of selected microbial and algal species in the Sea of Cortez (pump in/pump out solutions) and any demonstration diking project.

Products:

- Reports on the occurrence, distribution and magnitude of fish and wildlife mortality.
- Inventory of selected potential disease-causing agents of fish, wildlife and humans.
- Information that will contribute to development of disease-specific risk assessment models.
- System for early detection of wildlife mortality events.
- Criteria for evaluating public health risks
- Data for assimilation in a GIS database
- Recommendations for management of disease
- Repository of archived specimens and research material
- Baseline criteria for evaluating proposed engineering solutions as they relate to pathogens and disease control.
- Interim and final reports, technical and nontechnical bulletins, scientific publications, and educational material.
- Interim public health action plan to be implemented throughout the duration of the research effort.
- Appropriate public health intervention strategies to minimize and mitigate human exposure risks.

Anticipated Focus of Recommendations: IC; IIA, B, C; Leading to IIIA

Budget/Duration: $3.3 M each year for 3 years

Principal Contact: Tonie Rocke.

PD2. Avian Botulism in the Salton Sea: The Role of Fish and Other Environmental Factors.

Introduction: In the fall of 1996, over 15,000 pelicans and other fish-eating birds, including the endangered brown pelican, died from type C botulism at the Salton Sea. Upon further investigation, it was determined that a massive fish kill (tilapia) occurred simultaneously, and that fish were the probable source of toxin for birds. The role of fish in the die-off is unclear. Some evidence suggests that fish were ingesting toxin and also dying from botulism. Another possibility is that fish were dying from other bacterial infections (vibriosis), providing a suitable environment for the production of botulism toxin. Local environmental stressors, such as high temperature and salinity, may have been important contributing factors. Prior to this event, type C botulism had not previously been associated with fish or caused such extensive mortality in fish-eating birds.

Justification: The 1996 botulism outbreak at the Salton Sea was the largest documented die-off in pelicans in the U.S., killing nearly 15% of the western white pelican population, and many endangered brown pelicans. This event was very atypical of botulism outbreaks in other water birds and appears to be unique to the Salton Sea. Over 0.5 million dollars and many person hours were expended picking up dead and dying birds to prevent further losses from the disease and to rehabilitate sick pelicans. More pelicans died recently at the Salton Sea, and continued losses from botulism are expected, as well as additional fish kills. A better understanding of the role of fish in botulism outbreaks and other contributing environmental factors is needed to evaluate how proposed engineering projects in the Salton Sea may affect occurrence of this disease. Additionally, this knowledge will supplement efforts to develop alternative methods for controlling the disease, with our without engineered projects.

Objectives:

1. Using field and laboratory studies, assess the effects of type C botulism toxin in fish and identify potential sources of toxin for fish, including invertebrates, dead fish, and other decaying organic matter.
2. Evaluate the interaction between botulism spores and bacterial infections (vibriosis) in fish and potential sublethal effects of botulism toxin on disease resistance in fish, incorporating effects of increasing temperature and salinity.
3. Determine the distribution and abundance of botulism spores and toxin-producing cells in the Salton Sea ecosystem, including the major river deltas and selected agricultural drains.
4. Measure and analyze environmental conditions associated with botulism outbreaks in fish and birds and the distribution and abundance of botulism spores to develop risk assessment models.
5. Determine the prevalence of vibriosis in fish at the Salton Sea and environmental factors related to outbreaks of the disease.
6. Explore new methods for controlling botulism in pelicans, including mass vaccination and habitat manipulation.

Products:

- Information that will contribute to the development of risk assessment models for botulism outbreaks at the Salton Sea.
- Methods that may contribute to management of botulism outbreaks.
- Criteria for assessing impacts of proposed engineering solutions on the occurrence of botulism outbreaks.
- Products will be in the form of interim and final reports, technical and non-technical bulletins, and manuscripts in scientific journals.

Anticipated Focus: The results of this work will address Goal IIC, D, and E. Recommendations will be specific to the occurrence and management of botulism outbreaks in fish and birds in the Salton Sea.

Budget/Duration: 2.4 million total for 3 years

Principal Contact: Tonie Rocke

PD3. Algal Biotoxins in Fish and Wildlife Mortalities.

Introduction: In the last five to ten years, significant bird and fish mortality has occurred at the Salton Sea. The cause of many of these events has not been determined. Various environmental stressors may be involved, including algal biotoxins. There are many algae that produce biotoxins that can be harmful or lethal to wildlife, fish or humans. The role of biotoxins in causing both acute and chronic disease in animals at the Salton Sea needs to be investigated.

Justification: Knowledge of the algal species presently found in the Salton Sea is incomplete. The last major survey on a temporal or spatial basis was made many decades ago when the salinity was much lower. Because these algal assemblages respond to varying salinities, it is likely that communities have changed from those documented in the past. Preliminary observations verify that several toxic algal species are present in the Salton Sea that may cause wildlife and fish mortalities or may sublethally stress animals, rendering them more susceptible to disease. However, critical data is lacking on the species composition of the algae, the spatial and temporal differences in algal abundances, and which, if any of the species produce toxins or otherwise are harmful to biota. There are also implications that algal blooms have strong associations with bacteria, particularly vibrios. This relationship needs to be clarified as certain bacteria that are associated with such blooms are known fish and human pathogens.

Objectives:

1. Characterize the temporal and spatial distribution of algal species assemblages and abundances, with emphasis on potentially toxic species.
2. Investigate the distribution of toxins in selected biota.
3. Culture suspect algae for life cycle studies and verification of toxicity and characterization of toxic components.
4. Investigate the potential role of toxins in disease, mortality, or sublethal effects by conducting bioassay on fish and other target organisms to demonstrate pathogenicity, lethality, or retention of toxins for potential transfer up the food chain.
5. Develop management and control recommendations based upon the findings of the previously listed objectives.

Products:

- Catalogue of known toxic (and potentially toxic) algal species, documenting their distribution and density variation in the Salton Sea.
- GIS maps of the algal species distribution in relation to disease and mortality sites and species impacted.
- Literature review of known toxicity and ecology of each algal species.
- Informational publications on mortality and disease risks to wildlife, fish, and humans associated with biotoxins (pertinent to Salton Sea).
- Recommendations on methods to control and manage harmful algal blooms to minimize disease and mortality risks.
- Products in the form of interim and final reports, technical and non-technical bulletins
- Publications for scientific journals and presentation of work accomplished at scientific meetings.

Anticipated Focus of Recommendations: This proposal will address Goals IA, IC, ID, IIB, IIC, IID, IIE and ultimately IB, IIIA, IIIC

Budget/Duration: Year 1: $393,000; Year 2: $543,000; Year 3: $544,000

Principal Contacts: Jan Landsberg, Mary Ann Tiffany, Tonie Rocke.

PD4. Salinity, Contaminants, and Disease Interactions in Fish and Birds.

Introduction: A number of physical parameters in the waters of the Salton Sea have been identified as significant stressors to fish and wildlife. These stressors can occur concurrently and include elevated salinity, contaminants (selenium, heavy metals, pesticide residue), low dissolved oxygen (fish), and extreme temperatures. Environmental stress can reduce an animal's resistance to disease and is likely playing a role in the massive fish and bird mortalities. The survival of pathogenic bacteria in the Sea will also be influ-

enced by these physical parameters. Proposed engineering solutions to stabilize salinity will affect many of these environmental stressors.

Justification: Disease resistance of fish and waterfowl exposed to current and potential environmental conditions should be evaluated in controlled laboratory experiments. Close examination of the interactive effects of selected water quality parameters on disease resistance can only be achieved by controlled laboratory challenges. The range of water qualities which may occur with an engineering project (dike, brine transfers, pollution abatement) needs to be evaluated for their health effects on the biotic components of the lake. Data on the response of key indicator species would be used in any modeling approach for management options in the Sea. Physiological data from challenged animals would help explain any similar responses observed in wild fish and birds.

Objectives:

1. Determine survival of significant bird, fish, and human bacterial pathogens in water and sediment under a range of pertinent environmental conditions (salinity, temperature, dissolve oxygen, redox potential, pH, etc.).
2. Determine osmoregulatory function, immunologic responses, and disease resistance of key indicator species of birds and fish exposed to different levels of salinity and selected contaminants. In the case of fish, challenges would be held under a range of relevant temperatures and dissolved oxygen concentrations.

Products:

Year 1: Literature search materials and interim recommendations on environmental effects transmitted to Project's data contact.
Report on salinity / temperature / dissolved oxygen interactive effects on the resistance of local tilapia to select bacteria and their physiological state.
Report of salinity effects on the physiology and disease resistance of indicator waterfowl species.

Year 2: Report on laboratory studies on pathogen survival and risk assessment recommendations.
Report on selected contaminants / temperature / dissolved oxygen interactive effects on the resistance of local tilapia to select bacteria and their physiological state. Report of contaminant effects on the physiology and disease resistance of indicator waterfowl species.

Year 3: Final report on additional interactive laboratory studies and specific recommendations for threshold levels of key physical parameters on fish and wildlife health.

Anticipated Focus of Recommendation: Goal I, model of ecosystem function; Goal II C & D, examine causes of fish & wildlife mortality, test hypotheses in laboratory studies.

Budget/Duration:

Year 1	$200,000 (fish) + $200,000 (bird)	=	$ 400,000
Year 2	$150,000 (fish) + $300,000 (bird)	=	$ 450,000
Year 3	$160,000 (fish) + $300,000 (bird)	=	$ 460,000
	Total	=	$1,310,000

Principal Contact: J. Scott Foott and Tonie Rocke

PD5. Cause, Impact, and Contributing Environmental Factors of Massive Mortality in Eared Grebes on the Salton Sea, and Management Recommendations for Minimizing Losses.

Introduction: In 1992 an unprecedented disease outbreak occurred among eared grebes and lesser numbers of other water birds on the Salton Sea. Estimates of total mortality exceeded 150,000, representing more than 10% of the western North American eared grebe population. Despite intensive field and laboratory investigations, the cause of this outbreak remains unknown, although numerous known disease-causing agents have been ruled out. Similar undiagnosed outbreaks of lesser magnitude (several thousands) have occurred among eared grebes on the Salton Sea annually since 1994. Recent attention has focused on the possible contributing roles of algal and other microbial toxins, interactions with avian cholera (known to occur concurrently with undiagnosed mortality), and physiological responses to hyper saline conditions.

Justification: Continued outbreaks of this undiagnosed disease, apparently restricted to the Salton Sea, raise major concern over the long-term impact of these losses to the Flyway population, and the potential recurrence of devastating outbreaks such as occurred during 1992. Until the cause of this mortality is known, little can be done to control this disease or manage the environmental factors contributing to its occurrence. Considerable fiscal and personnel resources will continue to be expended by Federal and State agencies in attempting to minimize losses through intensive carcass pickup and disposal.

Objectives:

1. Identify the cause of mortality in recurring outbreaks in eared grebes through:

a) Comprehensive field and laboratory diagnostic investigations of outbreaks.

b) Experimental trials to reproduce disease, focusing on suspected causes such as biotoxins as indicated from field investigations.

c) Further diagnostic analysis of archived samples from previous outbreaks.

d) Identify physiological processes such as salt gland function that may contribute directly or indirectly to mortality.

2. Evaluate environmental factors and interactions contributing to the occurrence of mortality in eared grebes.

3. Develop recommendations and evaluate alternatives to minimize mortality, as identified above.

Products:

Year 1: Reports of progress in identifying cause of mortality and contributing environmental factors.

Year 2: Reports of progress as above and verification of year 1 results; Provide recommendation as appropriate; scientific publications as appropriate.

Year 3: Final report of findings on cause of mortality and management alternatives and recommendations; scientific publications as appropriate.

Anticipated Focus: Research will focus on Goal IIB, IIC, and IID, and will contribute to the development of ecosystem management for the Salton Sea as identified in Goal IIIA.

Budget/Duration: $450K/yr for years 1 and 2; $100K for year 3

Principal Contact: Christopher Brand.

PD5.5. Newcastle Disease Die-off of Double-crested Cormorants at the Salton Sea: Impact, Spread, and Potential Risk to Wild Birds, Domestic Poultry and Humans.

Introduction: During the summer of 1997 an outbreak of Newcastle disease occurred in juvenile double-crested cormorants at the Salton Sea. All of the 1,500 juvenile double-crested cormorants on Mullet Island died during this outbreak. Field investigations of the colony revealed no active nests remaining. The Newcastle disease virus isolated was identified as a strain of relatively low virulence to domestic poultry. Although Newcastle disease outbreaks in double-crested cormorants have been documented in Canada and the Great Lakes region in the early 1990s, the outbreak at the Salton Sea, along with a concurrent outbreak in Utah, represents the first known occurrence of mortality in wild birds from this disease in the western U.S.

Justification: The appearance of Newcastle disease in 1997 at the Salton Sea raises concern over the potential impact of this disease on cormorant populations, its spread in the western populations of cormorants, and the susceptibility of other migratory birds to this disease. Although the strain of Newcastle disease isolated from this outbreak appears to be of relatively low virulence in laboratory assays using domestic poultry, the risk and threat to domestic poultry in the Salton Sea vicinity from the recurrence of this disease at the Salton Sea is unknown. In addition, because Newcastle disease virus can potentially affect humans, the occurrence of this disease in cormorants represents a risk of unknown magnitude to wildlife resource managers dealing with disease outbreaks and the public potentially exposed to infected birds or their contaminated environments.

Objectives:

1. Determine the reservoir, prevalence of exposure in wild birds, and methods of transmission of Newcastle disease virus.
2. Assess the impact of Newcastle disease die-offs on double-crested cormorant populations.
3. Assess the risk of Newcastle disease virus in the domestic poultry industry in southern California, and zoonotic episodes among resource managers, poultry farmers, and the public.
4. Determine the susceptibility of other selected wild bird species to Newcastle disease virus.
5. Develop management strategies to control or minimize Newcastle disease die-offs in wild bird populations.
6. Develop an efficient interagency reporting (monitoring) system to document Newcastle disease die-offs in wild birds throughout the United States, Canada and Mexico.

Products:

- Risk assessment of Newcastle disease virus in the domestic poultry industry in southern California.
- Risk assessment of Newcastle disease virus on selected wild bird species.
- Management strategies to control, minimize or eradicate Newcastle disease from wild bird populations (depopulation, site decontamination, carcass pickup, mass vaccination).
- Interagency monitoring system for Newcastle disease die-offs in wild bird populations.
- Publications for scientific journals, public education and wildlife agency bulletins.
- Development of protocols designed to prevent vector-borne transmissions of virus to susceptible human populations.

Anticipated Focus of Recommendations: Goal II - Develop an understanding of factors driving the bird die-offs in the Salton Sea; Goal IIB - Develop a strategy for data collection and observations during die-offs; Goal IIE - Devise and test management methods to control or prevent bird mortality

Budget/Duration: Personnel - $600,000; Travel - $45,000; Equipment - $50,000; Operation & Maintenance - $100,000.

Total Budget = $795,000

Principal Contact: Christopher Brand and Pam Swift

Contaminants Team Proposals

C1A. Effects of Selected Water Quality Variables and Environmental Contaminants on Fish Mortalities in the Salton Sea: A Field and Laboratory Assessment.

Introduction: The Salton Sea is California's largest inland water body and an important water resource for people and wildlife of the Imperial and Coachella valleys. The Sea was originally created as a result of flood events in the lower Colorado River. Today, the major source of water is agricultural drainage. Over time, water quality in the Sea has changed from a freshwater environment to a saline environment that is now saltier than seawater. Environmental contaminants such as selenium, pesticides, and fertilizer compounds are also accumulating at concentrations that may threaten the viability of fish and wildlife populations. Although fish kills have been observed for more than two decades, their frequency and severity have been alarming in recent years. In addition, several previously abundant recreational fishes have declined in abundance, and other species are known to harbor potentially virulent forms of disease organisms. The end-result is that the sport fishery is on the verge of collapse, and several other beneficial uses of the Salton Sea have been reduced in value.

Justification: With few exceptions, the abundance of recreationally important fishes has declined in recent years within the Salton Sea. Two species of tilapia are exceptional because they are seemingly more abundant and widely distributed than in the past. However, even tilapia are exhibiting evidence of severe stress as evidenced by massive fish kills that occur sporadically throughout the Salton Sea. Selected water quality variables (especially dissolved oxygen concentrations) taken during some dieoffs have approached or exceeded levels that are typically lethal to fish. High water temperatures, high pH, and possibly high unionized ammonia concentrations and hydrogen sulfide concentrations may also be stressful to fish. In addition, the body burdens of fishes contain elevated concentrations of selenium and possibly other environmental contaminants associated with agricultural drain water and municipal-industrial sewage. Moreover, within the past two years, several potentially fatal infectious pathogens have been isolated from dead and dying tilapia. The purpose of this study is to determine the causes of fish kills in the Salton Sea by identifying and establishing cause-effect relations between water quality and contaminant variables, and episodes of fish mortality. These findings will be used to estimate safe (no effect) thresholds that can be used by resource managers to establish or refine site-specific water quality criteria for the Salton Sea and its tributaries.

Objectives: The objectives of this study are as follows: (i) to characterize fish kills in the Salton Sea by documenting the species, life stages, and condition (health) of fish involved in the die-offs; (ii) to monitor the timing and location of lethal conditions in the Sea by quantifying survival of captive fish (test animals) held in live cages; (iii) to identify water quality and contaminant variables associated with mortality of caged fish; and (iv) to

conduct controlled laboratory experiments that determine the individual and combined contributions of various water quality and contaminant variables (including mixtures of contaminants) associated with fish kills. The health status of fish will be incorporated into the experimental design of field and laboratory tests by including diseased and healthy (undiseased) fish as treatment variables. In addition to mortality, toxic endpoints of field and laboratory tests will include measurements of brain cholinesterase activity (a measure of neurotoxicity), ethoxy resorufin-o-deethylase (EROD) activity (a measure of liver enzyme induction), plasma chloride level (a measure of osmoregulatory disruption), reproductive endpoints, and other appropriate physiological or biochemical indicators of sublethal stress.

Products: This study will generate annual progress reports for the first two years and a final completion report at the end of the study in year three. In addition, summarized results will be presented at scientific conferences and submitted for publication in peer-reviewed technical journals.

Anticipated Focus of Recommendations: This study will address Goals IC, IIC, IID, and IIIA. Recommendations will encompass the biological, physical, and contaminant environments by focusing on relations among water quality and contaminant variables, and fish mortality.

Budget/Duration:

	Year 1	Year 2	Year 3
Labor	500,000	600,000	200,000
Equipment	65,000	65,000	0
Supplies	45,000	45,000	10,000
Travel	10,000	5,000	2,500
Contracts-Chemical Analyses	330,000	200,000	0
Miscellaneous	25,000	25,000	5,000
Subtotal	$975,000	$940,000	$217,500

Project Total: $2,132,500

Principal Contacts: Michael K. Saiki and Susan B. Jones.

C1B. Selenium Distribution and Toxicity in Total Organic Carbon and Fine Particles in Bottom Sediments of the Salton Sea: Subtopic - DDE Distribution.

Introduction: Elevated concentrations of selenium have been detected in the bottom sediments of the Salton Sea. Feeding of benthic invertebrates is one route by which selenium enters the food chain. Selenium concentrations in bottom sediments of the delta of the Alamo River have been detected at concentrations ranging from 0.2 to 2.5 ppm in

individual cores and as high as 3.3 ppm in a composite core sample. Recently, a bottom sediment core sample having a selenium concentration of 9.4 ppm, an organic carbon content of 10 percent and a very low composition density was collected from the south buoy in the Salton Sea. Benthic invertebrates, in particular pileworms, inhabit bottom sediments and are directly exposed to selenium containing bottom sediments.

DDT metabolites, particularly DDE, continue to be associated with eggshell thinning in birds inhabiting the Salton Sea ecosystem. Although banned in 1972, DDT continues to be transported from fields to the Salton Sea and is found in the eggs of several bird species.

Justification: Currently selenium is at concentrations of concern in the biota inhabiting the Salton Sea ecosystem. Because biota have a narrow tolerance range to selenium which both bioaccumulates and biomagnifies, any increase in selenium concentration in lower trophic levels will be reflected by a larger increase in top level biota, especially in piscivorous birds. Selenium enters the food chain through invertebrate feeding. Assessing invertebrate exposure to sediment from the Salton Sea and the potential toxicity of this sediment to biota would be a first step in understanding potential adverse biological effects in the food chain. Construction of dikes in the Salton Sea may change current patterns which could redistribute bottom sediments. The redistribution of these sediments could increase the biological availability of selenium to lower trophic organisms. An assessment of the distribution of the bottom sediments is needed to predict the effect of the proposed constructed dike on the potential for increased concentrations of selenium in lower trophic organisms and the resultant bioaccumulation and biomagnification. Analysis of the total organic carbon (TOC) content of these sediments and comparison of selenium to TOC ratios and particle size will help to define the source of the selenium.

DDE has been associated with eggshell thinning in bird populations throughout the world. As a result of such exposure, brown pelicans and peregrine falcons were classified as endangered species. Eggshell thinning is adversely affecting reproductive success of bird species nesting at the Salton Sea.

Objective:

1. Determine the extent and concentration of selenium in the total organic carbon and fine sediment fraction of the bottom sediments of the Salton Sea. Determine the particle size distribution of these sediments.
2. Determine the extent and concentration of organochlorine pesticides residues in the bottom sediments of the Salton Sea
3. Assess the toxicity of selenium-laden sediments to benthic invertebrates
4. Estimate the potential change in selenium bioaccumulation resulting from the suspension of bottom sediments and their availability to aquatic water column organisms.

Product:

- A map and digital coverage showing the concentration and distribution of selenium, total organic carbon, and particle size distribution of bottom sediments in selected transects will be produced.
- A report detailing the results of the assessment of bottom sediment toxicity to benthic invertebrates.

Anticipated Focus Recommendations: The study will address goals IC and IIIA.

Budget/Duration:

	Year 1	Year 2	Year 3
Personnel	170,000	180,000	80,000
Analytical	93,000	98,000	0
Equipment/supplies	65,000	20,000	5,000
Miscellaneous	15,000	18,000	12,000
Subtotal	$343,000	$316,000	$97,000

Project Total: $756,000

Principal Contact: Jim Setmire.

C3. Title: Immunological Competence and Contaminant Levels in Fish and Birds From the Salton Sea.

Introduction: Bird and fish kills have occurred along the Salton Sea over the past several years. While it is not clear what is the biochemical mechanism that explains all these kills, potentially fatal infectious pathogens have been identified in tilapia and brown pelicans found dead in the Salton Sea. This raises the possibility that the immune systems of the fish and birds are compromised, making them more susceptible to pathogens. This proposal focuses on ascertaining the immunological status and exposure biomarkers of fish and birds living in and around the Salton Sea.

Justification: The Salton Sea is a sink for salts, nutrients, selenium, and other less concentrated pollutants. As solutions for the Salton Sea are being sought, it may be important to ascertain if there is an interconnection between the contaminants (salts, selenium, algal toxins, other pollutants) and the immunological competence of the fish and birds. The information obtained from this study may help identify the contaminants that need to be dealt with so the solution to the Salton Sea will also address a possible mechanism for the fish and bird dieoffs.

Objectives:

1. Collect fish and birds from several locations on the Salton Sea, near the deltas, and from the river locations, when possible.
2. Collect fish and birds from relatively clean locations, and possibly raised in the lab.
3. Collect blood and tissue samples from the fish and birds.
4. Analyze for the general and specialized immunological parameters. Analyze the blood/tissue for certain contaminates, especially selenium, DDT and its metabolites, etc.
5. Challenge the fish and birds with a series of microbiological, toxin, and viral agents. After each test, assess the immunological parameters of the fish and birds.
6. Compare population and matched data of the contaminant and immunological parameters.

(Could add reproductive or other biomarkers as well) See PD3&4

C4. Conceptual Site Model of Historic, Current and Future Contaminant Inputs and Fates in the Salton Sea.

Introduction: A variety of historic and current environmental contaminants have been reported in association with the Salton Sea ecosystem. Based on current knowledge, these include, but are not necessarily limited to, the following compounds or categories: selenium, salinity, nutrients, organochlorines, organophosphates, biotoxins, and inert chemicals associated with pesticides. The potential sources for this contaminant loading into the Salton Sea include: past military activity, industrial and domestic wastewater, landfills, agricultural activities, non-point sources, aerial fallout, waters from the Alamo, Colorado, New, and Whitewater Rivers and natural sources (e.g., thermal vents). These environmental contaminants can have a full range of effects, from lethal to sublethal, on the living resources of the Salton Sea.

Justification: The Salton Sea ecosystem has a history of environmental contaminant loading. To develop a complete understanding of the factors affecting the Salton Sea ecosystem, historic and current environmental contaminant species, sources, pathways, fates and effects must be an integral part of an accurate, comprehensive conceptual site model. Environmental contaminant exposures are known to cause such far reaching and profound effects as acute mortality events, population perturbations, and community structure interruptions, which promote crisis management. These events can affect the very survival of certain endangered species that depend on the Salton Sea ecosystem. Such ecological disturbances have also resulted in diminished public use and enjoyment of the natural resources of the system. This, in turn, has had significant negative consequences for the local economy. By combining knowledge of contaminant effects, Sea inputs, and information from proposed sediment cores, attention will be focussed on a model that incorporates these essential factors in any decision-making as to the management of this complex system.

Objective: The objective of this proposal is to develop a conceptual site model which will define the contaminants of concern, identify the sources of those contaminants, predict the fate of the contaminants in the system, determine their pathways (*e.g.*, sediment deposition, transport within the food chain, aerial fallout, groundwater discharge, precipitation and surface water) to biological receptors of concern. This model will permit managers to understand, predict and theoretically control the role of environmental contaminants under a range of management scenarios for the Salton Sea.

Products:

Year 1: Gather inputs to model, focussing on aspects listed in proposal (current contaminants, sources, pathways, fates and effects: 1996-97; historic - 1990-95; pre-1990).

Year 2: Continue gathering inputs to model; integrate material into conceptual site model; incorporate proposed sediment cores and data from other proposed concurrent studies into conceptual site model.

Year 3: Assess power of conceptual model as a predictive and management tool; make recommendation for addressing acknowledged data gaps; adapt model outputs to management needs.

Goals Addressed: 1A, B, and C. To develop an understanding of the Salton Sea ecosystem: collect, compile and organize existing data, including sediment core information to develop a conceptual site model to be used in designing a strategy for methodical inventory of contaminants and monitoring of the ecosystem to provide a tool for managers.

Budget/Duration:

	Year 1	Year 2	Year 3	Total
Personnel				
Project Manager (1@100%/50%/50%)	100,000	50,000	50,000	200,000
Technical experts (5@20%)	100,000	100,000	100,000	300,000
Researcher/Investigator (1@100%)	100,000	100,000	0	200,000
Modeler (1@0%/40%/60%)	0	40,000	60,000	100,000
Info. Resource Specialist (1@20%)	20,000	20,000	20,000	60,000
Equipment				
Communications access	10,000	0	0	10,000
Modeling software	0	5,000	5,000	10,000
Miscellaneous	40,000	40,000	40,000	120,000
Total	$370,000	$355,000	$275,000	$1,000,000

Principal Contacts: Chip Demarest, Eugenia McNaughton, and Susan Jones.

C5A. Toxicity Assessment of Salt Precipitates from Salton Sea Associated Waters.

Introduction: The Salton Sea is an immense salt sink receiving and retaining about 4.5 million tons of salt annually. As a result of cumulative salt loading, the Salton Sea is approaching a level of salinity that would be intolerable for major fish populations. Any proposal to save the Salton Sea will necessarily have to include a mechanism for establishing a salt balance at a desirable target salinity. Salt balance is established by segregating and/or exporting salt from the Salton Sea. Most mechanisms for salt segregation (i.e., diked ponds) and/or export (i.e., pump-out to Laguna Salada) ultimately result in the precipitation of salts that then must be disposed. The Salton Sea is also a contaminants sink. For example, it receives about 9-10 tons of selenium annually. The Salton Sea also receives very large loads of boron. The loads of industrial and domestic contaminants are not well quantified, but are cause for concern. Historically, the Salton Sea has also received large inputs of organochlorine pesticides. Therefore, in addition to the potential inherent toxicity of certain salts, such as sodium-sulfates, even relatively nontoxic salts could pose a toxic hazard due to incorporation of inorganic and/or organic contaminants into salt precipitates. This has several important implications for assessing potential environmental impacts associated with proposals for managing the salt balance (i.e., the salinity level) of the Salton Sea. For example, will any of the salt precipitates exceed statutory hazardous waste criteria that would severely constrain how the salt precipitates could be transported or disposed? What would the environmental attributes of exposed salt precipitates be? Would they be highly friable and pose hazards associated with dust export and deposition? What would the dissolution (leachate) characteristics be for the salt precipitates? These are a few of the fundamental questions that require reliable answers in order to adequately understand the Salton Sea ecosystem or to evaluate most salinity management proposals.

Justification: Management of salt precipitates will ultimately be an important component of almost any proposal to control salinity of the Salton Sea. Also, any decline of the Salton Sea's elevation (naturally or managed) would also expose substantive patches of precipitated salts (associated with terminal evaporation of remnant puddles and pools created by retreat of the waterline across topographic irregularities). Thus, establishing the toxicological profile and environmental attributes of precipitated salts is a fundamental necessity for understanding the present ecosystem. It is also important for assessing potential environmental impacts from a broad range of salinity control and shoreline elevation management options.

Objectives:

1. To characterize the trace element and organic contaminant profiles of a representative sample of salt precipitates generated by evaporation of water from the New River, Alamo River, Drainage Ditches, and the Salton Sea. It is important to examine all of these classes of water because off stream impoundment of all these classes of water is a component of one or more current proposals. If those impoundments are even seasonally dry or

seasonally fluctuate in size it would be important to characterize the contaminant profiles of precipitates.

2. To examine the dissolution characteristics of salt precipitates and characterize the trace element and organic contaminant profiles of various classes of leachates (including standard bioassay toxicity testing.

3. To examine the friability (erosion capacity) of the salt precipitates and characterize the trace element and organic contaminant profiles of precipitate dust.

Products:
Year 1: Final Report

Anticipated Focus Of Recommendations: The results of this work will address goals IB and IIIB. Goal IB would be addressed because salt precipitates are an important contaminant sink that would have to be characterized for an adequate conceptual model of ecosystem function. Goal IIIB would be addressed because salinity control will have to be a primary component of any adaptive management strategy. The contaminant characteristics of salt precipitates could severely constrain adaptive management options for salinity control if the precipitates constituted statutory hazardous waste. At the end of this work (1 year) a definitive determination regarding the regulatory status of salt precipitates will be provided to managers.

Budget/Duration:	Year 1:	
Personnel	Principal Investigator (USFWS) 0.6 FTE	60,000
	Principal Investigator (UCD) 0.1 FTE	10,000
	Associate Investigator (UCD) 1.0 FTE	100,000
Analytical	Inorganics (150 samples by contract lab)	37,500
	Organics (150 samples by contract lab)	225,000
Equipment & Supplies	Field and laboratory equipment for sample collection and preparation, bioassay tests, etc.	15,000
Miscellaneous		5,000
Total		$452,500

Principal Contact: Dr. Joseph P. Skorupa.

C5B. Developing Site-Validated Response Curves for Selenium-Induced Avian Reproductive Toxicity.

Introduction: Selenium is a priority contaminant of concern at the Salton Sea. Recently, mass loading of selenium into the Salton Sea has been occurring at a rate of about 9-10 tons annually, which ranks among the largest known inland selenium sinks in the world. Water birds are particularly susceptible to selenium poisoning, and the immense

number of water birds attracted to the Salton Sea ecosystem is of world class stature. Thus, the clear potential for selenium poisoning of birds on a massive scale demands constant vigilance and the capability for precise risk evaluation and risk monitoring. Previous research has clearly established that the selenium content of avian eggs is an excellent currency for risk assessment and risk management. Fifteen years of research, primarily at agricultural evaporation ponds in California's San Joaquin Valley, has yielded precise exposure-response curves relating selenium exposure (in bird eggs) to egg viability. Specific curves have been developed for a selenium-tolerant bird species (avocets), a selenium-sensitive species group (ducks), and a bird species of intermediate sensitivity (stilts). A small amount of exposure-response data were collected for stilts nesting at the Salton Sea during 1992-93. Based on that sample, exposure-response relations appeared consistent with data from the San Joaquin Valley, and stilts appeared to be straddling the toxic effects threshold for selenium exposure; a level consistent with the apparent 5% reproductive depression that was documented. However, the sample size for the 1992-93 stilt study was not statistically sufficient to conclusively validate that San Joaquin Valley response curves apply to the Salton Sea. In the San Joaquin Valley it was also found that there were highly predictable relationships between waterborne selenium concentrations and concentrations of selenium in stilts' eggs. Combining that relationship with the exposure-response curves for egg viability makes it possible to precisely quantify selenium risks directly from measurements of waterborne concentrations of selenium, a powerful risk assessment and risk monitoring tool used extensively and successfully by resource managers in the San Joaquin Valley since 1994. Presently no systematically matched water and egg data are available for stilts nesting at and near the Salton Sea. However, with minimal effort (3 years) enough data could be collected to provide site-validated risk assessment and monitoring tools for selenium comparable to those now existing for the San Joaquin Valley.

Justification: Agricultural drainage water from the Coachella, Imperial, and Mexicali Valleys is highly seleniferous (containing up to 360 ug/L selenium) and will remain so for the foreseeable future. Substantive potential for selenium poisoning of birds will exist for off-stream wetlands (constructed or natural), off-stream impoundments, within-sea diked impoundments, and at the Salton Sea proper. Consequently, it is essential to develop precise quantitative tools (predictive equations) for risk assessment and monitoring that are fully validated for site applicability.

Objectives:

1. To conclusively determine whether San Joaquin Valley exposure-response curves for selenium exposure and egg viability are site applicable to the Salton Sea and associated wetlands.
2. To establish a site-specific bioaccumulation curve relating waterborne selenium to egg selenium for black-necked stilts nesting at the Salton Sea and associated wetlands.
3. To statistically integrate results from objectives 1 and 2 to produce precise quantitative risk assessment and monitoring tools for avian exposure to selenium at the Salton Sea and associated wetlands.

Products:
Year 1: Annual Progress Report
Year 2: Annual Progress Report
Year 3: Final Report

Anticipated Focus Of Recommendations: The results of this work will address goals IB, IIIB, and IIIC. Goal IB will be addressed because both the exposure-response curves and the water-to-egg bioaccumulation curve would be critical needs for the contaminants module of a conceptual model of ecosystem function. Goal IIIB will be addressed because the response and bioaccumulation curves would provide the predictive capability necessary to devise alternative adaptive management strategies. Goal IIIC will be addressed because the response and bioaccumulation curves will facilitate low cost monitoring of selenium risk to birds and allow precise quantitative interpretation of monitoring data (facilitating reliable adaptive management responses).

Budget/Duration:

Personnel	Principal Investigator 0.50 FTE X 3 yrs	150,000
	Principal Investigator 0.33 FTE X 3	99,000
	Principal Investigator 0.33 FTE X 3	99,000
	Principal Investigator 0.33 FTE X 3	99,000
Analytical	Se Analyses (150 samples/yr @ contract lab) X 3 yrs	75,000 ?
Equipment & Supplies	$7K/yr X 3 yrs	21,000
Miscellaneous	House/Trailer rental April-July X 3 yrs	1,800
	Refuge support access (copiers, fax, etc.) X 3 yrs	1,500
	Report preparation support (maps, photos, etc.) X 3 yrs	300

Totals:

Year 1	182,200
Year 2	182,200
Year 3	182,200
Project Total:	$546,600

Principal Contact: Dr. Joseph P. Skorupa.

C6. Evaluating Constructed Wetlands and Riparian Corridors for Nutrients Removal and Contaminant Accumulation.

Introduction and Justification: There is a proposal to link the Salton Sea and the Sea of Cortez with Bi-National Riparian Corridors along the New River and the Alamo River. Approximately 26,000 acres of green belts and wetlands are proposed for wildlife habitat while providing treatment of the waters. There is evidence that wetlands can be effective sinks for nutrients, sediments, and trace contaminants.

There are concerns with the use of wetlands for water treatment, including the effectiveness of nutrient removal, the fate of toxic trace elements and organic chemicals, and the potential for food chain transfer of contaminants. Wetlands are currently being considered for both the south and north ends of the Salton Sea to enhance wildlife habitat. Results from wetland studies in the Central Valley of California suggest that selenium concentrations as low as 2 ppb in the water can accumulate to elevated concentrations in sediments and plant materials, and adversely impact waterfowl reproduction. The biomagnification of toxic trace elements and organochlorine insecticides could affect the long term health of constructed wetlands at the Salton Sea and along the bi-national riparian corridor.

Hypothesis and Objectives: Riparian corridors and constructed wetlands are essential to the ecological health of the Salton Sea but the accumulation of contaminants within these wetlands could ultimately limit their value as high quality wildlife habitat.

Important variables that have to be studied are the mass loading and contaminant partitioning into sediments and biota; atmospheric losses; plant uptake and translocation; vegetation density, type, and harvesting frequency; water depth and residence time, and seasonal effects.

This project will be conducted at the wetlands currently under consideration at the Salton Sea. Recently, the Torrez-Martinez Desert Cahuilla Indian tribe received a start-up grant to develop a wetlands at the mouth of the Whitewater river. This research project would allow for an expansion of this wetlands project to include detailed monitoring of nutrients and contaminants in a series of controlled wetland ponds. The University of California has the full cooperation of the tribe on this project.

Experimental Design and Products: Wetland ponds will be constructed such that flows can be regulated and monitored. Ponds will be constructed at different depths and planted with various species (cattails, bulrush, and rabbitsfoot bush) that grow well in water of this quality and have shown a potential for effective treatment. Weekly monitoring of inflow and outflow water quality will be done. Water quality analysis will include electrical conductivity, pH, total suspended solids, total and dissolved organic carbon, nitrate, ammonium, total nitrogen, phosphate, selenate, selenite, and organic selenium species, sodium, calcium, magnesium, potassium, chloride, sulfate, bicarbonate, manganese, iron, heavy metals, DDT and metabolites (both dissolved and on the suspended solids), organophosphate insecticides, and methylene blue active compounds (surfactants). Vegetation and sediment sampling for total nutrient removal and contaminant concentrations will be done monthly. Selenium speciation and oxidation state in the sediments and vegetation will determined using state-of-the-art synchrotron x-ray techniques. Denitrification versus biological uptake of nitrogen will be determined using natural abundance ^{15}N isotope fractionation. Depending upon the type of vegetation and rate of growth, some of the ponds will be harvested or mowed. Flow rates and residence times will be varied based upon removal efficiency. The use of these ponds by wildlife will be monitored and birds collected for contaminant analysis. Monitoring of this site will provide base-line data for

proposed wetlands throughout the Salton basin. Construction will be completed in the first year and management and monitoring conducted for a minimum of two years following construction.

Focus: This project directly addresses Goal IIIC. This is a project that will "implement, test and monitor a management strategy" to reduce nutrient, sediment, and contaminant loading to the Salton Sea, while providing wildlife habitat.

Budget: Some of the construction costs will be covered by the current projects being built. Additional costs will include the need for replicated ponds with water control structures. Construction costs include earth moving equipment, vegetation collection and planting, water diversion structures, plumbing, flow measuring devices (weirs), valves, and water samplers. These costs will be highest in the first year but maintenance costs are expected for each year thereafter ($400,000 estimated total for 3 years; actual construction costs will have to be determined). On-site management of the ponds will be required ($50,000/year for 3 years). At the north shore site, this could be done by members of the Torrez-Martinez Indian tribe. Water, sediment, and vegetation sampling and analysis would be done. Cost estimates include labor (one post-doctoral scientist and one graduate student), transportation, supplies and expendables, publication costs, and overhead. ($130,000/year for 3 years). If this were to be done by the University of California, Riverside, the principal investigator would contribute 10% of his time to this project and all equipment in the Department of Soil and Environmental Sciences would be available for the project.

Principal Contact: Christopher Amrhein

C7. Effects of Environmental Contaminants on Reproduction by Piscivorous Birds in the Salton Sea.

Fish-eating birds have suffered significant mortalities in the recent past at the Salton Sea, mostly related to disease. However, reproductive effects, ranging from shell thinning (night-herons 1993) to total colony failure (cormorants and brown pelicans 1996), have also been documented for many of these species. Historically, eggs of piscivorous birds, top level predators, have been analyzed for various contaminants. A systematic collection of random eggs along with a comprehensive look at the reproductive success of the primary species nesting at the Salton Sea has not been accomplished. This study proposes to evaluate the effects of a suite of contaminants on reproduction by piscivorous birds in the Salton Sea. Results will be used to evaluate spatial and temporal differences in contaminant concentrations in eggs and establish a baseline to evaluate changes to the Sea.

C8. Human Exposure to Environmental Contaminants From Hunter-killed Waterfowl From the Salton Sea.

Waterfowl present at the Salton Sea during the hunting season may acquire elevated concentrations of environmental contaminants, including organochlorines, trace elements, and metals. These contaminants may pose a human health hazard if the waterfowl are consumed by people. To evaluate potential exposure of humans to contaminants in waterfowl hunted in the Salton Sea, samples will be collected at hunter-check stations from hunting areas throughout the Sea. Livers and breast tissue will be collected from willing hunters and analyzed for contaminants early and late in the hunting season to estimate accumulation of contaminants by waterfowl while at the Salton Sea. Liver concentrations will be compared with other samples collected within the Sea and elsewhere. Waterfowl consumption will be determined through hunter surveys, and residues in waterfowl breast tissue will be used to estimate health risk to humans.

C9. Title: Human Exposure to Selenium From the Salton Sea Fish.

Introduction: Levels of selenium in tissues from fish living in and near the Salton Sea have resulted in a fish advisory being posted for human consumption. Solutions for returning the sea to a viable recreational fishing location should deal with the selenium and other contaminant problems. In the meantime, pollutant levels should be monitored. During implementation, and after the solution is in place, there is the need to identify those populations who are eating fish or other animals that feed in the Salton Sea, involve these consumers in a facilitated educational process about the selenium concerns, and engage any identified exposed populations in a biomarker of exposure and effect study. In addition, an on-going fish monitoring program is needed.

Justification: Fish in the Salton Sea pose a health hazard to humans. A program needs to be put in place that will monitor the level of selenium-contamination in fish, track human consumption, and educate the public to keep potential users of the sea aware of the selenium concerns. As the lake and its inputs are remediated, it is necessary to have a program in place to identify when the lake's fish are again safe to eat.

Objectives:

1. Establish a monitoring program for selenium and other contaminants (such as DDT and other organochlorine pesticides) in tissue from fish (other animals) taken from and around the Salton Sea and consumed by humans.
2. Conduct a needs assessment to identify and survey current consumers and potential future consumers of the fish and other animals.
3. Engage current consumers in a process to educate themselves about the selenium concerns.
4. If a current consumer population is identified, engage these consumers in a selenium (and other contaminants) biomarker of exposure and effect monitoring program.

C10. Food Chain Contaminant Concentrations for Salton Sea Birds

Introduction: Birds are at the top of most food chains in the Salton Sea ecosystem. They are thus exposed to high concentrations of contaminants, particularly the organochlorine pesticides that biomagnify. Fish-eating birds are at the top of a multi-step food chain and so are exposed to the highest concentrations of these contaminants. Selenium can also bioaccumulate in prey organisms to dietary threshold levels for birds. Waterfowl, shorebirds, and fish-eating birds could all be impacted by selenium if concentrations increase in the Salton Sea ecosystem. Previous studies have identified these two contaminants as the most likely to result in impacts to birds in the Salton Sea ecosystem.

Justification: Previous studies have measured the concentrations of organochlorine pesticides and selenium in several food chain organisms in the Salton Sea ecosystem. However, these data are several years old and confirmation of these levels is desirable as the ecosystem is more comprehensively characterized. Other research teams will be collecting birds for food habit studies. These collections will make available prey items for chemical analysis. Bird tissues will also be collected for chemical analysis to relate food habits to the potential for impacts from contaminant exposure.

C11. Comparative Characterization of Dissolved Organic Carbon in the Salton Sea, its Major Tributaries, and Drainwater (see PE 8)

Introduction: The dissolved organic carbon (DOC) concentration in the Salton Sea is very high at about 50 mg/L, yet virtually none of it has been characterized at the molecular level. A variety of possible sources exist for the Sea's DOC including: 1) autochthonous (within lake) production in the Sea's highly eutrophic environment, and 2) allochthonous (outside lake) production followed by transport to the Sea.

The buildup to such high DOC levels in the Salton Sea suggests some component of this DOC is relatively recalcitrant to biological or chemical degradation. Can this property lead to buildup of potentially hazardous levels in the Sea, or in any impounded portion of the Sea, over time?

Justification: The accumulation of dissolved solids in closed-basin lakes like the Salton Sea over time is readily apparent. However, it is also possible that nonconservative constituents, such as DOC, may build up to increasing levels over time if some portion of the DOC is not readily degradable. Depending on the physical and chemical characteristics of the macromolecules that make up the DOC in the Salton Sea, the DOC itself may be important in complexing trace elements and pesticides thereby lowering their bioavailibility in the water column. One of the most prominent features of the New River is the appearance of foam every morning at the international boundary. Although most of the additives to detergents such as optical brighteners and ionic surfactants exhibit low toxicities and are photodegradable, a group that includes the neutral surfactants are suspected to be endocrine disruptors. Are these compounds present in the Salton Sea and are their levels increasing?

Team Recommendations

Physical Environment Team Recommendations

1. All measurements and data are collected/made using documented and reproducible methods. Collection of long-term data organized/supervised by a central entity with long-term existence.

2. Appropriate and sufficient QC (Quality Control) accompanies all measurements.

3. Data ownership and availability are determined and agreed upon by all involved parties before any data are collected. Data are available to all involved entities soon after collection and are released to the public later.

4. A central coordinator is chosen through whom all press releases, press and public contacts are made, particularly during epizootic situations. The coordinator also acts as the conduit for data sharing among investigators.

5. All data are georeferenced using agreed upon standards and protocols.

6. A roster of all people involved in the project is distributed to the participants.

7. Hold annual or semi-annual internal conferences and/or distribute a newsletter to facilitate communication among parties. Establish E-mail groups for electronic conferencing.

8. Provide line item funding up front that includes all costs and salaries as well as travel for attendance at meetings such as this one and at future conferences.

9. Evaluate effects of any activities on Mexico and initiate contacts very soon with appropriate political and scientific counterparts in Mexico to discuss any remediation plans that affect Mexico. Invite more U.S. Parties such as the US Navy, BIA.

10. Acquire instrumentation, facilities, and a boat that can be used by all. (But not before funding actual investigations). Expand existing field stations if needed.

11. Evaluate impact of remediation alternatives on ground water and mineral rights on tribal lands impacted by proposed remediation alternatives.

12. Appoint a master project coordinator.

13. Agencies should make clear to Congress and stakeholders that 3 years of focused science can only reduce some of the major uncertainties about the problems of the Salton Sea, and that final solutions to the problems are unlikely to emerge from such an effort. An adaptive approach to managing the sea and conducting science is more likely to be successful. Such an effort would involve taking careful small actions, monitoring the response of the sea to those actions, assessing the mechanisms that cause the responses, and using the knowledge gained to design subsequent actions, monitoring, and assessments.

14. Agencies should assess the linkages and feedbacks among water circulation, contaminant and sediment transport, aquatic organism populations, pathogens, and bird populations in addition to managing individual studies of these ecosystem components. Knowledge of these linkages and feedbacks is probably as important as detailed knowledge of the components themselves in finding solutions to the problems of the Salton Sea.

15. Contact scientists in Israel who considered opening a connection between the Dead Sea and Mediterranean Sea in the 1980's to determine what factors led to abandoning this plan.

Biological Environment Team Recommendations

The Biological Team recommends that certain issues be brought directly to the attention of decision makers, that these issues are common to all team efforts, and must be in place for the most efficient use of funds, personnel, and equipment. Failure to adequately address these issues prior to research initiation will most likely result in an inability of research teams to provide the intended products.

1. Must have limnological baseline studies. These studies are vital to providing a base of information on which virtually all other studies of all of the teams will rely.

2. Must have GIS based habitat mapping of the Salton Sea, surrounding marshes, deltas, tributaries and drains. This issue is addressed in several studies and is partially the basis of work anticipated by the University of Redlands. Management must insure that adequate funds are made available to provide for wildlife habitat mapping either as part of the University of Redlands efforts or insure that an entity collaborates with the University to provide this product as a layer of information in the overall GIS strategy.

3. Must have research station equipped with wet/dry labs, computers, housing facilities, secure equipment storage, including major equipment needed (e.g. large boat, 30-35' with cabin). Undoubtedly cost savings can be realized if personnel associated with these research efforts can be provided with adequate office and living quarters while on assignment. Furthermore, the collaborative nature of these research efforts will be enhanced through mutual exchange of information facilitated by a central on-site facility.

4. Need to address and resolve issues surrounding data ownership, data storage, and data retrieval.

5. Need to address data czar responsible for large scale synthesis of the resulting data from all team efforts.

6. Need to have an incident command structure in place for rapid response to fish kills, algal blooms, bird die-offs, etc.

7. Need line item budget resident in a single federal agency for drawing upon by all command incident operations (travel, per diem, emergency costs) without further management intervention.

8. Any effort to develop a pilot marsh program should require the input of all teams regardless of team of origin.

9. Where sampling protocols overlap between and among teams, the science director must bring principal investigators together and develop cooperative sampling wherever possible and practical to achieve maximum efficiency and cost savings.

Cultural Resources Team Recommendations

We consider all of our proposals as essential, bare-bones proposals that represent the minimum required to get a handle on the cultural resources and prehistoric human ecology of the Salton Sea ecosystem. Although we present them in a "priority" order, the order really reflects the logical or linear nature of the cultural resource work that is necessary. All of these proposals are "Must Haves."

1. Coordinate between Cultural Team and Biological Team on a protocol for field identification and coding of habitat types and soil types. This includes the wetlands and uplands in and around the Sea.

2. Coordinate between Cultural Resources Team and Physical Team on the protocols for collection of cores designed to sample sediments and other environmental constituents that span the Holocene.

3. It is clear that considerable taxpayer funds will be necessary to conduct research on the Salton Sea ecosystem as well as the engineering fixes. We owe it to the local public and all Americans to present the results of our research in a nontechnical fashion. We propose that any facility destined to house researchers might also double as a visitor or/and interpretive center that displays research results and processes in an engaging fashion. Also, please consider a program to distill research results into interpretive pamphlets or other media accessible to a nontechnical audience.

4. Any future "Analyses Matrices" prepared by the Salton Sea Authority or other entity should include cultural resources as a variable to measure.

5. Please note the Appendices to our proposals.

Pathogens and Diseases Team Recommendations

1. Decision makers/stakeholders should recognize that some of the disease problems at the Salton Sea may not be solved by any of the engineering projects; in those cases, cause-specific disease management methods will be needed.

2. A coordinated event investigation capability should be incorporated into the existing Incident Command system, with dedicated resources and vehicles, so that essential epidemiologic investigations can take place simultaneous to bird carcass pickup. Addi-

tional sources of funding should be explored, including FEMA (Federal Emergency Management Agency).

3. Since pump in/pump out alternatives are being considered, the potential impact of the exchange of biological materials (microbial pathogens, algae, etc.) between the Sea of Cortez and the Salton Sea needs to be assessed first.

4. A comprehensive multi-agency approach to study and manage the Salton Sea ecosystem will require a research coordinating team with representatives from all disciplines and stakeholders (e.g. SSICC - Salton Sea Interagency Coordinating Committee) that will direct and integrate research activities at the Salton Sea, resolve issues related to data sharing, retrieval, storage and proprietary concerns, and that will develop standard protocols for data collection. A Public Information Officer should be included to ensure consistent information is provided to the press and public. Also required is an on-site research facility equipped with wet and dry labs, vehicles, boats, etc.

5. The management team is encouraged to take measures necessary to assure that this Salton Sea ecosystem initiative is elevated within respective information needs processes and priorities of the participating agencies and stakeholders (e.g. The biological information needs, or BIN process within USGS). In addition, agencies and institutions that are currently conducting activities on the Salton Sea independent of this initiative should be encouraged to integrate our research objectives and priorities with their projects to the extent possible.

Contaminants Team Recommendations

The Contaminants team recognizes the expertise that currently exists in the North American Water Quality Assessment (NAWQA) program, particularly relative to endocrine disruption in fish. We recommend that the Salton Sea be elevated to a high priority site in that program.

1. The University of Redlands should compare this list of proposals to the bibliography they have developed to determine if there are overlaps with previously conducted studies.

2. The bibliography developed by the University of Redlands needs to be annotated and provide access to the literature being cited.

3. Research scientists working on studies at the Salton Sea need access to the GIS database being established for the Salton Sea by the University of Redlands to interpret their data in the context of the entire ecosystem. This access should be defined in a Memorandum of Understanding (MOU) or similar agreement between the federal agencies and the University.

4. Agency leaders, the science coordinator, and others need to continue to identify other Federal, state, and local agencies, universities, and private entities that have programs that may have information pertinent to the Salton Sea research proposals provided herein.

5. There needs to be a research facility at the Salton Sea that includes a differential Global Positioning System (GPS) for standardization of sample site location. This facility would function as a focal point of research by a diverse group of researchers and greatly facilitate coordination among those groups.

6. Although the Contaminants team was not able to address this in a proposal, management needs to consider an assessment of contaminant distribution in important wetlands in the Salton Sea ecosystem outside the Sea itself. These are important areas for wildlife where exposures are possible, but they have not received adequate evaluation to date.

7. Information is needed on the characteristics of the Sea of Cortez if a pump in/pump out alternative is pursued. There could be effects if waters from the Sea of Cortez are mixed with the Salton Sea. At a minimum we need:

- salt composition
- biota that may be introduced into the Salton Sea
- contaminants/pollutants
- activities/facilities which may be a source of contaminants to the Salton Sea

8. Decision makers need also to consider what may be introduced into the Sea of Cortez from the Salton Sea, both biotically and chemically, and what the impacts of those introductions may be on the Sea of Cortez.

Appendix A

Participating Agencies and Universities Represented at the Saving the Salton Sea Workshop

Federal Agencies

1. Fish and Wildlife Service
2. Bureau of Reclamation
3. Environmental Protection Agency
4. Geological Survey (Water Resources and Biological Resources Divisions)
5. Army Corps of Engineers
6. Agency for Toxic Substances and Disease Registry (USDA)
7. Bureau of Land Management
8. Torrez-Martinez Desert Cahuilla Indians

State Agencies

1. California Department of Fish and Game
2. California Public Health Department
3. California State Parks
4. State of California Office of Historic Preservation
5. California Regional Water Quality Board

Local Government Agencies and Offices

1. Imperial Irrigation District
2. Coachella Valley Water District
3. Imperial County Department of Public Health Services
4. Riverside County Environmental Health

Universities

1. University of Redlands
2. University of California, Davis & Riverside
3. Scripps Institute of Oceanography
4. San Diego State University

Appendix B

Deterioration of the Salton Sea Ecosystem

(10 Year Chronology of Events and Actions Taken)

1987 - Early documentation of avian deaths in the Salton Sea. Staff of the Salton Sea National Wildlife Refuge manage the incidents in cooperation with California Department of Fish and Game (CDF&G) employees.

* The National Wildlife Health Center diagnoses the causes of the avian deaths.

1988 - The Salton Sea Task Force is initiated with the encouragement and sponsorship of the California Department of Fish and Game in response to concern over the decline of the fishery resource. The task force members included all Salton Sea stakeholders and was successful in focusing attention on the problems of the sea.

1989-1991- Sporadic avian deaths continue to be documented in the Salton Sea. Staff of the Salton Sea National Wildlife Refuge manage the incidents in cooperation with CDF&G employees.

1992 -.150,000 eared grebes and ruddy ducks are found dead on the Salton Sea. National media attention is focused on the die-off. Fish and Wildlife Service (Service) personnel managed the dilemma. The majority of the grebe mortality is undetermined - avian cholera accounted for a portion of the mortality.

(October) The United States Congress through Public Law 102-575 Title XI Sec. 1101 authorizes 10 million dollars to the Secretary of Interior for the Bureau of Reclamation (BOR) 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 in inland water bodies. The legislation further provides that such research shall include testing an enhanced evaporation system for treatment of saline waters, and studies regarding in-water segregation of saline waters and of dilution from other sources. The project shall be located in the area of the Salton Sea of Southern California

1993- Riverside and Imperial Counties, California, the Imperial Irrigation District and the Coachella Valley Water district entered into a Joint Powers Agreement creating a public agency known as the Salton Sea Authority (Authority). The Authority was created to coordinate actions relating to improvement of water quality, stabilization of water elevation, enhancement of recreation and economic development potential of the Salton Sea and other beneficial uses. The Salton Sea Authority replaced the Salton Sea Task Force, which was formed during 1988.

1994 -The Authority received a grant from the U. S Environmental Protection Agency Clean Lakes Program (Grant) to conduct environmental and economic analyses of salinity and elevation options for the Salton Sea. The Authority begins work assessing the needs of the Salton Sea in relation to salinity and elevation.

* 2,500 dead birds, mostly eared grebes are removed and the total water bird die-off is estimated at 20,000; the cause of most of the mortality is from unknown causes although avian cholera accounted for some deaths. Service staff manage the dilemma.

1995 (December) - Under the auspices of the Grant ,The "Salton Sea Management Project Draft Evaluation of Salinity and Elevation Management Alternatives" (Management Alternatives) is completed and released for public review by the Salton Sea Authority.

1996 (April) - Fish and Wildlife Service (Carlsbad Ecological Services Office) provides comments on the Management Alternatives. Several biological issues are identified and permitting guidance is presented in the Service response.

(August) - An unprecedented Avian botulism episode occurs killing over 14, 000 birds to include more than 1,400 endangered brown pelicans.

* Thousands of tilapia fish die, potential causes are identified as Vibrio infections and botulism

* The National Wildlife Health Center identifies sick fish as being the source of botulism toxin affecting pelicans and other fish eating birds.

(September) - Service coordinates a meeting with Salton Sea Stakeholders to discuss water quality and availability issues as well as biological concerns and bird mortalities.

*Congressmen George E. Brown and George Miller request the Service to keep them informed about how the Service will address the issue.

* The Service Pacific Region requests an emergency appropriation from the headquarters office to help pay for the resources needed to deal with the catastrophe.

(October) - The Biological Resources Division of the U S Geological Survey (BRD), with support of the Fish and Wildlife Service, brought together research scientists with appropriate scientific expertise to evaluate mortality events occurring at the Salton Sea and field managers who have responsibility for land and resources management. The main objective for the workshop participants was to develop an interagency ecosystem approach proposal to address fish and wildlife health issues on the Salton Sea. The product from the workgroup is entitled the Salton Sea Ecosystem Initiative.

(December) -The Service coordinates second stakeholders meeting to discuss the health of the Salton Sea ecosystem.

1997 (February) - The Service responds to Congressmen George Brown and George Miller's September 1996 request for information.

* The Service Deputy Pacific Regional Director attends Salton Sea Authority Meeting to continue dialogue on a proposed diking solution to correct salinity and water elevations.

(April 15) An interagency team chaired by the Service meet to develop a process on how to adequately address the biological concerns associated with an engineering fix to the Salton Sea Ecosystem. The Service and BRD representatives are on the team.

(April -16) Team findings are presented to stakeholders at a meeting in Ontario, CA. The stakeholders support the findings of the team which include conducting a workshop with top level scientists to decide how to proceed with a natural resource impact analysis of any proposed engineering fixes to correct the deteriorating Salton Sea Ecosystem.

(April 23) Planning is initiated to conduct a Save the Salton Sea Needs Assessment Workshop. The "Salton Sea Ecosystem Initiative" is used as a guide for framing the purpose and goals of the workshop.

(May) First case of NewCastles disease occurs in double crested cormorants west of the Rocky Mountains at the Salton Sea, killing over 90 percent of the juveniles in a single nesting colony.

* Over 2,400 grebes die of unknown causes, with signs similar to the 1992 and 1994 events.

* Thousands of tilapia fish die, presumably, from Vibrio infections.

(June) The Service assigns an employee to work full time as the science coordinator for the Imperial and Coachella Valley California.

(July) Several media contacts occur between the service and area, regional and national reporters.

* The Service espouses primary roles in dealing with the Salton Sea

1. Keeping the band-aids on the ecosystem while long-term solutions are being developed.
2. Coordinating Research efforts to develop a GIS Salton Sea ecosystem model and aiding in the development of long-term solutions.
3. Coordinate and as appropriate conduct long-term monitoring of any implemented engineering solutions to correct the deteriorating Salton Sea ecosystem.

* Partners from the Salton Sea area pool their resources and construct an onsite wildlife field hospital.

(August 4-8) Salton Sea needs assessment workshop conducted in cooperation with the Fish and Wildlife Service, Bureau of Reclamation and California Department of Fish and Game to develop a process to address the natural and cultural resource issues, and research and investigation needs for any proposed engineering solutions to repair the Salton Sea Ecosystem. Representatives of 21 Federal, state and local agencies, universities and government offices participated.

Appendix C

Salton Sea Workshop Participants

(Team Leaders are the first entry on each team)

Biological Environment Team

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Appendix D

List of Research Proposal Titles

PE1A. Extension of Circulation Model Applied by UC Davis to Estimate Sediment Transport in the Salton Sea.

PE 1B. Limnological Characterization of the Salton Sea.

PE3. Development of a Nutrient Budget and Eutrophication Evaluation for the Salton Sea

PE4A. Development of Hydrologic and Salt Model for Salton Sea.

PE4B. Development of Water-Quality Models for the Salton Sea.

PE5. Salton Sea Sediment Characterization and Geologic Hazards Evaluation.

PE6. Resuspension and transport of sediment in the shallows of the Salton Sea.

PE7. Use of Remote Sensing to Identify and or Track Water Quality Changes in the Salton Sea.

PE8. Comparative Characterization of Dissolved Organic Carbon in the Salton Sea, its Major Tributaries, and Drainwater.

PE 9. Atmospheric Entrainment of Salt and Dust from the Dry Lakebed Exposed by a Receding Salton Sea Shoreline

BE 1. Algal and Invertebrate Populations of the Salton Sea in Relation to Physical and Chemical Limnology.

BE 2. Fish Ecology of the Salton Sea.

BE 3. Trends and Ecology of Birds on the Salton Sea

BE4. Determination of Wetland Habitat Types, Functions, Importance and Value to the Salton Sea Ecosystem and Potential for Restoration and Enhancement.

BE5. Research Protocols:

BE6. Habitat Base Mapping /GIS:

CR1. Cultural Resources Overview of Existing Information on the Archaeology, Prehistory, and History of the Salton Sea Watershed.

CR2. Native American Consultation

CR3. Geographic Information Systems (GIS) Layer and Model of Prehistoric Human Ecology and Cultural Resource Site Distributions in the Salton Sea Region.

CR4. Cultural Resource Field Inventory for the Salton Sea Study Area.

CR5. Reconstruction of the Holocene Environmental Record of the Salton Basin and Implications for Prehistoric Human Ecology.

PD1. Disease-causing Agents for Fish, Wildlife, and Humans in the Salton Sea Ecosystem: a Systematic Monitoring and Health Assessment Program.

PD2. Avian Botulism in the Salton Sea: The Role of Fish and Other Environmental Factors.

PD3. Algal Biotoxins in Fish and Wildlife Mortalities.

PD4. Salinity, Contaminants, and Disease Interactions in Fish and Birds.

PD5. Cause, Impact, and Contributing Environmental Factors of Massive Mortality in Eared Grebes on the Salton Sea, and Management Recommendations for Minimizing Losses.

PD5.5. Newcastle Disease Die-off of Double-crested Cormorants at the Salton Sea: Impact, Spread, and Potential Risk to Wild Birds, Domestic Poultry and Humans.

C1A. Effects of Selected Water Quality Variables and Environmental Contaminants on Fish Mortalities in the Salton Sea: A Field and Laboratory Assessment.

C1B. Selenium Distribution and Toxicity in Total Organic Carbon and Fine Particles in Bottom Sediments of the Salton Sea: Subtopic - DDE Distribution.

C3. Title: Immunological Competence and Contaminant Levels in Fish and Birds From the Salton Sea.

C4. Conceptual Site Model of Historic, Current and Future Contaminant Inputs and Fates in the Salton Sea.

C5A. Toxicity Assessment of Salt Precipitates from Salton Sea Associated Waters.

C5B. Developing Site-Validated Response Curves for Selenium-Induced Avian Reproductive Toxicity.

C6. Evaluating Constructed Wetlands and Riparian Corridors for Nutrients Removal and Contaminant Accumulation.

C7. Effects of Environmental Contaminants on Reproduction by Piscivorous Birds in the Salton Sea.

C8. Human Exposure to Environmental Contaminants From Hunter-killed Waterfowl From the Salton Sea.

C9. Title: Human Exposure to Selenium From the Salton Sea Fish.

C10. Food Chain Contaminant Concentrations for Salton Sea Birds

C11. Comparative Characterization of Dissolved Organic Carbon in the Salton Sea, its Major Tributaries, and Drainwater (see PE 8)

Appendix E

Definition of Geographic Terms.

For the purposes of the cultural resource proposal of the *Saving the Salton Sea Workshop* the following terms “Salton Sea Watershed “ and “Salton Sea Study Area” have specific geographic meanings. The proposals call for cultural resource work in both regions.

Salton Sea Watershed

Proposals 1, 2, and 5 will cover the Salton Sea Watershed.

The Salton Sea Watershed is that large area located between the San Bernardino and San Jacinto Mountains from Beacon, California east, bordered on the east by the Little San Bernardino and Chocolate Mountains to the Fort Yuma Indian Reservation, and Yuma, Arizona, encompassing the East Cocopah Indian Reservation, extending Southwest through San Louis Rio Colorado, skirting the west edge of the Desierto de Altar to Luis Encinos Johnson where it turns west to the Sierra Juarez and proceeds north along the Yuha Desert, west of Ocotillo, California to the east edge of the Coyote Mountains where it continues north along the east side of Vallecito Mountains, along Pinto Ridge up the west and north sides of Borrego Valley, around Coyote Mountain to the west side of the Santa Rosa Mountains which it proceeds south for a short distance and once again continues north to include the Indio Mountains, Cahuilla Hills, Palm Canyon and the east edge of the San Jacinto Range from the Whitewater River east and south, including the Coachella, Imperial and Mexicali Valleys, along with the lands adjacent to the Laguana Salada.

Salton Sea Study Area

The Salton Sea Study Area is a smaller region that will be the focus of proposals CR3 and 4. The Salton Sea Study Area is divided into two regions.

The first study area is located between Highway 86 on the west, Highway 111 on the east, Avenue 70 on the north, and the southern boundary, which includes Obsidian Butte. The south boundary is a strip one mile wide extending from the southwest corner of the Salton Sea at Highway 86, just west of the U.S. Fish and Wildlife Refuge, Township 13 South, Range 12 East, Section 3 and extending east to Highway 111 in Township 10 South, Range 14 East, Section 31.

The second study area includes strips of land at key geographic features, including: Alamo River, New River, Laguna Salada, Whitewater, San Sebastian/San Felipe, Wonderstone, and Mammoth Washes, Kane Springs, other washes and springs, main canals, drains, and roads.

Appendix F

Tribal and Other Indigenous Groups in the Salton Sea Watershed

Southern California Tribes

Augustine
Barona
Cabazon
Cahuilla
Campo
Cuyapaipe
Inaja & Cosmit
Jamul Indian Village
La Jolla Band of Luiseno Indians
La Posta
Los Coyotes
Manzanita
Mesa Grande
Morongo
Pala
Pauma & Yuima
Pechanga
Ramona
Rincon
San Manuel
San Pasqual
Santa Rosa
Santa Ynez
Santa Ysabel
Soboba
Sycuan
Torres-Martinez Desert Cahuilla Indians
Twenty-nine Palms
Viejas

Arizona Tribes

Chemehuevi
Colorado River
Fort Mojave
Cocopah
Quechan
Tohono O'odham
Ak Chin Indians
Gila River Indians
Havasupai
Hualapai

Northern Mexico, Baja Tribes

La Jolla
Guadalupe
Chapala
Los Encinas
Calamajue
San Ignacio
Kamia
Cuyapaipe
Cocopah
Sahatapa
Willya
Los Flores
La Puerta
Portrero
Kupa
La Palma

Appendix G

A Proposal for Expeditious Permit Review

Title: Integration of the Corps' Clean Water Act Section 404 Permitting Process with the Department of the Interior's Environmental Review Process for the Salton Sea Project.

Introduction: The Salton Sea Authority's proposed diking alternative project for the Salton Sea will be funded, in part, with Federal funds through the Department of the Interior, requiring that an Environmental Impact Statement (EIS) and a Record of Decision (ROD) be approved. The project will also require compliance with the Clean Water Act and an individual Section 404 permit. In order to insure an expeditious resolution of both processes, the U.S. Army Corps of Engineers (Corps) is proposing that the processes be integrated. The first step in the integration is this proposal to develop an interagency Memorandum of Understanding, including a milestone schedule, and the coordination to develop the needed interagency process.

Justification: To date, the Corps has not been involved in the Alternatives Analysis of the Salton Sea Authority's selection of the diking alternative. This should be immediately rectified, to insure that the project be in compliance with Section 404 of the Clean Water Act. In order to resolve this, the Corps is proposing to integrate the 404 process with the National Environmental Policy Act (NEPA) process, to bring the proposed project into compliance with Section 404 of the Clean Water Act, expeditiously.

Objectives:

1. To develop a Memorandum of Understanding (MOU) among the Department of the Interior, the Corps, and the Environmental Protection Agency (EPA) to integrate the process for reviewing project alternatives.
2. To develop a schedule with strict milestones to insure that the EIS and Corps permit decision are both approved by the end of 1999.
3. To coordinate the process with all of the involved agencies.

Products:

Year 1: Develop a Memorandum of Understanding among the Corps, the Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service, and the Bureau of Reclamation integrating the 404 process with the NEPA process. Develop a joint NEPA/404 purpose and need, a basic and overall project purpose statement, a scope of alternatives analysis, and a 404 milestone schedule integrated with the NEPA, EIS milestone schedule.

Year 2: Initiate and complete a jurisdictional determination as to an environmental baseline of existing Waters of the United States, including jurisdictional wetlands and other waters of the United States. Develop a complete scope of analysis of all alternatives with impacts that meet the overall project purpose. Review scope of alternatives and eliminate alternatives that are impractical based on cost, logistics, and/or technology. Prepare initial draft 404(b)(1) Alternatives Analysis.

Year 3: Obtain agreement on the Least Environmentally Damaging Practicable Alternative, including mitigation, and issue the Public Notice. Make decision on 404 permit in conjunction with signing of Final EIS and ROD.

Anticipated Focus of Recommendations: Proceeding with this proposal would insure smooth, expeditious resolution of the two Federal environmental processes in tandem, an essential step in fulfilling Goal III.

Budget Duration:

Year 1 - $10,000 for Corps staff time, to develop the MOU.

Year 2 - $10,000 for Corps staff time to perform jurisdictional determination, hold meetings within the milestone schedule, review alternatives, and assist development of the alternatives analysis.

Year 3 - $0

Principal Contacts: Robert Smith and Terry Dean.