Evaluation of a Proposal for Conversion of the Salton Sea Ecosystem

Analysis of a project proposed by the Pacific Institute for Studies in Development, Environment and Security
Oakland, California, October 2001

By participants in workshops coordinated by the U.S.D.I. Salton Sea Science Office and held during December 2001 and January 2002
Riverside, San Diego and Indian Wells, California

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Evaluation of Benefits Proposed by Pacific Institute

EXECUTIVE SUMMARY

Nearly 30 scientists and engineers were asked to assist in an evaluation of a proposal by the Pacific Institute. The origin of the proposal must be put into proper context to understand the total review contained herein. The proposal calls only for creation of freshwater (10-15 ft maximum depth, 3-4 g/L salinity) impoundments at the northern (2010 ac) and southern (26,800 ac) ends of the Salton Sea, with their surface elevations stabilized at -230 ft. Outflows from these impoundments would flow into a residual Salton Sea. This specific proposal was predicated on the assumption that a major transfer of water from the Imperial Valley to San Diego County and the Coachella Valley would take place, thus causing the level of the residual Salton Sea to drop significantly. The proposal was developed in an attempt to salvage many of the components of the existing Salton Sea Ecosystem recognizing that these components would likely cease to exist with the advent of a water transfer. This important point should not be lost during the reading of this document. ***This review did not attempt to separate out those effects due to a water transfer from those due to development of freshwater impoundments. Thus this document contains review and comment on ecosystem effects from both a transfer of water resulting in a drop in water levels of the Salton Sea, and the development of freshwater wetlands as proposed by the Pacific Institute.*** This review document delineates these effects in most cases by using the terms “Residual Sea” for the lake level with reduced water inflows, and “impoundments” for the freshwater areas proposed by the Pacific Institute.

The overall review indicated clearly that this proposal is very unsatisfactory. The Science Office views this as an iterative process of which this is the first step. We expect further iterations of this review process and interactions with these expert teams to produce a more workable proposal and greatly refined cost estimates. However, the consensus view of the workshop participants was that even with substantial modifications, the proposal would result in freshwater impoundments incapable of supporting the diversity and magnitude of biological resources supported by the current Salton Sea.

On the assumption that impoundment dams would be completed in 2007 and that total inflows to the Salton Sea basin would soon drop to 1.0 maf/yr and remain at that level indefinitely, the residual Sea would drop about 30 ft, stabilizing at an elevation of -257 ft and an area of about 147,000 ac (37 percent smaller than the present Sea) by 2025. The salinity of this residual Sea would increase indefinitely, reaching 100 g/L by 2015 and 200 g/L just prior to 2030. By 2025 about 57,200 ac of exposed lake bottom would exist around the margins of the Sea and between it and the impoundment dams due to water level drops. Artificial wetlands along the New and Alamo rivers are proposed for removal of sediments, pathogens, pesticides, nutrients and other contaminants from flows prior to their entry into the southern freshwater impoundment. In order to remove >90 percent of the sediment loads of these rivers, about 9000 ac of these treatment wetlands would be needed. This document does not attempt a rigorous evaluation how well these treatment wetlands might accomplish these functions.

Impoundment dams would have to be designed for seismic and hydraulic stability and might cost about $1,040,000,000. Treatment wetlands might cost up to $450,000,000 Annual maintenance and operation costs of this complex of systems were not estimated but clearly would be in the millions of dollars.

The impoundments would be less well mixed than are the corresponding areas of the Sea at present. They might be more subject to periods of anoxia and would experience greater temperature extremes. Impoundments would be isolated, however, from the consequences of summer overturn events that generate anoxic, reducing conditions in surface waters that then are occasionally carried into near shore zones by currents.

The ecological and recreational values of the impoundments would be determined primarily by salinity and contaminant levels and the fact that they would represent only about 12 percent of the area of the present Sea. As freshwater systems, they would quickly be colonized by large numbers of freshwater plants, invertebrates, and fish, with carp, tilapia, catfish, threadfin shad, and possibly largemouth bass dominating among the latter. These fish would be much more heavily infested with parasites than are present Salton Sea fish. As the impoundments would effectively be sluggish extensions of the rivers that feed them, they would have contaminant levels similar to those of the rivers. Selenium levels in impoundment waters would be roughly six times those in the present Sea. Fish and invertebrates in impoundments thus would be likely also to have much higher selenium concentrations than do fish and invertebrates of the present Salton Sea. These would pose significant increased risk to both sport fisherman and to fish- and invertebrate-eating birds, such as pelicans, grebes, ducks and shorebirds. The fish-eating birds would have fewer but more contaminated fish available to them than they do now.

Even after flowing through treatment wetlands, inflow waters would have higher concentrations of microbial pathogens than does the present Salton Sea. These would further inhibit or advise against various types of recreational use of the impoundments. Dense aquatic and terrestrial vegetation would colonize possibly 50 miles of now barren shoreline within the impoundments. This would serve as excellent habitat for certain birds but also for mosquitoes, including *Culex tarsalis*. The latter is a known vector in the region of western equine encephalomyelitis, St. Louis encephalitis, and, potentially, West Nile encephalitis, as soon as that gets to California from eastern U.S. The 9000 ac of treatment wetlands could also serve as major new mosquito-producing habitat and might also be sites of selenium concentration in the food web. Other biting insects (horseflies, biting midges) would also likely increase in abundance.

The residual Salton Sea would soon go fishless as salinity rose. The current aquatic invertebrate assemblage would also die out. For some years afterward, high densities of brine shrimp, brine flies and water boatmen would be found here and serve to attract large numbers of invertebrate-eating waterbirds. However, with increasing salinity the production of even such salinity tolerant species drops rapidly. A residual Salton Sea at a salinity of 200 g/L would be as barren of birds as is most of The Great Salt Lake of Utah. Selenium levels in these salinity tolerant invertebrates would also be much higher than those in invertebrates of the present Salton Sea.

Though under the project proposed by the Pacific Institute the ecosystems in the region would initially continue to be as attractive to birdwatchers as the present ones, by most other criteria they probably would be less valuable for wildlife or human recreation and have negative economic repercussions for the region. Fishing, boating, swimming, and camping at the Sea would be less attractive options than they are now. Increased particulate matter air pollution would occur, might affect human health over a large region, and might affect agriculture as well.

Scope and Purpose of This Document

This document summarizes the consensus opinion of nearly thirty scientists and engineers familiar with the Salton Sea as to the properties the system proposed by the Pacific Institute would be likely to have.

This system would be a multi-component one consisting of large freshwater impoundments at the northern and southern ends of the Sea, extensive treatment wetlands along the courses of the New and Alamo rivers, a large area of exposed lake bottom, and a residual Salton Sea in the center of the basin that would be much saltier and smaller than the present one.

We describe the expected salient features of these systems, trying to be clear about where uncertainties lie.

We focus especially on predicting the general nature of the impoundment ecosystems, which would be more complex than the highly saline residual Salton Sea that would still occupy most of the lakebed.

We do not attempt many predictions about particular species, fine spatial and temporal variations in the system properties. We also do not attempt to characterize the transitional states the system would pass through during the years required for dam construction and during the several months required for the impoundments to reach initial equilibrium salinity levels after dam closure.

We omit value judgments about the overall desirability of the proposed project. Weighing of the pluses and minuses requires attaching of a value to each one of them that is primarily a subjective, non-scientific process. Project desirability would also depend on the political and engineering feasibility of alternative possibilities, and we do not analyze those here.

Workshop and Evaluation Process

The possibility of creating freshwater impoundments with abundant fish at the northern and southern ends of the Sea and letting the main body of the Sea become highly saline and fishless was suggested by the Pacific Institute in comments it submitted on the draft EIS/EIR for the Salton Sea Restoration Project. This idea captured the imagination of some people concerned with the future of the Sea and with the need for California to finalize various agreements relating to water transfers and allocation of Colorado River water. The project seemed to represent an engineering option with low annual operating costs once built, did not depend on maintenance of current inflows to the Sea, and postulated some positive ecological aspects. Questions were soon put to relevant authorities – the Salton Sea Authority (SSA) and the USDI Salton Sea Science Office (SSSO) – as to the desirability and feasibility of this option.

To facilitate a scientific review, the Pacific Institute prepared a 7-page, prospectus on the features such impoundments might have and how the converted systems might at least partially meet the stated objectives of the Salton Sea Restoration Project as articulated by the SSA. The purpose of this Pacific Institute prospectus was to provide a concrete, if preliminary, proposal that could be evaluated by scientists and engineers.

In November 2001, the SSSO invited nearly 70 experts to carryout this evaluation, and organized four 1-day workshops covering the topics of hydrology, water quality, biology, and disease and contaminants. Given the short notice and being just before a major holiday, about 30 scientists and engineers convened on December 17 and 19, 2001 in San Diego and Riverside. The deliberations and conclusions of each group were recorded by a focus group member who also agreed to present the group findings at a later public workshop. Participants are listed in Appendix A.

On January 8, 2002, a public workshop on the Pacific Institute proposal was held at the Miramonte Resort in Indian Wells. At this workshop the Pacific Institute proposal was summarized by Michael Cohen of the Pacific Institute. Focus group members from each subject matter workshops presented the conclusions reached by their group and additional presentations were made on engineering and design considerations, on hydrologic modeling, and on the probable dimensions of the proposed impoundments, the residual Sea, and the lake bottom that would be exposed. The presenters collectively functioned as a panel. Following presentations the panel discussed among themselves and reached consensus on major issues that had been raised. Conclusions and commentary were recorded on flip charts in a facilitated discussion and in personal notes of the person assigned to write up the present document. All presenters also provided handouts of text, notes, and graphics used in their presentations. The agenda and procedural guidelines for this general workshop are given in Appendices B and C, respectively.

The Present Salton Sea

The most salient features of the Sea as it now exists are as follows. Its surface lies at an elevation of about -228 ft. Its area is 231,973 ac (362 sq miles), its volume is 7,391,803 ac-ft, and its maximum depth is 50 ft. It is saline (41-44 g/L, depending on season), rich in nutrients (ca. 5 mg N/L and 0.1 mg P/L), and with dense phytoplankton populations year round. Midlake mean water column temperature ranges from about 13˚C in January to about 32˚C in summer, though shallow near shore waters commonly go to >40˚C. During the warmer half of year, full mixing is only occasional and bottom waters are usually anoxic. Occasionally large overturn events render the whole water column anoxic, and there is heavy mortality of algae, invertebrates and fish. Fish populations vary from year to year and seem to be in a severely stressed state, though corvina up to 20 lb and tilapia up to 3 lb are still being caught. Millions of water birds use the Sea every year as a wintering area or a stopover point during their migrations. It is the most important habitat for such birds in southwestern United States. Large mortalities of certain species - pelicans, grebes, ducks, and cormorants - have occurred in recent years due to avian botulism, avian cholera, Newcastle disease, and still unidentified factors. The Salton Sea continues to be heavily used for human recreation. In decreasing order of popularity, principal activities probably would be bird watching and nature study, fishing and boating, and camping.

Pacific Institute Proposal

This is attached as Appendix D. Some of the estimates given below were developed after the original proposal was presented. Time prevented us from considering all possible alternatives for implementing the proposal. In order to standardize the assumptions used by all focus groups, several assumptions were made as to how the impoundments would be built and function. Although the proposals suggest building dikes at two different elevations, with or without treatment wetlands, *we based our review on the assumptions that a dike would be built at the –245 foot elevation at the south end, at the –240 elevation at the north end, and the process would include treatment wetlands*. The proposal did not specify where the dikes would tie into the shoreline, thus the mapping group made this decision and it is reflected in the maps used for discussion. Similarly, the proposal did not specify where and to what extent the dikes would have discharge points for the overflow water going to the residual Sea. The basic assumption was made by the hydrology group, and carried into the other group discussions, that there would be a discharge point near landfall at both ends of the dike and somewhere along the dike there would be a spillway capable of withstanding a 100 flood event.

The essence of the proposal is to build dams that will impound low salinity waters in the northernmost and southernmost portions of the Sea, recognizing that with a water transfer the main body of the lake will become, eventually, a highly saline, fishless lake. Water level in both impoundments would be maintained at the -230 ft level, about two feet lower than the current elevation of the Sea.

At the northern end the dam would be constructed along the -240 ft elevational contour (current water depth of about 12 ft), and at the southern end it would be constructed along either the -240 ft or -245 ft (current depth of about 17 ft) contour. It is proposed that the water level in both impoundments would be maintained at about -230 ft.

The northern impoundment would have a surface area of about 2010 ac and a volume of about 9000 ac-ft. These represent about 0.87 percent of the surface area and 0.12 percent of the volume of the current Sea (at -228 ft), respectively. The northern impoundment would be fed by the Whitewater River and nearby agricultural drains.

The southern impoundment with a dike at –245 ft would have a surface area of 26,800 ac and a volume of 181,000 ac-ft. These would represent about 12 percent of the surface area and 2.4 percent of the volume of the present Sea (at -228 ft). With the dike at –240 ft, this impoundment would have a surface area of 10,500 ac and a volume of 47,000 ac-ft. These would represent about 4.5 percent of the surface area and 0.64 percent of the volume of the current Sea at –228 ft, respectively. The southern impoundment would be fed by the New and Alamo rivers and nearby agricultural drains.

To improve water quality of the inflows to the southern impoundment, it is proposed that artificial wetlands be created along the New and Alamo rivers. These could function to remove silt, nutrients, pathogens, pesticides and selenium to varying degrees from the rivers. They would also function as wildlife habitat. Approximately 9000 ac of such wetlands would be needed to meet the objective of removing >90 percent of the silt load.

Outflows from the freshwater impoundments would be carried by channels, lined or unlined, to the main body of the Sea. Initially this would be at the same elevation (-230 ft) as the impoundment surfaces. If total inflows to the basin are reduced to 1.0 maf/yr and no less, this main body of the Sea would eventually stabilize at an elevation of about -257 ft and its salinity would increase indefinitely.

Drop of the residual Sea's elevation to -257 ft would leave exposed about 57,200 ac (89 sq miles) of the present lakebed of the Sea. This would include broad strips a few miles wide between the bases of the dams and the margins of the shrunken Sea and about 8300 ac between the present margins of the Sea at -228 ft and the impoundment shorelines stabilized at -230 ft.

According to the Pacific Institute, the proposed project would offer the following benefits:

1. Compatible with water re-allocation efforts
2. Sustainable over the long term

3. Increases diversity of habitats at the Salton Sea
4. Preserves and enhances fisheries in impounded areas
5. Promotes increased recreational and economic development opportunities
6. Compatible with other off-site actions

Comparison Systems

The project proposed by the Pacific Institute ideally would be evaluated against specific alternative possibilities and the ecosystems they would produce. However, possible alternatives are numerous, most have not been put forward in any detail, and consideration of all salient variables under the various alternative scenarios would require more time and information than is available.

Nevertheless, it is useful to briefly list some of the major alternative scenarios against which this proposal can be evaluated and that decision makers will need to consider.

These include:

1. The Sea as it has been over the last 10-20 years but with salinity and lake level stabilized or slightly reduced by one of the engineering schemes under evaluation by SSA. Because this is the state for which we now have much concrete scientific information, it is the state most readily compared with the systems proposed by the Pacific Institute. It is also the state that has been the goal of the Salton Sea Restoration Project as defined by the SSA with stakeholder input.

2. A No Action alternative that assumes no further reduction in inflows.

3. A No Action alternative that assumes inflows will soon be reduced to 1.0 maf/yr and will remain at that level for the next 74 years. Those inflow assumptions were ones used by the Bureau of Reclamation in modeling the system that would result from implementation of the Pacific Institute proposal.

4. A No Action alternative that assumes inflows will soon be reduced to 1.0 maf/yr and that, once the precedent of water transfers from the Salton Basin to the coast has been set, larger transfers and further reductions in inflow would take place over the coming decades. This alternative has received little discussion but is arguably the most realistic of the No Action alternatives.

Dams and Wetlands: Designs and Costs

The Pacific Institute proposal considered two primary options for the southern impoundment, one with the dam built along the -240 ft contour and one with it built along the –245 ft contour. There was consensus among all the evaluation teams that we should focus the evaluation on the latter option. The first option would result in a smaller, shallower impoundment that would be markedly less attractive as wildlife habitat or for fishing and other recreational activities.

Thus in the remainder of this report all references to the southern impoundment are to one built on the –245 ft contour.

Dams

Though the Pacific Institute proposal refers to the impoundment-retaining structures as *dikes*, the California Division of Safety of Dams is likely to classify them as *dams* because they would be greater than 6 ft in height and impound more than 50 ac ft of water. This means dam safety would be a major concern at the regulatory level.

The dams would need to be designed to withstand safely the 'project flood'. They would need spillways or weirs and channels to convey water to the new Sea, would require break risk analysis, and would need to be designed for seismic stability.

The least expensive design would involve uncompacted underwater berm construction. This would be subject to potential failure from internal erosion due to seepage and pressure resulting from the 15 ft hydraulic head that would exist after the elevation of the Sea had fallen. Costs for the two dams are estimated at $370,000,000 to $450,000,000.

Quite likely it would be necessary to go to a sheet pile design to achieve the required seismic and hydraulic protection. With that type of construction, the cost for the two dams is estimated at about $1,040,000,000.

The Pacific Institute proposal offered a rough preliminary estimate of total dam costs of about $382,000,000. This was based on the assumption that dike-type structures would be sufficient, an assumption that now appears unrealistic.

The Pacific Institute proposal did not suggest where the outflows from the impoundments were to be placed. The evaluation team thought the best locations would be at the extremities of the impoundments where the dams joined the shoreline. That positioning would minimize development of stagnant areas within the impoundments.

A case could also be made for placing multiple outflow points along the dikes. Once the level of the Sea had fallen each of these would create a channel crossing the exposed lakebed. These channels would quickly evolve into corridors of salt cedar vegetation that could diminish wind speeds and entrainment of particulate matter from the lakebed, thereby potentially reducing air pollution.

Treatment Wetlands

Treatment wetlands have been proposed as a desirable component because of their ability to remove sediment, improve quality of water coming into impoundments, and provide habitat for wildlife. It has not been established, however, that they would provide a net positive benefit.

For example, Total Maximum Daily Loads (TMDLs) for sediment have been established for the Alamo and New Rivers. The water quality issue here is not turbidity *per se* or the potential for sediment accretion, but rather the phosphorus and pesticides that are adsorbed to the sediment particles. Sediment accreting in wetlands would concentrate the pesticides and make them more available. Likewise, it has not been demonstrated in the pilot project on the New River that wetlands reduce concentrations of selenium reaching the Sea. Instead, by slowing the flow of selenium-containing drainwater, the wetlands may become another aquatic habitat (in addition to the irrigation drains) where the element is available to be concentrated through the food chain.

Finally, the extensive acreage of the proposed wetlands will increase water loss by evaporation and reduce by 6-8 percent the amount of water, but not the amount of salts, flowing into the impoundments and the residual Sea, accelerating salinity increase in the latter.

Those questions aside, it is estimated that 9000 ac of treatment wetlands would be needed to remove all or most sediment from the New and Alamo river flows. As only about 2000 ac of suitable river bottom lands are available for wetland construction, the remaining 7000 ac needed would have to be constructed on bluffs many feet above the rivers. Assuming appropriate land could be found, the need to locate wetlands on bluffs would add significant additional costs in terms of piping, pumping, and maintenance.

Design details would be critical because the optimal design for one wetland function often will be suboptimal for other functions. Desired functions would need to be clearly prioritized.

Capital costs for developing the 9000 ac of wetlands are estimated to be $450,000,000 based on a per acre cost of $50,000. This is a rough figure based on costs of setting up the small scale pilot wetlands already in operation along the New and Alamo rivers. Economies of scale would likely result in lower actual costs if extensive wetlands were constructed, although such economies might be offset to some extent by the need to locate most of the artificial wetlands on bluffs.

Maintenance and Management

The dams, impoundments, and treatment wetlands would require a significant annual investment in maintenance and management activities.

For the treatment wetlands, chief needs would be pumping operations, periodic sediment removal, vegetation control and removal, and insecticide applications for mosquito control.

For the impoundments, chief needs would be dam maintenance, monitoring of outflow structures, vegetation control to maintain access to open water at certain points along the shoreline, mosquito control along roughly 50 miles of newly vegetated shoreline, and possibly security patrols if dams are to be made off limits some or all of the time.

If it were desired to create additional habitat diversity and manipulate impoundment water levels in a manner similar to the way artificial wetlands on many wildlife refuges are managed for waterfowl, then internal dikes within one or both impoundments would be needed as well. This would involve increased capital costs and increased costs associated with water management and was not evaluated further by any of the groups

The evaluation team made no effort to estimate maintenance and operation costs, but given the scale of these systems, these costs would be at least in the millions of dollars per year, and possibly greater than the maintenance and operation costs for systems under evaluation for control of salinity of the Sea.

Sediments and Sedimentation

Sediment is currently delivered to the Sea almost entirely by the New and Alamo rivers and amounts to about 20 ac ft/yr. This is a negligible volume relative to the 181,000 ac ft volume of the proposed southern impoundment. So sediment removal would not be needed to prevent filling in of the impoundment. The sediment is mostly in the form of suspended clay particles, though it is not clear that estimates have been made of the amount of sand transported as bed load.

The treatment wetlands would be designed to remove >90 percent of sediment present in inflows to the wetlands. A benefit of this would be that phosphorus and pesticides adsorbed on clay particles would be precipitated out with the sediment. If these remained immobilized in the wetland sediments until they were scraped up and hauled to some disposal area that does not drain into the Sea, then there would be potential for slight improvement in water quality related to these contaminants.

If the wetlands remove 90 percent of the sediment in wetland inflows, the sediment loading to the Sea would *not* be reduced to the same degree, at least not initially. There are two reasons. First, as relatively sediment-free water comes out of the wetlands back into the rivers, it would tend to recharge itself with sediments from the bed of the river channel until the equilibrium sediment load dictated by current speed is reacquired. Second, if the impoundment level is established at –230 ft, the gradient of the lower river channels would steepen slightly relative to what they are now with the Sea at –228 ft, and current speed would be higher.

The type and distribution of bottom sediments in the impoundments might show some gradual changes relative to present conditions. With reduced loading of fine sediments, there might be a shift to slightly coarser, sandier sediments in shallow waters. Silt and clay that now is suspended by wave action and then eventually falls permanently to the bottom in deeper waters will no longer be replaced by much new sediment from river inflows. There would also likely be a large increase in particulate organic matter content of impoundment near shore sediments. This would derive from production of the continuous band of vascular plant vegetation that will occupy the shoreline and shallow waters of the impoundments.

The Imperial Irrigation District has a dredging program for maintaining channel depth near the river mouths. This likely will need to be continued if impoundments were constructed, although to the extent that the impoundment surface elevation is set at a level lower than the present surface of the Sea, there initially would be a lessened tendency for sediment buildup in these lower portions of the rivers. Eventually, however, channel maintenance would be required to the same extent as it is today.

Hydrology and Physical Limnology

Residence Time

Residence time is the time elapsed between entry of a water mass into the impoundment and its departure via outflow or evaporation. It is a function of inflow rates, impoundment volume, and impoundment evaporation rates, and is calculated for the average water mass, i.e. on the assumption that all water masses entering an impoundment have the same residence time.

Residence times for the two impoundments would be short, on the order of 3-6 weeks for the northern impoundment and 9-16 weeks for the southern impoundment. The impoundments thus would essentially be sluggish extensions of the rivers and drainage canals feeding into them.

Dilution Factor

Related to residence time is the dilution factor, the degree to which properties, such as contaminant concentrations, of inflow waters would tend to be overwhelmed by corresponding properties of the receiving waters by simple dilution, ignoring biogeochemical processes that operate to alter these properties further. This dilution factor is a function of inflow rates and impoundment volumes.

For the present Sea the dilution factor is roughly 50 times greater than what it would be for the proposed northern impoundment and roughly 200 times greater than what it would be for the southern impoundment.

Salinity

Salinity will be the single most important factor causing impoundment biotic communities to differ from those of the present Sea. Because of the short impoundment residence times, salinity will drop quickly from Salton Sea salinities (> 42 g/L) to salinities only slightly higher than salinities of the inflowing rivers.

Exact trajectory for salinity during the first months following dam completion is unpredictable at the moment – and perhaps not of much importance. It would depend a great deal on mixing rates, impoundment configurations, and positioning of outflow points.

Equilibrium salinity (S_e) in impoundments, however, would be a simple function of inflow salinity (S_i), inflow rate (F, ac-ft/yr), and impoundment evaporation rate (E, ac-ft/yr), viz.

$$S_e = S_i F /(F - E)$$

In general this predicts that these impoundment systems would have salinities 15-20 percent higher than the waters flowing into them.

Certain factors might or would cause the salinity of the inflows to increase. These include reduction of low salinity tailwater runoff from agricultural fields, reduction in input of low salinity municipal wastewaters from Mexicali (if and when Mexico chooses to reclaim this water), and evaporative concentration of New and Alamo river flows as they pass through 9000 ac of treatment wetlands.

Salinity of Whitewater River (Coachella Valley Flood Control Channel) inflows is projected to increase slightly over time as additional amounts of Colorado River water are transferred to the Coachella Valley, in part to replenish its aquifer. This transferred water will be more saline than the well water that constitutes the water supply for domestic uses in the Valley. As the Coachella aquifer is replenished, in part via percolation of municipal wastewaters, more saline groundwater will discharge into the Whitewater River.

Taking all these factors into account, it is predicted that the southern impoundment would within a few months achieve an equilibrium salinity level of about 4 g/L and that the northern impoundment would initially have a salinity of 1.2 g/L that would rise gradually over 15-20 years to an equilibrium salinity of about 2.8 g/L.

Two additional factors for which the influence has not been quantified might increase slightly the equilibrium salinity levels expected.

First, greatly increased abundance of shoreline and shallow water vegetation would likely result in water losses from the impoundments via evapotranspiration that would be in excess of evaporative losses calculated simply from impoundment surface areas. By reducing impoundment overflows, this would also accelerate salinity increase in the residual Sea.

Second, especially in the southern impoundment, a slight, transitory elevation of salinity above the predicted level might result from dissolution of gypsum, or calcium sulfate, that is abundant in sediments in many places. As the impoundment waters freshen, this will tend to go back into solution, slowing the rate of salinity decline in the impoundment. Gypsum dissolves slowly, however, and much of it is well below the sediment surface where even slower dissolution would occur.

The predicted equilibrium salinity levels of 2.8-4.0 g/L are of particular biological significance. Limnologists conventionally set 3 g/L as the dividing line between fresh and saline waters. This is not entirely arbitrary. Most of the world's fresh waters have a salinity of < 1 g/L and most of its inland saline waters have a salinity of > 5-10 g/L. The nature of lake biota correspondingly changes rather abruptly as one goes from 1-2 g/L to 6-8 g/L. A difference of just a few g/L in this salinity range can cause large changes in the nature of the system, much larger changes than might be produced by going from, say, 8 g/L to 20 g/L. Some species of aquatic vascular plants that would colonize the impoundments would find themselves near the upper limits of their salinity tolerance.

Currents, Turbulence, Vertical Mixing and Wave Action

Physical mixing in the impoundments would be predominantly wind-driven just as it is in the present Sea. However, current speeds, turbulence, and wave action would be reduced relative to present conditions in this part of the Salton Sea. Winds now have fetch of up to 40 miles over which to exert their influence on water movements in the Sea. In the impoundments winds would have much shorter fetches. Additionally, the high ratio of shoreline (including dam margins) to surface area would have a dampening effect on current speeds. Several consequences would follow from this.

Vertical mixing of the water column would be reduced in the southern impoundment relative to what it is now in this part of the Sea. This tendency to poorer vertical mixing would be mitigated to some extent by elimination of vertical salinity gradients now often detectable along the southern shoreline and many miles east and north of the Alamo River mouth.

The long, narrow shape of the southern impoundment would tend to increase inflow-driven currents in proportion to the degree that inflow/outflow rates were high. Current speed and direction within the impoundment would be influenced by the number and position of the overflow points. For maximum homogeneity of water quality within the impoundment, overflow points would be located at either end of the dikes. For maximum heterogeneity, they would be located on the dam about halfway between the New and Alamo river mouths.

Wave action along the shoreline of the northern impoundment would be greatly reduced from what it is now when wind is from the south. Wave action along the shoreline of the southern impoundment would be reduced to a lesser extent, as fetches of a few to several miles in that impoundment would still be sufficient for significant waves to be generated. Shoreline wave action and near shore turbulence action are significant as factors influencing sediment composition, impoundment turbidity and establishment of aquatic vegetation.

Temperature and Oxygen

The impoundments are likely to experience higher maximum water temperatures in summer and lower minimum temperatures in winter than the corresponding parts of the Sea now experience. The impoundments will be isolated from the protective thermal inertia provided by the main water mass of the Sea that now continually mixes with near shore waters.

The main consequence of lower winter water temperature would be for tilapia. Even in the present Sea, these fish experience winter water temperatures that, in combination with other stresses such as high salinity, occasionally drop to lethal levels. Massive winter kills of tilapia in the impoundments thus might occur more frequently than they do now in the Sea. Other fish likely would not be directly affected, though indirect effects would be likely to the extent that these other fish fed on or competed with tilapia.

Higher summertime temperature maxima in combination with altered mixing and current regimes, would likely affect a broader spectrum of fish and invertebrates. Increased water temperature reduces the solubility of oxygen at the same time it tends to increase metabolic rates, and hence oxygen demand, by fish and invertebrates. Other things being equal, the lower salinity of impoundments would cause the solubility of oxygen to be higher than in the Sea. However, in eutrophic water bodies, as the Sea is and as the impoundments would be, salinity effects on oxygen levels are likely to be obscured by the strong control of oxygen levels by biological factors, namely the intensity and diel variations of photosynthesis and respiration by autotrophs and heterotrophs, and by mixing regimes.

How impoundment oxygen levels wound respond to altered hydrographics is difficult to predict, especially for the warmer half of the year. In the present Sea in summer the near shore waters often have higher oxygen levels than do waters at the same depth in the center of the lake. The dams would slow currents and reduce vertical mixing. This would increase the likelihood of frequent or prolonged periods of anoxia in the deeper waters of impoundments. Even brief anoxic events, if pervasive in an impoundment, could cause such depletion of fish or macroinvertebrate populations for which recovery could take more than a year.

On the other hand, the impoundments would be completely isolated from the deeper anoxic waters and highly reducing bottom sediments found over the main part of the Sea. The impoundments would thus be less affected than are current near shore waters by major overturns of the water column in summer. These overturns create anoxic, reducing conditions over the whole water column in the center of the lake, and currents sometimes then bring those lethal waters into the near shore zones.

Turbidity

Turbidity is a function of the amount of particulate matter in suspension. It would be a critical determinant of the nature of the impoundment ecosystems primarily via its influence on the depth to which submergent and emergent vascular plants would colonize the impoundments. Secondarily it is important as a determinant of how deep benthic algae may occur, of interactions between visual predators and their prey, and of biogeochemical processes mediated by or involving suspended particulate matter.

Turbidity is primarily due to two components – plankton and suspended sediments. Turbidity is very high in the areas of the Sea that would be occupied by the impoundments. Disturbance by turbulence, wave action and currents in these areas results in constant resuspension of fine bottom sediments. Shallowness and proximity to the nutrient-laden inflows also cause plankton densities to be higher in these areas than in mid-lake.

In the southern impoundment in the immediate vicinity of river mouths, turbidity would be low because so much suspended mineral matter would be removed by the treatment wetlands. Over most of both impoundments, however, turbidity would likely be high. It is difficult to say whether it would be higher or lower than in the present near shore waters of the Sea. A number of factors would cause turbidity to be high, a number of other factors would cause it to be low, and it is uncertain how these would balance out.

Favoring lower turbidity would be: reduced inputs of sediments by rivers; reduced turbulence, wave action, and currents; suspension-feeding on phytoplankton by the Asiatic clam (*Corbicula*) if it densely colonizes the impoundments; uptake of nutrients by benthic algae and by epiphytic algae coating the surfaces of submerged vascular plants (thus inhibiting phytoplankton growth); secretion of phytoplankton-inhibiting compounds by vascular plants; and grazing on phytoplankton by zooplankton, tilapia and threadfin shad.

Favoring higher turbidity would be: dense phytoplankton owing to high nutrient inputs even if some nutrients were removed by treatment wetlands; and disturbance of sediments by carp and other bottom-feeding fish if they were to densely colonize the impoundments.

The Residual Sea

Under the proposed plan, the present Salton Sea would decline in area and elevation until about the year 2025. Its area would drop from 235,000 ac to 147,000 ac, its maximum depth would drop from about 51 ft to about 28 ft, and its mean depth from 25 ft to perhaps about 17 ft.

Salinity would rise to 100 g/L prior to 2015, to 200 g/L just prior to 2030, and still increase gradually thereafter, according to USBR models. These exceptionally high rates of salinity increase for the residual Sea increase represent the combined effect of high salinity of inflow waters and decreasing lake volume. Salton Sea inflows have much higher salinities than are typical of streams feeding more natural saline lakes. For example, Salton Sea inflows are 80-100 times saltier than waters flowing into Mono Lake, California's second largest saline lake.

The lake would likely experience slightly colder mean water temperatures in winter and warmer ones in summer, as a result of its increased shallowness.

Oxygen levels in the water column would tend to be reduced because of the low solubility of oxygen in highly saline water, but bottom waters might be completely anoxic less often as a result of the shorter water column being mixed to the bottom more easily. It is uncertain how these two factors would balance out.

The New Food Webs

The overall project would increase habitat diversity and biotic diversity in the region. The southern impoundment would become the largest freshwater lake in California south of Lake Tahoe. New vascular plant vegetation along impoundment shorelines would roughly equal to that now occupying the entire length of the U.S. portion of the New River. The treatment wetlands would represent the second largest marsh habitat in the Colorado River delta region, the largest being Ciénaga de Santa Clara in Mexico. The residual Salton Sea would remain the largest lake in California but would lack fish and would have increased densities of certain macroinvertebrate species over some period of time.

It should be kept in mind that diversity per se is not necessarily good and should not be an automatic objective, mantras in the literature, both scientific and popular, notwithstanding. There would be ways of increasing bird diversity in the Salton Basin that could result in severe damage to particular bird species. Would that be an acceptable trade-off? The quality of a sport fishery bears little relation to the diversity of fish species present. Greater diversity and abundance of parasites, diseases, and disease vectors is unlikely to benefit fish, wildlife or humans in the region.

Here we summarize some of the changes expected and kinds of organisms likely to dominate the food webs or biotic communities of the proposed impoundments and, more superficially, other new habitats that would be created.

Algae

Algae would remain the major base of the food webs in the impoundments, though strongly supplemented by production by vascular plants and with macroalgae assuming a more important role than they have in the present Sea.

Phytoplankton. Phytoplankters that now dominate in the sea are dinoflagellates, diatoms, and raphidophytes. The impoundments would likely be dominated by chlorophytes (green algae) and cyanobacteria (blue-green 'algae'). This shift in composition would result from the fact that few dinoflagellates and raphidophytes tolerate salinities as low as 2-4 g/L, and the fact that reduced turbulence in the impoundments would make it more difficult for diatoms to remain suspended in the photic zone. Their silica frustules make them susceptible to sinking in quiet waters.

In general the short residence times would tend to favor dominance by small phytoplankton species capable of rapid growth. Species present in inflow waters would be especially favored as they would be continuously being inoculated into the impoundments.

Total phytoplankton abundance, measured as biomass per liter, could be either lower or higher in the impounded areas than in the corresponding areas of the present Sea. As discussed in the section on turbidity, some factors would tend to favor higher levels and others lower. At present, phytoplankton densities in these shoreline areas are typically much higher than in offshore waters.

Macroalgae. Abundance and diversity of macroalgae would be greater in the impoundments than in the present Sea, as a consequence of lowered salinity, reduced wave action, and increased areas of hard substrate. These would include green algae such as *Enteromorpha*, *Cladophora* and other filamentous forms that would form floating mats in quieter areas, attach to solid substrates, including dam faces, and possibly accumulate as drift on shorelines when they die or are pushed there by waves. Stoneworts such as *Chara* or *Nitella,* with rhizoids anchoring them to sediments, may also appear. And microbenthic cyanobacteria would also be able to form thin algal mats on soft and hard substrates just as they do now in the Sea.

Abundance of these macroalgae would likely be strongly influenced by turbidity, which limits the depths at which they can grow, by wave action, and by grazing by certain fish, water birds and invertebrates. Faces of the new dams would presumably be of rock or concrete and their great linear extent would tremendously increase the abundance of attached macroalgae. The inner sides of the dams generally would experience much less strong wave action than do the dikes along the present southern shoreline of the Sea, allowing larger masses of macroalgae to develop on these inner sides than are now observed on the dikes.

Microperiphyton. This refers to the small algae of various sorts that are found growing on the surfaces of aquatic vascular plants, loosely or tightly attached to them. Such algae represent a food supply for a variety of aquatic invertebrates than cannot feed on the vascular plants themselves. Though inconspicuous, these small algae can take up nutrients rapidly from the water, thus competing with phytoplankton, macroalgae, and the vascular plants themselves. If abundant on plants in the impoundments they would tend to have a clarifying effect on the water column by reducing phytoplankton densities.

Vascular Plants and Shoreline Vegetation

Now almost absent from the Sea and its shorelines, vascular plants would become abundant in the impoundments and along their shorelines. An additional 50 miles of shoreline would become vegetated, although full development of this vegetation would take some years. These vascular plants would contribute large amounts of plant detritus to the shoreline ecosystem and new habitat for birds in particular. These plants would probably boost overall production of the system and represent an increased food supply for decomposers and detritivores. The detritus would also increase the organic matter content of sediments making them softer, 'muddier,' and more subject to anoxia.

Vascular plants are a group especially sensitive to salinity variations in the vicinity of the 3 g/L dividing line between fresh and saline systems. Many species that can thrive at 2 g/L cannot tolerate 5 g/L. Thus precise prediction of the new assemblages of vascular plants would require precise prediction of impoundment salinities and review of the literature on the ecophysiology of aquatic vascular plants in the region.

Three principal categories of vascular plants would be involved in this increase: submergent, floating, emergent, and terrestrial. These are discussed in turn.

Submergent vegetation. These are plants that are rooted in sediments and have all or most of the plant body beneath the water surface. Among species likely to colonize the impoundments would be those in the genera *Ruppia*, *Potamogeton*, *Zannichellia, Hydrilla*, *Najas*, and *Myriophyllum*. *Ruppia* and *Potamogeton* serve as food for some waterfowl species. *Ruppia* beds occurred in the Sea a few decades ago and were favored habitat of the sargo. Submerged vegetation serves as a substrate often colonized by microalgae and by invertebrates. It also creates structural complexity that provides invertebrates and smaller fish some protection from predation by larger fish.

Abundance of submergent vegetation would likely be sharply limited by turbidity, and by disturbance or grazing by common carp and the plant-eating Zill's tilapia (*Oreochromis zilli*) now restricted to freshwater influents. Some submergent species can root in sediments tens of feet deep and grow to the surface there if turbidity is low enough and light levels sufficient.

Invasion of the impoundments by the fast growing exotics Hydrilla (*Hydrilla verticillata*) and Eurasian watermilfoil (*Myriophyllum spicatum*) would be likely. Both species already occur in the region. The Imperial Irrigation District controls Hydrilla in canals and ditches in the Imperial Valley with sterile, triploid grass carp, and the California Department of Food and Agriculture and U.S. Department of Agriculture have a program to eradicate it from the state. Both are primarily freshwater species, but Hydrilla grows at salinities up to 7-10 g/L and watermilfoil in salinities up to 15 g/L. Once established in the proposed impoundments, neither species could ever be eradicated, given the great size of the impoundments. In the past, some California water bodies invaded by Hydrilla have been closed to recreational boating in order to prevent plant fragments from accidentally being transferred to other water bodies on boats or boat trailers.

Emergent vegetation. Emergent aquatic plants are those that are rooted in the lake bottom or on damp shorelines and whose photosynthetic and reproductive structures extend well above the water surface. Common types are cattails (*Typha*), bulrush (*Schoenoplectus*), common reed (*Phragmites*), and giant reed (*Arundo*). Some such plants can grow in water more than 10 ft deep, if they can get established, can extend more than 10 ft above the water surface, and can grow so densely as to form impenetrable thickets separating open water from terrestrial habitats. The dense emergent vegetation that grows along the edges of the lower portions of the New and Alamo rivers is rooted in water often 5-6 ft deep.

Now restricted to the immediate vicinity of the deltas and other inflow points of rivers and streams, emergent vegetation would start colonizing all impoundment shoreline areas with sandy or muddy substrates very soon after dams were completed. These vegetation beds would then tend to expand into deeper water, in large part by vegetative reproduction. This would probably be a slow process that went on for years before plants reached some depth beyond which they could not grow. This emergent vegetation could come to occupy up to 5 percent of the total areas of these shallow impoundments, tremendously increasing the extent of marsh habitat in the region.

The history of Ciénaga de Santa Clara in the Mexican portion of the delta gives an idea of what can happen. Once an apparently barren, 25 mile long, saline depression periodically inundated by ocean water, the whole northern end of the Ciénaga became a densely vegetated marsh of *Typha*, *Schoenoplectus*, and *Phragmites* once large volumes of 3 g/L wastewaters from Arizona agriculture began being diverted into this basin. Of course, this is a much shallower system, with maximum water depths on the order of 3 ft, than would be the Salton Sea impoundments.

As with submergent vegetation, the depths that emergent vegetation can colonize are likely to be limited by turbidity and the feeding and sediment-disturbing activities of carp. Some feel that this vegetation is unlikely to occur in water more than 3 ft deep. Even so limited, there would be important consequences.

For example, with the water surface of the southern impoundment set at –230 ft, the deepest water between Mullet Island and the southern shoreline would be about 4 ft. It seems likely that eventually a broad band of dense emergent vegetation would completely connect Mullet Island with the mainland. Over time this might become traversable by mammals, allowing access to this bird nesting island by foxes and coyotes. A major dredging operation could presumably prevent such access from developing.

Terrestrial vegetation. The shoreline of the Salton Sea is mostly devoid of terrestrial vegetation, with the exception of shorelines near points of surface or groundwater inflow. The primary reason for this undoubtedly is the high salinity of soils and soil porewaters near the lake's edge.

Once impoundments were created, their fresher waters, together with the occasional rainfall events of the region, will greatly reduce soil salinity along the shores of impoundments. This would lead to great increases in the abundance of terrestrial vegetation, which would abut or intermingle with the emergent aquatic vegetation developing in adjacent shallow water areas. Various grasses (e.g. *Distichlis*) and shrubs (e.g., *Salicornia*, *Atriplex*, *Pluchea, Baccharis*) would colonize these shore habitats. Salt cedar (*Tamarix*) likely would be the tree species that would most successfully establish in these freshened areas, but other trees such as cottonwood (*Populus*) and willow (*Salix*) might succeed in some areas as well, especially if planted.

Taken together, the submerged, emergent and terrestrial vegetation that would develop along the impoundment shorelines would represent a great 'greening' of the shoreline ecosystem. There would be new forms of animal life, especially invertebrates and birds, that could use this vegetation as physical habitat for roosting, nesting, or hiding, as food, or as a place in which to find food.

A band of vegetation, probably dominated by salt cedar, would develop along every channel connecting an overflow point on a dam to the margin of the residual Salton Sea. This assumes that these channels would be unlined except in the immediate vicinity of the outer faces of the dams. With numerous overflow points and channels, the vegetation bands created could reduce wind shear at the ground surface and entrainment of particulate matter into the atmosphere. The vegetation bands would also increase evapotranspirative water loss and reduce inflows to the residual Sea, however. That would accelerate salinity increase in the residual Sea and cause its equilibrium elevation and surface area to both be lower than predicted by current USBR models.

The vegetation of the 9000 ac of treatment wetlands would presumably be heavily managed but nevertheless represent significant additional aquatic vegetation habitat in the region. In present pilot scale wetlands, an attempt is being made to eliminate salt cedar, seeds of which are present in large quantities in river water and germinate in large numbers on the shorelines of the pilot wetlands. Dense salt cedar stands would make maintenance of wetlands difficult and cause increased water loss via evapotranspiration. The cost of keeping 9000 ac of wetlands free of salt cedar should be considered in estimating annual maintenance and operation budgets.

Invertebrates

In the impoundments, the species-poor invertebrate assemblage of the Salton Sea would be quickly replaced by a much more diverse assemblage. Key elements of the present food chain, such as the pileworm (*Neanthes*) and barnacle (*Balanus*) would disappear completely, while a few elements might persist, e.g. the copepod (*Apocyclops*), the rotifers (*Brachionus, Synchaeta*), and the amphipod (*Gammarus*).

Large numbers of new species of crustaceans, insects, oligochaete worms, mollusks, flatworms, rotifers and nematodes would colonize the water column, the sediments, and the surfaces of aquatic plants. A long species list could be compiled from studies of other marshes and lakes in California or the Southwest with salinities of 2-4 g/L. It would not be possible to predict the absolute and relative densities of these new invertebrate species. They would depend in part on complex food web interactions, such as predation on invertebrates by fish and birds in the new ecosystem.

Increased abundance and diversity of shoreline vegetation would be accompanied by large increases and diversity in the abundance of terrestrial invertebrates, especially insects and other arthropods (e.g. spiders, mites), relative to what now can be found along the mostly barren shorelines. Some of these arthropods may feed directly on green plant tissues. Others may be detritivores. Detritus produced by this vegetation will create shallow water sediments and shoreline soils rich in organic matter, and this can serve as the base for detritus-based modules of the overall food web.

The impoundments likely would increase abundance of biting insects in the vicinity of the Sea. These could include mosquitoes (Culicidae), biting midges (Ceratopogonidae), and horse flies (Tabanidae). Aquatic larvae of the mosquito *Culex tarsalis* are common at the margins of vegetated water bodies in the Salton Sea region, including shallow pools among salt cedar and salt grass on the margin of the Sea itself. This mosquito is a vector of western equine encephalomyelitis and St. Louis encephalitis. Another local mosquito species, *Culex erythrothorax*, is a very aggressive biter and found abundantly in cattail beds, but is not a known disease vector.

The structural complexity provided by the stems and foliage of submerged and emergent vegetation would provide mosquito larvae and other invertebrates significant refuge from fish predation. In general fish-inhabited marshes are major breeding grounds for mosquitoes, both in coastal and inland areas. Slight fluctuations in water level as occur seasonally or as a result of seiches or wave action at the Sea are significant creators of mosquito breeding pools free of fish and other predators.

Biting midges and horseflies breed in damp soils with moderate to high levels of organic matter, often near the margins of bodies of fresh water. Their increase would seem highly probable, but it is not possible to predict whether or not this would be to levels representing a significant nuisance to persons visiting or living near the impoundment areas.

Freshwater invertebrates of many sorts, including mosquitoes, would also become very abundant in treatment wetlands. On a per unit area basis, their production might exceed that of invertebrates in the impoundments. Fish in the treatment wetlands are likely to be smaller and scarcer and their prey, such as mosquito larvae, will have more physical structure in which to hide.

Fish

The fish assemblages that would develop in the impoundments would be radically different from the present one in the Sea. Corvina, sargo, bairdiella, and long-jaw mudsucker would disappear. Mozambique tilapia would persist as would threadfin shad, mosquito fish, mollies and mullet. Almost all of the freshwater exotics found in the Coachella, Imperial, and Mexicali valleys would eventually find their way into the impoundments and establish permanent populations. These include common carp, catfish, largemouth bass, sunfish, Zill's tilapia, and shiners. The triploid sterile grass carp used for weed control in agricultural drains could also invade though they should not be able to reproduce. It might be predicted that the fish assemblage would be dominated by the tilapias, threadfin shad, carp and catfish, as these feed predominantly near the bottom of the food web. Large mouth bass could become one of the more popular sportfish.

The abundances of the different species would exert strong influences on each other and on other components of the impoundment ecosystems via predation, disturbance of the sediments, and, in the case of carp and Zill's tilapia, grazing of macroalgae and aquatic vascular plants.

Fish production on a *per unit area basis* might be lower in the impoundments than in the corresponding portions of the present Sea. The major reason for this is that fish presently in these near shore areas are recipients of advected food supplies, e.g. plankton, that are produced over the entire area of the Salton Sea. During the warmer half of the year, these food supplies are not consumed in the central 80 percent of the lake because almost all fish move into the near shore areas.

On the other hand, some factors would tend to offset the above to some extent. These would be the greater variety of fish present, and hence of foods utilized, feeding modes, and microhabitats utilized, and less physiological stress caused by salinity, leading perhaps to greater and more regular reproductive and recruitment success.

Total fish production *for the region* (excluding aquacultural production) would be drastically reduced as the proposed impoundments would represent, at most, only 12 percent of the area of the present Sea.

Habitat of the Desert pupfish, an endangered species, might be somewhat compromised. Retreat of the margin of the residual Sea would make impossible movement through the Sea of individuals moving from one drain or creek to another, though it is uncertain how important such movements are. The high diversity of exotic freshwater species in the impoundments might increase the likelihood of some of them invading pupfish habitats such as San Felipe Creek and reducing their numbers via predation or competition.

Amphibians and Reptiles

Soft-shelled turtles have been seen in the New and Alamo rivers and doubtless would colonize the impoundments. Bullfrogs occur in the region, and used to be collected for food in the Rio Hardy when it was in better condition. The African clawed frog is now widespread in southern California and doubtless would colonize the impoundments. Toads and tree frogs might use the impoundments and treatment wetlands for breeding. Abundance of amphibians would be closely tied to the nature of aquatic vegetation present, as this would be needed as critical refuge from piscine and avian predators. Amphibians especially are likely to be sensitive to many aspects of water quality.

Birds

The avifauna of the region would be markedly affected by the creation of impoundments and treatment wetlands and by the rise in salinity of the residual Sea that will ultimately preclude the presence of fish. Some types of birds would become more abundant, others less abundant.

Changes would reflect changes in available habitats and food supplies. We focus on predicting changes for four major categories of birds.

Users of shoreline vegetation. The predicted large increases in shoreline and shallow water vegetation would lead to large increases in bird species that can use that habitat for nesting, roosting, or feeding. These would include particularly rails, bitterns, blackbirds, wrens and warblers. Once tall salt cedar stands had developed, various herons and egrets would be likely to nest in them. Passerines that glean insects from the foliage of such vegetation would also increase. Ducks, coots, and even geese that can feed on submergent aquatic vegetation would also be more abundant. There might be pressure from duck hunters to manage vegetation and water level so as to create optimal waterfowl habitat. Some of these same birds would be able to utilize the managed vegetation of the 9000 ac of treatment wetlands.

Aerial feeders. Production of insects with aquatic larvae and aerial-terrestrial adults is now essentially zero in the Sea. This production would likely be high in the impoundments though strongly influenced by fish predation. Adults of non-biting midges (Chironomidae) and perhaps mosquitoes (Culicidae) would be especially abundant and likely to attract more flycatchers, swallows, swifts, and nighthawks to the skies above the impoundments.

Feeders on aquatic invertebrates. We distinguish three categories: wading shorebirds (e.g. avocets, stilts, dowitchers, godwits, etc.), beach runners (e.g. sandpipers, plovers), and open water feeders (eared grebes, Wilson's phalaropes, shovelers, ruddy duck, etc.).
We would expect to see reduced abundances in the impoundments of the first two categories as the open shoreline and mudflat areas they utilize would eventually be taken over by dense shoreline vegetation. The open water feeders would probably also be less common as we would predict that the diverse fish assemblage in the impoundments would result in lower overall density of macroinvertebrates of the types these birds feed on.

At least some of these feeders on aquatic invertebrates would be likely to find, at least for a many years, increased food supplies in the residual Sea that would be left to becomes fishless. Once it was fishless, the dominant invertebrates there would be copepods (*Apocyclops*), water boatmen (*Trichocorixa*) and brine flies (*Ephydra*). Only after salinity became high enough (> 80-100g/L) to eliminate the copepods and waterboatmen would brine shrimp (*Artemia*) become abundant, as the first two are predators on the latter.

Fish-eating birds. In general these would become very much less abundant in the region, even though some individual species might come to have higher densities in the impoundments than they do in the current corresponding portions of the Sea. Fish-eating birds, such as egrets and herons, that like quiet water and are willing to use vegetated marshy areas might become more abundant in the impoundments than they are now along the Sea's southernmost and northernmost shorelines.

The Double-crested cormorant and the two pelicans would be likely to become less abundant even in the areas to be impounded, once the main part of the Sea became fishless, even if fish production per unit area were high in the impoundments.

The cormorant would be affected by loss of Mullet Island as a nesting area, if this became connected to the mainland by filling in of shallow water areas with vegetation, as described earlier.

For the Brown pelican, the Salton Sea is a novel and not critical habitat. This species is essentially marine and nests on islands in the Sea of Cortez, though it has unsuccessfully attempted to nest at the Salton Sea in recent years. With reduction in abundance of fish in the region and elimination of attractive nesting areas, this species would likely occur in fewer numbers and might tend to abandon the area altogether. Though this would represent a loss of diversity, it would not necessarily represent significant damage to that species.

The scenario would be different for the White pelican. This species is severely reduced in number in the West perhaps because of disappearance and degradation of shallow lakes in the western U.S. and northern Mexico in general. The Salton Sea is one of the most important wintering and stopover points on the migration route of this species. Thus, significant negative impacts on the species could follow the elimination of 88 percent of the Salton Sea as fish-producing habitat. Also, areas that the pelicans currently use for loafing – small islands, sand spits, etc., though not Mullet Island – would no longer be suitable for this purpose once these areas are occupied by dense vegetation following freshening of impoundments and soil porewaters. Though vegetation beds offshore or around islands can be used for loafing, and even nesting, by pelicans, most of the new vegetation beds will be near the shoreline and accessible by terrestrial predators.

Greater diversity of small fish – mosquito fish, shiners, mollies, and young of the numerous larger species, especially tilapia – would likely represent a more diverse food supply for smaller fish-eating birds, such as terns, black skimmers, and western grebes. The balance expected among species and size classes would be difficult to predict. Predation by the larger fish present, such as large mouth bass, would have much influence on this. Whether overall abundance and availability of small fish would be greater or lesser than in these shallow areas of the present Sea would also be difficult to predict.

Snags, the remains of trees killed decades ago by rises in level of the Salton Sea, are found in shallow water at many locations around the margins of the Sea. They are used for nesting and perching by herons and cormorants. These snags would be stranded far from the water if the level of the Sea dropped as predicted, and probably would no longer be used by these species. One reason would be the much higher heat loads these large birds would be subject to, absent the temperature-moderating effect of water surrounding the snags. Another might be the ability of terrestrial predators to patrol the immediate vicinity of the snags and, in some cases, climb into them.

The margins of the residual Sea and/or the upper surfaces of the dams potentially could be used as nesting areas by Snowy plovers, Black-necked stilts, Caspian terns, Black Skimmers, Double-crested cormorants, and other species. For the dams to be useful for this purpose an unpaved upper surface would be needed and there would have to be restrictions on access by predators, humans, and vehicles during the nesting seasons.

The Residual Sea

As this would continue to receive nutrients via overflow waters from the impoundments, algae and cyanobacteria tolerant of high salinities would persist, often in bloom conditions. These would serve as food for the few invertebrate species - protozoans, copepods, water boatmen, brine flies, brine shrimp - that would dominate in the Sea once salinities exceeded 60-70 g/L and all or almost all fish had disappeared.

The overall productivity of the residual Sea would decline fairly rapidly as its salinity increased. This is because all those organisms - bacteria, algae, invertebrates - capable of surviving high salinities do this in large measure by dedicating more energy to maintenance functions, such as osmoregulation, and less energy to growth and reproduction.

Certain invertebrates such as brine shrimp and brine flies may become conspicuously abundant as their predators and competitors are eliminated by rising salinity. These invertebrates also posses unique sodium pumps allowing them to survive extremely saline waters. Food supplies for particular bird species – such as Eared grebes, phalaropes, avocets, stilts, certain gulls – that feed on such invertebrates can indeed become much more abundant than they were at lower salinities where overall system productivity was higher but was being utilized by other components of the food web (fish, predaceous invertebrates).

Even those invertebrates that tolerate high salinities grow and reproduce best at salinities lower than those of the present Salton Sea. Physiologically their populations will be in a state of decline from the moment they establish themselves in the Sea. Their abundance would also be influenced by oxygen conditions. Uncertainty as to oxygen conditions at the sediment surface, where larvae of brine fly larvae live, makes it unclear what percentage of the bottom of the shallower, saltier sea could be used by such invertebrates, especially during the warm part of the year.

The most important point is that salinity increases would cause greatly decreased system productivity. Once salinities approached and exceeded 90-100 g/L there would be a rapid decline in the production of the very invertebrates most favored by birds that frequent salt lakes. Highly saline water bodies such as The Great Salt Lake of Utah have very low rates of production per unit area, and many of the principal bird feeding areas at them are actually the lower salinity areas or subsystems around their margins where freshwater flows into the lake.

The residual Salton Sea would not function as a giant, well-stocked bird feeder for more than a few years, given the projected very rapid increase in its salinity.

Disease, Parasites and Contaminants

The project proposed by the Pacific Institute would create or exacerbate a number of problems relating to disease, parasites and contaminants.

The potential problems concerning disease and parasites reflect the fact that the salinity of the Salton Sea functions as a prophylactic: neither its present salinity, nor one closer to ocean water, can be tolerated by certain pathogens, disease vectors and parasites that would become abundant in freshwater impoundments.

With respect to contaminants, the general problem is that the proposed impoundments would represent sluggish extensions of the inflowing rivers. Consequently they would have contaminant levels closely reflecting those in the rivers themselves. The diluting and metabolizing power of the volume of the whole Salton Sea would no longer be available in these new freshwater ecosystems.

Fish Diseases and Parasites

At present the fish in the Sea are known to host only a single metazoan parasite, a monogenean fluke (*Gyrodactylus*), and this only rarely. A few microbial ectoparasites (*Amyloodinium*, *Cryptobia*, *Ambiphrya*) are known to infest large percentages of fish, especially juvenile tilapia, at certain times of year. On rare but significant occasions, botulism has been found in moribund tilapia, often associated with *Vibrio* infections.

In freshwater impoundments *Vibrio* infections might be greatly reduced if in fact their present occurrence is due in part to stress on tilapia immune systems created by present high salinities. If *Vibrio* infections, combined with other stresses, have been responsible for the development of tissue anoxia in tilapia and subsequent production in their guts of type C avian botulism toxin, then fewer moribund, toxic tilapia would be available to pelicans and other fish-eating birds. This role for *Vibrio* infections remains only a working hypothesis, however.

We cannot predict how the types or degrees of infestation by microbial parasites might change in the impoundments relative to the Sea. *Cryptobia* and *Ambiphrya* are known to occur in freshwater habitats, aquaria and aquaculture operations. Many other species of microbial parasites may be capable of tolerating a salinity of 2-4 g/L and could appear in the impoundments as well.

In the proposed impoundments, fish would be more heavily infested with metazoan parasites (flukes, cestodes, roundworms, crustaceans). The life cycles of most of these parasites require an intermediate host, usually an insect, crustacean or snail. Few species of such potential invertebrate hosts are found in the present Sea, but many-fold more such host species would establish populations in the freshwater impoundments. This would lead to greater diversity and higher infestation rates of parasites on and in impoundment fish. The lower salinity water itself would also facilitate survival of the free-swimming stages that some of these parasites have.

One such parasite would be the introduced Asian fish tapeworm *Bothriocephalus acheilognathi* This has been found in shiners and mosquito fish in creeks draining into the Sea. It is a harmful parasite of commercial and recreational significance. It uses freshwater copepods as an intermediate host, spreads rapidly, can cause high mortality of juvenile cyprinids in particular, and could become common in fish in the impoundments. With increasing abundance in the area it might also soon infect local Desert pupfish populations.

Black-spot disease is caused in North American freshwaters by infestation of fish by a fluke (*Uvulifer ambloplitis*) that requires snails as intermediate hosts. The flukes are visible to the naked eye as black spots on the skin, fins and flesh of fish, making them less attractive for human consumption.

Whether parasite loads would be heavier in impoundment fish than they are in these same fish species where they occur in other freshwater ecosystems in southern California is not certain. In freshwater systems in general, however, parasite loads for fish, amphibians and reptiles are higher in eutrophic water bodies than in meso- or oligotrophic ones – and the impoundments will be highly eutrophic.

Bird Diseases and Parasites

During the 1990s there were a number of large mortality events involving Eared grebes, White and Brown pelicans, Double-crested cormorants and various duck species. Cause of the death of ca. 150,000 Eared grebes in 1992 was never determined, the pelicans were almost all killed by type C avian botulism after feeding on tilapia containing the botulinum toxin, the biggest cormorant mortalities were due to Newcastle disease, and duck mortalities have been due mostly to avian cholera.

Some tentative predictions as to how the disease situation would differ on the impoundments can be made.

Smaller populations of Brown pelicans might lead to reductions in botulism mortality of pelicans, although if tilapia populations persist in the impoundments and the fish are stressed by high temperature and low dissolved oxygen, botulism would probably continue to afflict fish-eating birds.. Classical type C avian botulism, however, would likely become more common because aquatic vegetation would attract larger numbers of ducks to the impoundments than are currently found in these parts of the Sea now. Moreover, fresher, quieter waters, increased levels of sediment organic matter, higher summer water temperatures, and lower oxygen levels would represent conditions much more favorable to development of botulism-loaded insect larvae or other invertebrates than are present conditions in the Sea. Classic type C avian botulism is most commonly associated with freshwater systems, and in salt water systems is usually associated with areas of freshwater inflows.

Increased waterfowl densities would also likely result in increased mortalities due to avian cholera, as waterfowl are the primary carriers of this disease in the wild.

Salmonellosis would also likely become more common if there are large increases in colonial nesting birds in vegetation on the margins of the impoundments or on top of the dams.

Newcastle disease is mainly associated with ground-nesting, as carried out by cormorants at the Sea. Though the factors initiating outbreaks are unknown, once present the frequency of this disease would probably be a function of the numbers of cormorants nesting on Mullet Island or the dam surfaces. The dependence of those numbers on accessibility of those areas to predators has been mentioned.

The increased number of invertebrate and fish species in the impoundments that could serve as intermediate hosts for parasitic helminths would likely increase infestation of birds by those parasites. The importance of this to the health of the bird populations is difficult to judge, however. Most birds would be exposed to these parasites in many of the other aquatic systems they visit for food during the course of a year’s travels.

Human Diseases and Parasites

The proposed impoundments would cause increased exposure of humans to water-borne pathogens, to vector-borne viral diseases, and to swimmer's itch, especially if the impoundments and adjacent areas were heavily used for recreation.

Water-borne Pathogens. In the recent past the New and Alamo rivers have received on a regular basis from Mexicali and on an irregular basis from Imperial Valley towns, large quantities of untreated or poorly treated (e.g. only primary treatment) municipal wastewaters. More than two dozen bacterial and viral pathogens have been detected in the New River. At present the Salton Sea functions as a large diluter and digester of such pathogens, and there is no evidence that the Sea is an unsafe environment for swimming and other water-based activities.

Even with treatment wetlands processing the full flow of the New and Alamo rivers, the proposed impoundments, with their much reduced capacities for such dilution and digestion, would not be deemed safe for many recreational activities. Treatment wetlands might remove 90-99 percent of microbial contaminants, but that likely would still result in unacceptable levels of them in the impoundments themselves. Without a continuous, expensive monitoring program for pathogens, public health advisories on recreational use of impoundments would have to err on the conservative side.

Though progress is being made toward the objective of providing secondary treatment for all municipal wastewaters in the region, this is slow. Most of the human population in the Salton Sea watershed lives in Mexicali, this city has a population growth rate of a few percent per year, and wastewater treatment infrastructure is not keeping up with this growth.

Vector-borne Viral Diseases. These could become a serious problem if the Pacific Institute proposal were implemented. The regional abundance of mosquitoes would increase greatly in response to the large increase of heavily vegetated, shallow water and marsh habitat that would form on impoundment margins and in treatment wetlands. Some of these mosquitoes would merely be annoying as biters, but others, such as *Culex tarsalis*, are vectors of serious viral diseases of man and other animals.

The viruses that cause St. Louis encephalitis and western equine encephalomyelitis are known from birds in the Imperial and Coachella valleys, although at present cases of human disease are rarely reported. If much recreational use were made of the proposed impoundments, there would be increased likelihood of transmission of these viruses by mosquitoes from the avian reservoir species to humans.

Culex tarsalis likely could also serve as a vector for the West Nile virus, another agent of human encephalitis. Though not yet reported in California, this virus was only first detected in the U.S. in 1999, now is widespread in avian reservoirs in eastern North America, and is likely to be in California soon.

Parasites. If the impoundments were used for swimming, swimmer's itch, or schistosome cercarial dermatitis, might become a problem. This is caused by penetration of human skin by the aquatic larval stage (cercaria) of certain flukes that have life cycles involving snail, fish and bird hosts. High densities of snails and waterfowl in the impoundments would favor the presence of these parasites. Though the larvae die soon after penetration and do not actually parasitize humans, they nevertheless cause serious welts and rashes that are highly irritating, can last for some weeks, and would thereby diminish the recreational value of the water body during the seasons the fluke larvae are present.

Toxic Algal Blooms

Lower salinities and higher nutrient levels, especially of phosphorus, in the impoundments would lead to greater abundance of cyanobacteria than in the present Sea.

Cyanobacteria have potential for creating blooms toxic to fish and wildlife, including terrestrial mammals. Such blooms occur frequently in other shallow, eutrophic freshwaters though not in waters as saline as the current Sea. Toxic species of cyanobacteria could appear in the biota without having harmful effects, of course. Indeed some of the cyanobacteria in the present Sea now, as well as some of the dinoflagellates and raphidophytes there, are capable of producing toxins. But there is no hard evidence so far that these have harmed fish or wildlife.

Short water residence times in the impoundments would diminish the likelihood that cyanobacteria could achieve dense enough blooms to affect fish or wildlife. On the other hand, portions of an impoundment partially isolated from the rest of the impoundment by shoreline embayments or by stands of aquatic vegetation could have effective residence times much longer than the impoundment as a whole. These could become sites of dense bloom formation.

Phosphorus and Nitrogen

These nutrients are important in determining the productivity and abundance of algae and higher plants, and hence the productivity and abundance of the higher levels of the food web as well. When present in high concentrations, however, they lead to such high levels of production that the respiration and decomposition of this production leads to anoxia and other water quality problems such as high ammonia or high sulfide levels.

Nutrient levels in New and Alamo rivers are somewhat higher (9 mg N/L, 0.3 mg P/L) than mean levels in waters of the Sea itself (5 mg N/L, 0.1 mg P/L). In the absence of treatment wetlands, nutrient levels in the southern impoundment would be similar to the higher levels in river inflows. This would tend to create higher phytoplankton densities than are found in at least the offshore waters of the present Sea. Moderating such effects would be the short residence time of water in the impoundment and loss of nutrients via the outflows, uptake of nutrients by periphyton and vascular plants, and self-shading of the phytoplankton. Exacerbating such effects would be increased recycling of nutrients from bottom sediments back into the water column by benthic invertebrates and bottom-feeding fish such as carp and catfish.

Fully developed treatment wetlands might remove, via denitrification, significant amounts of nitrogen from river flows. This nitrogen tends to be lost rapidly via the same process in the Sea. Treatment wetlands are not efficient at removing phosphorus. The most that might be expected would be about a 10 percent removal. Though phosphorus is the nutrient in shortest supply in the present Sea, and would be in the proposed impoundments, a 10 percent reduction in loading would not be likely to cause reduction in algal blooms or frequency of anoxia. In the impoundments, as in the present Sea, phytoplankton production is likely to be light-limited most of the time and not limited by shortage of phosphorus.

Large reduction of phosphorus inputs via other processes – such as improved management of tailwater drainage and improved municipal wastewater treatment – would diminish the likelihood of impoundments becoming severely hypereutrophic. But evaluation of the efficiency and feasibility of those other projects is outside the scope of this evaluation.

Un-ionized ammonia (NH_3) would have a higher probability of reaching toxic levels in the impoundments. Ammonia is excreted by fish and invertebrates and released by decomposition of proteins. It normally exists in the form of the ammonium ion (NH_4^+). In that form it is non-toxic to animal life and actively taken up by some algae. As pH increases, however, an increasing fraction of the total ammonia will be in the form of un-ionized ammonia. Daytime pH values would be expected to be higher, up to 10 or higher, in the impoundments than in the present Sea. Such high pH values would result from rapid photosynthetic uptake of CO_2 from the water by dense phytoplankton. High photosynthetic CO_2 uptake occurs regularly in the present Sea, but pH values are rarely greater than 8.8 because the present high concentrations of dissolved salts have a buffering effect.

Selenium

The importance of selenium in current bird disease and reproductive success issues and to human health at the Sea is unknown. But selenium concentrations in the inflows already are at levels of concern, and those levels would be increased by the proposed project.

In general, selenium is a concern because of 1) its ability to bioaccumulate in the food web, 2) the narrow range between the concentration that is nutritionally beneficial and that which is toxic, 3) its effects on fish and bird reproduction and embryonic development, and 4) its potential effects on human health.

In the present system, selenium concentrations average about 6 µg/L in inflows to the Salton Sea (8 µg/L in Alamo River, 4 µg/L in New River), about 1 µg/L in the Salton Sea water column, about 2 µg/g wet weight of Salton Sea fish, and < 1 µg/g dry weight of sediments in area of proposed impoundments. Most selenium entering the present Sea is possibly entombed in the deeper sediments where it is minimally available to the biota.

The EPA criterion for water for protection of aquatic life is 5 µg/L, but lower limits such as 2 µg/L are being considered for areas where significant bioaccumulation has been noted.

In the absence of treatment wetlands, fish and other organisms in the proposed impoundments would be exposed to selenium levels roughly 6 times greater than now experienced by fish and other organisms in the Sea. The concentrations expected in impoundment fish and invertebrates might thus be expected to be much higher than those in present Salton Sea fish and invertebrates. If that transpired, it is likely that an advisory would be issued by the state recommending no human consumption of impoundment fish.

Water conservation measures underway, such as reduction of tailwater drainage and operational losses, could in the future cause selenium concentrations in river inflows to increase by as much as 30 percent.

The Pacific Institute proposal acknowledges that selenium-related problems for birds might be exacerbated by resuspension of sediments during dam construction. This, however, would be a less important mechanism for increased selenium exposure of birds than would be the accumulation of higher selenium levels in the impoundment fish and invertebrates after the dam was completed. It should also be noted that selenium deposited in impoundment sediments would not be immobilized there but would be recycled back into the food web by benthic invertebrates and bottom feeding fish such as carp and catfish.

In principle it might be possible to design the treatment wetlands for removal of selenium by adding sediment basins ahead of the wetlands, but there are no even approximate estimates of the cost of doing this or of the reductions that might be expected. To the degree that treatment wetlands trapped selenium via accumulation in plants and other organisms, these wetlands themselves might become a potential problem for wildlife. Past use of large-scale biological treatment technologies (e.g. wetlands, evaporation ponds) has generated serious ecological problems and hazardous selenium waste. Selenium concentrations of 3 ug/g wet weight have already been found in algae in the pilot wetland near Imperial. Under certain conditions, selenium can be lost by volatilization from a system, but that process is not likely to occur at quantitatively significant rate.

Other actions that could reduce selenium loading to the system are being considered. These include steps being proposed in the state of Colorado to reduce input of selenium-rich agricultural wastewaters into the river and the fallowing of poorer quality Imperial Valley land where soils are relatively high in salts and selenium. However, even if over a number of years such projects could reduce selenium levels in New and Alamo rivers by 50 percent, that would still result in southern impoundment selenium levels 3 times greater than those in the present Sea. More importantly, unless the selenium problem is dealt with at the source, the building of any number of selenium-removal wetlands upstream of the Salton Sea does not solve the selenium problem. It only makes it someone else's problem.

Pesticides and Other Water-borne Contaminants

Available information indicates most such contaminants, though often detectable in river inflows, are undetectable or present in very low concentrations in the water, sediments and biota of the present Sea. Of greatest significance probably is DDE, a metabolite of DDT, which is found in Salton Sea fish at concentrations of 0.08 µg/g wet weight, and may still contribute to egg shell thinning that has been noted over recent decades in colonial nesting birds at the Salton Sea. This DDE is presumably entirely derived from soil residues dating from prior to 1972, when DDT ceased being used in the United States, and is declining over time.

Treatment wetlands would have the potential to remove these contaminants, though again possibly at the expense of increasing their concentrations in the wetlands food webs and wildlife that were part of them.

In the absence of treatment wetlands, impoundments and their food webs would be exposed to the contaminant levels of the rivers themselves. Though low and possibly ecologically and toxicologically inconsequential in most cases, these levels would nevertheless be many-fold levels in the present Salton Sea.

Particulate Air Pollution

Pollution of the atmosphere with particulate matter is already a problem in the Coachella and Imperial valleys with the PM10 standard being exceeded many days every year. That standard refers to the concentration in the air of particles smaller than 10 µm in diameter. These cause respiratory problems in humans.

By allowing the level of the Sea to decline and exposing at least 57,800 ac of former lakebed, a worsening of air quality in the region is likely. This will depend largely on the physical structure, particle size distribution, and moisture content of the soil surface. The exposed Salton Sea lakebed would be almost equal to the dry lakebed at Owens (Dry) Lake in northern California, which has produced severe air quality problems in that region for many decades.

Use of overflow waters to create bands of wind-interrupting vegetation could mitigate this problem to some extent. However, to the degree that evapotranspiration of overflow waters is increased by these bands of vegetation, the residual Sea would have an even lower final equilibrium level, leaving an even larger acreage of former lake bottom exposed.

The Residual Sea

The residual Sea could pose a serious hazard to wildlife in the form of selenium. It would likely pose no disease or parasite problems for birds, and toxic algal blooms are unknown in such highly saline systems.

It would continue to receive nutrients and contaminants via overflow waters from the impoundments. Phosphorus would be less likely to be immobilized in sediments than it is in the present Sea and might thus be superabundant relative to demand by algae. In any case it would be unlikely to cause any problems.

Selenium would be the big danger. Selenium probably would not be sequestered permanently in the sediments or biota of the impoundments. Rather it would cycle among the biota, sediments, and water column of those systems until eventually carried out of them in overflow waters. The quantity of selenium going into the residual Sea would thus be approximately the same as that entering the impoundments, roughly 7 tons/yr. The selenium loading *per unit area* of the residual Sea would therefore be greater than it is for the present Sea. Moreover, in the shallower residual Sea, selenium would also be less likely to be permanently sequestered in the sediments, especially if those sediments were more subject to burrowing and feeding activities of invertebrates. Selenium levels in brine shrimp, brine flies and water boatmen in the residual Sea thus would likely be much higher than those in invertebrates in the present Sea.

Recreation and Economics

Our evaluation of the Pacific Institute proposal focused primarily on the physical, chemical, and biological characteristics that the systems produced by implementation of the Pacific Institute proposal would be likely to have. Specialists in recreation and economics were not on the evaluation team only because of a lack of time to locate these experts.

Nevertheless, our findings have some direct and obvious implications for recreation at the Salton Sea and the regional economy. We briefly outline these below

Bird watching

This is an activity engaged in at the Sea by many thousands of individuals a year, especially at the southern end of the Sea. Construction of the proposed impoundments would have a few negative impacts on the quality of the area for bird watching and a few positive ones.

Negative effects would include: reduced access to and visibility of northern and southern shoreline areas as a result of the extensive development of shoreline vegetation; reduction in abundance of fish-eating birds in general; and increased abundance of biting insects.

Positive effects would include: increased diversity of birds, especially of waterfowl, passerines, and rails as a result of development of aquatic and shoreline vegetation, and of fish- and invertebrate-eaters, as a result of greater diversity of fish and invertebrate prey in the impoundments; availability of dam surfaces both as loafing and nesting areas for birds, and as viewing areas for birders; and increased abundance of certain invertebrate-eating birds, at least for some years, on the residual Sea.

Since the Salton Sea is already an excellent, nationally and internationally recognized location for bird-watching, it would not likely experience even greater popularity in that regard even if certain bird species did become more abundant there or if others disappeared. It seems less certain that large increases in biting insects might not reduce the area's popularity for bird-watchers.

Fishing

Fishing could be quite good in the impoundments for tilapia, largemouth bass, carp and catfish, though it is unpredictable just which of these would establish good numbers of good-sized individuals. Special attractions might include the fact that tilapia sport fisheries do not exist elsewhere in the state and the possibility that largemouth bass would reach large sizes in the impoundments.

That sort of fishery, except for the tilapia, can be found in many other waterbodies in the region and in southern California, however, and fewer fishermen would be willing to travel long distances to take advantage of it. It will no longer be a special, unique fishery capable of generating tales of 30 lb corvina that got away.

Rather it would become known as a fishery where contaminant levels were higher than elsewhere for the same species and higher than in the former Salton Sea. Selenium levels we estimate would be six times greater than those in fish of the present Sea would cause the state to warn against any consumption of impoundment fish. Detection of microbial pathogens or indicators of fecal contamination in the impoundments would lead to the same warning. The accurate perception that the impoundments were sluggish extensions of wastewater drains would discourage fishing for many years even after contaminant levels had been reduced – if that ever were achieved.

In short, a sport fishery would not be compatible with the proposed project, at least not over the short or medium term.

Boating and swimming

Boating in the impoundments, because of reduced current speeds and wave size, would probably be safer than in the current sea, and the entirety of the impoundment areas would be accessible to smaller boats. On the other hand, contaminant levels in fish, invasion by aquatic vegetation, and the considerable number of obstructions (rocks, tree trunks, old man-made structures) in the shallow northern and southern ends of the Sea would render the impoundments much less attractive to boaters in general than is the present Sea. There would be no need for pontoon boat tours for birdwatchers, such as the State Recreation Area currently conducts. Persons with larger, faster boats interested in a quasi-oceanic boating excursions would no longer be attracted.

Swimming would probably be non-existent in the impoundments. Potential bathers would be put off by softer sediments, aquatic vegetation, absence of beaches, more biting insects, the presence of swimmer's itch and microbial pathogen levels higher than those in the present Sea. Though swimming is less common than it once was along the exposed, coarser sediment shorelines of the present Sea, this has more to do with irrational fears of algal blooms and resultant turbidity and inaccurate press reports than it does with the reality of the situation. Naturally on those specific occasions when there is a moderate to large fish kill nearby or washing up on shore, or when there is a bloom of the surface film-dwelling alga *Pleurochrysis* in progress, or when heavy waves have stirred up sediments, swimming is not an attractive option. But for most of the year the present Salton Sea is an excellent place for swimming.

The main part of the Sea where salinity would be allowed to increase over time might remain suitable for both boating and swimming for some decades, though of course boating fishermen would not be interested in it. This possibility would be much influenced by the nature of shoreline and shallow water sediments along the margins of the receding residual Sea. If these were fine and muddy, little use would be made of the Sea for these purposes. However, once the level of the residual Sea stabilized access roads, docks and boat ramps could be put in, if expected boat use on the fishless Sea would justify such.

Camping

There is a fair bit of both tent camping and mobile home camping around the edges of the Salton Sea, and much of this is associated with bird watching, desert nature study, scientific excursions by university classes, and just relaxation under the desert stars. More than fishermen and boaters come to the Sea. Very little of this camping takes place along the shorelines of the areas to be impounded, and in general the impoundments – by increasing the abundance of biting insects as well as on non-biting insects, such as chironomid midges, likely to swarm to campsite lighting fixtures – would make these areas even less attractive than they are now for camping, unless campsites were a considerable distance – perhaps hundreds of yards - from the water's edge.

Camping on shorelines of the receding residual would not be an attractive option. Air pollution with particulate matter would be higher than on the present shoreline especially during breezy or windy weather. It would not make sense to provide much in the way of facilities (roads, parking areas, docks, restrooms) until the level of the residual Sea stabilized. Camping in the higher elevation, sandier spots would leave one far from the water.

New camping areas, or general centers of recreational activity, established near where impoundment dikes intersected the shoreline could enhance recreational values. These could provide easy access of boaters, birdwatchers or fishermen both to impoundments and to the residual Sea. These would be areas of high biotic diversity. Those on the west side of the Sea could be tranquil sites free of the hooting and rumbling of nighttime freight trains that run along the east side of the Sea.

Economics

In general the economic consequences of implementing the Pacific Institute proposal would seem quite negative. Value of most shoreline properties would drop precipitously. Many fewer people would come to the Sea for fishing, boating, and camping, though the numbers coming for bird watching would remain high. Increased particulate matter air pollution would exacerbate the above and increase medical and public health costs, and might affect agriculture if much of the particulate matter consisted of salts. The cost to Imperial County of mosquito control along 40 miles of new shoreline mosquito habitat and in 9,000 acres of treatment wetlands would be high.

Evaluation of Benefits Proposed by the Pacific Institute

We quoted at the beginning the benefits that the Pacific Institute claimed for the proposed impoundments, and they are repeated below, with our comments on each. We recognize that the intent of the Pacific Institute was, in part, to put these forward as benefits only relative to benefits or costs associated with No Action alternatives or with other proposed schemes for maintaining the environmental values of the Salton Sea.

Our comments take into account, however, that the Pacific Institute's proposed benefits will be interpreted by many as being *net* benefits defined in some more absolute sense.

Compatible with water re-allocation efforts. The impoundments would be compatible with these. However, there is an underlying presumption here that these "re-allocation efforts" are positive actions or at least politically inevitable. Many members of the evaluation team and others believe that some of them, such as the proposed water transfers from Imperial Valley to San Diego, are neither and that they will have high environmental and economic costs.

Sustainable over the long term. This is true only in the narrow sense that salinity increase over time would not be a problem as it is in the current Salton Sea and would be in a residual Salton Sea outside the impoundments. As presented the Pacific Institute Proposal is not sustainable. Only with substantial increases in infrastructure, operational and maintenance costs can it be said that once constructed, annual maintenance and operation costs *may* not be greater than those estimated for possible projects to restore the entire Sea involving evaporation and replacement waters. We suspect, however, that costs will be substantially higher and a more thorough review would bring this to light.

Increases diversity of habitats at the Salton Sea. This is true but diversity is not an automatic good. One major consequence of the increased habitat diversity will be increases in the diversity and abundance of biting insects, increases in diversity and abundance of parasites and pathogens, and increased extent of habitat where high selenium levels pose a threat to wildlife and humans.

Preserves and enhances fisheries in impounded areas. This might be more accurately stated as "Creates new fisheries in impounded areas", as neither preservation nor enhancement of what exists now is involved. From the point of view of sport fishermen and fish-eating birds the impoundment fishery would be greatly inferior to the existing fishery. The fish would not meet standards for human consumption, and their elevated selenium levels would make them more dangerous to fish-eating birds than are fish in the existing Sea.

Promotes increased recreational and economic development opportunities. This would not be true, for reasons given above. These opportunities would be diminished relative to those provided by the Sea even in its present unrestored state.

Compatible with other off-site actions. This is true of other possible restoration projects for the Sea, as well as of the No Project alternative, and does not constitute a benefit.

A Proposal to Preserve and Enhance Habitat at the Salton Sea

submitted by the

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OVERVIEW

Recent discussions and legislative efforts at the state and federal level have again focused attention on the Salton Sea. These recent discussions, on the potential impacts on the Salton Sea of a proposed water transfer from Imperial Valley to the San Diego area, have highlighted the challenges faced by those working to address the current and future problems of the Sea, and the inadequacy of any temporary or piecemeal approach. Efforts to facilitate the proposed water effort are further hampered by indications that the federal/state Salton Sea restoration effort will be unlikely to achieve its own limited goals if the water transfer is implemented.

The current problems of the Salton Sea, manifested in frequent die-offs of fish and birds, arise from a complex set of human and natural factors. These include the high concentration of nutrients in agricultural run-off (creating an overly-productive system that can rob organisms of oxygen) and the combination of a hot arid climate, a below-sea level depression with no natural outlet save evaporation, and relatively salty Colorado River water that accumulates additional salts when used to leach fields. Fish and bird mortality at the Sea is more directly linked to nutrient inputs (exacerbated by the Sea's high salinity); the inexorable rise in salinity is a future problem, one that will ultimately prove intolerable to fish in the Sea, and largely eliminating the Sea as a resource for fish-eating birds. A reduction in inflows to the Sea, due to the proposed water transfer and various other current and proposed actions, would accelerate the Sea's transition to a water body unable to support fish.

In an effort to satisfy the dual objectives of addressing the ecological health of the Salton Sea and facilitating the proposed water transfer, the Pacific Institute for Studies in Development, Environment, and Security proposes a Salton Sea Habitat Enhancement Project. This project involves the construction of long dikes at the north and south ends of the Salton Sea, in conjunction with the development of constructed wetlands along the Alamo and New rivers and the implementation of management practices to reduce nutrient loads from agricultural, municipal, and industrial sources. The diked areas would capture inflows and maintain elevation near current levels, with excess waters flowing through pipes in the dikes to the main body of the Sea. These impounded north and south shore areas would transition to brackish, estuarine conditions, preserving and enhancing fisheries and assuring a food source for fish-eating birds such as brown and white pelicans and cormorants. The stability and lower salinity of the impounded areas would also promote increased recreation and economic development. This project builds upon the recommendation included in the Pacific Institute May 2000 comments on the Salton Sea Restoration Project draft EIS/EIR.

The proposed project offers the following benefits:

1. Compatible with water re-allocation efforts
2. Sustainable over the long term
3. Increases diversity of habitats at the Salton Sea
4. Preserves and enhances fisheries in impounded areas
5. Promotes increased recreational and economic development opportunities
6. Compatible with other off-site actions

The proposed action is not a simple fix, nor would it be inexpensive. Yet it is our belief that the Salton Sea merits attention and intervention, and should not be simply ignored. It is also our belief that state and federal authorities will not be interested in repeated, small-scale interventions that do not address the root causes of the current problems afflicting the Sea, and certainly will not be interested in projects that are incompatible with California's stated objective of reducing its dependence on the Colorado River.

BACKGROUND

The Salton Sea lies 35 miles north of the U.S.-Mexico border in one of the most arid regions in North America. The Sea has the largest surface area of any inland body of water in the state of California. Presently, the Sea is 35 miles long, 9 to 15 miles wide and has a volume of roughly 7.5 million acre-feet; its surface elevation lies approximately 228 feet below sea level. The Salton Sea is a terminal lake; the only outflow for its waters is via evaporation. As water evaporates, salts, nutrients, and other elements are left behind to concentrate in the Sea. Current salinity of the Sea is roughly 44,000 mg/L, about 25 percent saltier than ocean water.

The Salton Sea provides a host of ecological values that are important not only within the Imperial and Coachella valleys but also throughout the historic reach of the Colorado River delta and the length of the Pacific Flyway. The unusually high incidence of disease and mortality currently reported at the Salton Sea threatens these values. Although the Salton Sea is a product of human activity, the Sea and its environs provide a complex mosaic of habitats, ranging from open water, estuaries, and salt marsh to mud flats and riparian corridors. These and other habitats support more than 400 species of birds and a variety of other wildlife, including endangered species such as the desert pupfish and the Yuma clapper rail. These habitats are especially vital given the destruction of wetlands throughout most of southern California and the lower San Joaquin Valley and within the Colorado River delta itself.

A series of problems confronting the Salton Sea has captured the attention of the public and policymakers. These problems include the deaths of millions of fish and tens of thousands of birds, diminished interest in the Sea as a recreational destination, the loss of shoreline and property due to rising levels of the Sea, elevated nutrient levels in the Sea causing frequent algal blooms and subsequent fish kills, and increasing salinity.

The federal Bureau of Reclamation and California's Salton Sea Authority are the lead agencies in an effort to identify potential restoration alternatives for the Sea. In January 2000, these agencies released the draft Salton Sea Restoration Project Environmental Impact Statement/ Environmental Impact Report (DEIS). The U.S. Environmental Protection Agency (EPA) and the U.S. Fish and Wildlife Service, as well as a large number of NGOs (including the Pacific Institute) and private citizens, found the DEIS to be inadequate and unsatisfactory. The lead agencies are presently developing a new set of alternatives, which are expected to focus on evaporation ponds, to reduce and stabilize salinity.

The goals of the Restoration Project are:

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

The Pacific Institute's February 1999 report entitled *Haven or Hazard: The Ecology and Future of the Salton Sea* set out a series of principles to guide any intervention at the Sea:

1. The primary goal of any restoration plan must be to provide for a healthy ecological system and protect human health.
2. Any restoration plan should be firmly grounded in a scientific understanding of the ecology of the Salton Sea and related ecosystems.
3. Any restoration plan should address all of the water quality factors responsible for the current problems at the Salton Sea.
4. Parties responsible for the current problems facing the Salton Sea and beneficiaries of its restoration should bear an equitable share of the costs.
5. Any restoration plan must be compatible with region-wide water conservation and voluntary reallocation programs.
6. Any restoration plan for the Salton Sea must be compatible with protection and restoration of the Colorado River delta, the upper Gulf of California, and other ecosystems in the region.
7. The Restoration Project must be transparent, inclusive, and fully integrated with other actions impacting the Salton Sea.

Inflows

Calculated annual inflows to the Salton Sea averaged 1.36 million acre-feet (MAF) from 1950-1997. An estimated 85 percent of these inflows come from agricultural sources. The Salton Sea Restoration Project DEIS (January, 2000) lists 19 past, present, and reasonably foreseeable future projects that could impact the quantity and quality of inflows to the Salton Sea, many of them due to the implementation of measures to conserve agricultural water. The actions that could reduce inflows to the Salton Sea include the Imperial Valley-San Diego area water transfer (the planned rate of transfer is expected to increase by 20,000 AF/year, to a minimum of 130,000 AF/y and a maximum of 300,000 AF/y), reductions in wastewater flows from Mexico (23,000 AF/y), and reduction in seepage from the lining of the All-American Canal (23,000 AF/y) and Coachella Canal. The net impact of these various actions would be to reduce the quantity of water flowing into the Salton Sea. The Salton Sea Reclamation Act of 1998 similarly recognizes the likelihood of such reductions, directing the Secretary of the Interior to

> apply assumptions regarding water inflows into the Salton Sea Basin that encourage water conservation, account for transfers of water out of the Salton Sea Basin, and are based on a maximum likely reduction in inflows to the Salton Sea Basin which could be 800,000 AF or less per year.

Elevation

The current surface elevation of the Salton Sea is about 228 feet below sea level (elevation fluctuates annually by as much as a foot due to seasonally varying inflows and evaporation rates). The Sea's current elevation supports an extensive array of shoreline habitats that in turn support a great diversity of birds and other wildlife. Reducing the elevation of the Sea could adversely impact much of this habitat, and would also expose a land bridge connecting Mullet Island, an important rookery, exposing nesting birds and their chicks to predation. Reducing the elevation of the Sea could also isolate populations of pupfish in agricultural drains by limiting their ability to move back forth through the Sea. Some recreational uses of the Sea require a stable elevation, for the construction of recreational facilities such as piers and boat-loading ramps, though the actual elevation itself is less important. Economic development similarly requires a stable elevation, presumably one that would not reduce the value of existing properties.

Seismicity
The Salton Sea lies in a very seismically active region. Since 1900, 15 earthquakes measuring 6.0+ on the Richter scale and another 53 of estimated magnitude 5.0+ have occurred in or near the Salton Sea, according to the U.S. Geological Survey. The west side of the Salton Sea is moving at about 8 cm/year relative to the east side, and the ground level on the south shore of the Sea is subsiding at a rate of more than 2 cm/year. This would affect structures such as dikes built in the area, increasing maintenance costs and potentially compromising their long-term integrity and resilience in the face of earthquakes.

Socioeconomics
According to a recent economic study from U.C. Riverside by Bazdarich, the total value in 1998 of all Salton Sea properties within ½ mile of the shoreline was $154.8 million. Total population within five miles of the Salton Sea, estimated from 1990 census tract data, is fewer than 15,000 people. Restoring recreational uses applies to a broad population base, potentially drawing visitors from San Diego and Los Angeles and points further. Recreational sites at the Salton Sea include various bird-watching, fishing, and duck-hunting areas around the Sea, as well as the Salton Sea State Recreational Area around the northeast of the Sea, and the Sonny Bono Salton Sea National Wildlife Refuge at the southeast end.

Salinity
The threat that increasing salinity poses to fish is one of the driving forces of the Salton Sea Restoration Project. Loss of all or parts of the Salton Sea fishery would have profound impacts on fish-eating birds, such as brown and white pelicans and cormorants, that rely on the Sea for food. Loss of fish from the Sea would also eliminate the sport-fishery and decrease opportunities for recreational and economic development. Yet increasing salinity is a natural phenomenon for terminal lakes such as the Salton Sea, meaning that efforts to reverse such increases will require continuous intervention and management.

Salinity of the Salton Sea is reported at 44,000 mg/L, roughly 25 percent saltier than ocean water. The salinity at which fish would no longer be able to survive in the Sea is not known, though it is probable that in the next 5-20 years, salinity will rise to the point where fish are no longer able to reproduce in the Sea, and eventually are unable to survive at all. The endangered desert pupfish reportedly can tolerate much greater salinity than the other species in the Sea, but eventually its salinity tolerance will be exceeded as well. The loss of the Sea's fishery would have profound impacts on the host of fish-eating birds that depend on the Sea as a stopover, including brown and white pelicans and cormorants.

Nutrient Loading
The Salton Sea suffers from the misperception that it is dying. The opposite is closer to the truth: the Sea is an extremely productive body of water. Local authorities claim that the Salton Sea may be the most productive fishery in the world. Several factors contribute to this productivity, the most important of these being the extremely high levels of nutrients present in the water flowing into the Salton Sea, creating eutrophic conditions. These nutrients are used in fertilizer and are also present in effluent from dairy and cattle operations, as well as in municipal and industrial effluent. Nutrient-rich conditions promote algal growth and conditions conducive to the transmission of disease. Algal respiration and the decomposition of dead algae consume large quantities of oxygen, decreasing concentrations of dissolved oxygen (DO) in the Sea, asphyxiating fish.

Selenium
Selenium toxicity can lead to reproductive failure, deformities, and death among aquatic organisms and birds, and can also adversely affect people. The Sea provides subsistence fishing for Native Americans and may also contribute to a significant portion of the diet of others in the area, despite the California Health Advisory Board's posted warning discouraging people from consuming more than four ounces of Salton Sea fish in any two-week period. Preliminary studies show increased selenium levels in white and brown pelicans, and that increased selenium levels may suppress the functioning of avian immune systems, making them more susceptible to disease.

The proposed project could exacerbate selenium-related problems at the Sea, due to the construction of the dikes. Such construction would disturb the Sea floor, resuspending selenium and other contaminants found there, some of which would enter the food chain.

THE DIKING ALTERNATIVE

The Salton Sea is a terminal body of water – it has no outlet. While water itself evaporates from the Sea, salts and nutrients and other contaminants are left behind to concentrate. Most of the proposed solutions for the Sea would create an outflow of some kind, via pipelines, evaporation ponds, or via impounded areas within the Sea itself. Diking options have been around for many years – they vary based on the size and number of dikes and impounded areas, but the basic principle is the same: provide an outlet from an impounded area to another area where contaminants will concentrate, creating a flow-through system for at least part of the Sea.

The proposed alternative involves constructing dikes within the Sea near the north and south shores to capture inflows and stabilize elevation at –230 feet. Water above elevation –230 feet would flow via gravity through pipes in the dikes to the main body of the Sea. Such a gravity-fed system requires a reduction in inflows. The impounded north and south shore areas would transition to brackish, estuarine conditions. Actual salinity in these impounded areas would depend on several factors, including the volume and salinity of inflows (salinity of the Alamo and New rivers is currently about 2,900 mg/l) and the total volume of the impounded area. Varying or reduced inflows would impact the central portion of the Sea, but would be expected to have lesser impacts on the impounded areas. The central portion of the Sea would transition to a hyper-saline body, at a rate faster than would occur without the dikes. Such conditions would eliminate fish from the main body of the Sea, though invertebrates such as brine shrimp and brine flies would thrive there, providing a food source for many species of waterbirds.

Dikes would be constructed along the -240 foot contour at the north end of the Sea to impound the Whitewater River, and along either the -240 foot or -245 foot contour at the south end of the Sea, to impound waters from the Alamo and New rivers, San Felipe Creek, and agricultural drains. Determination of the preferred location would be influenced by biological and cost considerations: further investigation is required to determine the additional benefits associated with a fifteen foot deep (at -245') versus a ten foot deep (at -240') impoundment. The eastern extent of the southern dike could join the shoreline either near Bombay Beach (protecting Mullet Island), or further south, near Wister. The western extent of the dike could be configured to exclude San Felipe Creek, limiting predation of desert pupfish that use that habitat. For an indeterminate period, desert pupfish would be expected to colonize a Sea that exceeds the salinity tolerance of other fish.

The following table shows the estimated length of the dikes, and the area and volume of water that they would impound, and estimated costs of each.

Dike Location	Length (miles)	Impounded Area (acres)	Impounded Volume (AF)	Est. cost ($)
North End	7	2,000	9,000	$42,000,000
South End at -240'	29	10,500	47,000	$175,000,000
at -245' to Wister	28	20,500	143,000	$250,000,000
at -245' to Bombay Beach	38	26,000	181,000	$340,000,000

Costs are based upon estimates included in Parsons' *Analysis of Salton Sea Restoration Plans* and in the Salton Sea Restoration Project draft EIS/EIR and should be considered as preliminary at best. The Parsons report recommends a dike with a crest width of 20 feet, 5 feet of freeboard (above the water surface), and sunk 5 feet into the sea floor. Parsons also recommends a slope of 3.5:1 for in-Sea dikes, to increase stability in the face of earthquakes. The crest of the dike could be built to allow bicycle and pedestrian traffic, and potentially motor vehicle access to bird-watching sites, fishing piers, and boat docks at appropriate areas. The Salton Sea Authority and the Bureau of Reclamation have identified potential borrow sites in nearby areas for the estimated material required for the dikes.

The resulting impounded areas behind the dikes would be coupled with treatment wetlands, to reduce nutrient and selenium loading, and with the implementation of management practices to reduce nutrient loads from agricultural, municipal, and industrial sources. Because the proposed diking alternative is not dependent on existing quantities of inflows, such treatment wetlands would not have a harmful impact on the Sea itself. A series of constructed wetlands along the lengths of the Alamo and New rivers would improve the quality of water entering the Sea. Additionally, the impounded areas would be more amenable – because of the smaller size of the water body itself and the increased ability to flush accumulated nutrients from the sub-system – to the proposal to treat inflows with alum, binding phosphates (the limiting nutrient at the Sea).

Treatment wetlands would serve the additional function of reducing the amount of sediment deposited into the Sea. The implementation of on-farm conservation efforts and reductions in inflows are expected to reduce the volume of sediments entering the Sea by as much as a third over time, increasing the time before sediments fill the impounded areas. To further reduce the inflow of sediment to the Sea, small weirs could be constructed at appropriate locations along the Alamo and New rivers, promoting deposition of sediment behind the structures, potentially aerating water that flows over the weir, and encouraging the growth of emergent wetlands.

Considerations

The impounded areas within the Sea, and the constructed wetlands, would require monitoring and management to ensure that contaminant levels do not rise to dangerous levels. Such impounded areas would strand most of the existing shoreline communities and the State Recreation Area as the elevation of the main body of the Sea decreases, potentially necessitating compensation for property owners. A large seismic event could cause a major rupture in the dike, potentially sufficient to allow some or all of the impounded water to flow into or mix with the central portion of the Sea. Repairing the ruptured area would permit the re-filling (or flushing, if water from the central portion of the Sea mixed with the impounded area) of the impounded area. The loss of most of the fishery would decrease the availability of food for open-water fish-eating birds, such as pelicans and cormorants, though the impounded areas would continue to provide a source of fish for these birds.

Conclusion

The objective of the proposed diking alternative is a project that is sustainable over the long-term, preserves and enhances ecological values and promotes recreational and economic development opportunities, while being compatible with water re-allocation efforts and other actions that could reduce inflows to the Sea. If implemented, such a plan could result in a southern impoundment with a variety of recreational opportunities, including fishing, duck hunting, and bird-watching, across a huge expanse of open water. Shoreline habitat would be preserved; the estuarine conditions could promote increased productivity and support a greater diversity of marine species, linking to vibrant riparian corridors and wetland habitats in the Alamo and New rivers. The northern impounded area could support similar diversity, or could be managed to stabilize at a different salinity, potentially sustaining a different array of species. The central portion of the Sea could transition to a water body with a productive invertebrate system, feeding a host of other waterbirds.

Such a limited approach would satisfy a narrow interpretation of the stated goals of the Salton Sea Restoration Project and the Reclamation Act, though it would not address the condition of the Sea as a whole. Yet such a limited approach, if implemented in conjunction with efforts to limit inflows of nutrients and selenium, could preserve a significant amount of avian habitat and promote recreational and economic development in the immediate area.

Appendix B

Salton Sea Science Advisory Committee

Salton Sea Advisory Committee
Membership
January 2002

Albert Johnson	Professor Emeritus, San Diego State University
Philip Roberts	Professor and Dean, University of California, Riverside
Tim Krantz	Professor, University of Redlands
Bart Christensen	CalEPA /State Water Resources Control Board
Glenn Black	The Resources Agency/ California Dept Fish and Game
Rey Stendell	U. S. Geological Survey

Appendix C

Science Advisory Committee meeting summary

BACKGROUND – SAC MEETING

The following highlights from our discussion of the Pacific Institute Proposal are provided for your deliberations. There were three primary areas of comment – general considerations, general areas for focus and specific issues.

General Considerations

1. The purpose is not to support or reject the Pacific Institute proposal but rather to evaluate the information provided for the purpose of identifying scientific questions associated with the proposal.

2. The Salton Sea Science Office seeks input in the form of a document by the SAC that identifies primary areas where additional evaluations are needed (issues) and recommendations for obtaining those evaluations (i.e. workshops, specific experts or small groups to address specific issues or questions, etc.) to provide a basis for a scientific critique of the proposal.

3. Political and other non-scientific considerations associated with the proposal are not a focus for the Science Office in developing your response.

General Areas For Focus

The following subject areas were identified from the initial proposal discussion and should be considered as areas for general consideration:

1. Causes of fish and wildlife mortality
2. Nutrient reduction processes and amounts
3. Fishery (composition and biomass)
4. Feeding by fish eating birds
5. Recreation (types and compatibility with avifauna needs)
6. Economic development (types of activities and compatibility)
7. Salinity levels (what will they be and when achieved)
8. Monitoring program (who and what)
9. Physical processes (changes from current conditions)
10. Inflows (quality, volume)
11. Water circulation problems
12. Maintenance of shoreline conditions within impoundments
13. Degradation processes
14. Location of dikes relative to encompassing current areas of biological importance

Specific Issues

The following 9 issues and questions associated with those issues resulted from the general preliminary discussion that took place. These can be included, modified, added to, discarded or otherwise adjusted in the report to the Science Office.

1. Issue – Fishery Evaluations

   Several questions need to be evaluated relative to the ability of the proposal to provide for a fishery within the impounded areas.

   a) What species will the proposal impoundments sustain? The issue here is the life cycle needs of species.
   b) What will be the biomass of the fishery relative to providing a food base for fish eating birds?

c) Will the impoundments provide for the invasion of new species and if so will competition cause shifts in the species composition of the fishery?
d) Will the current fish populations be able to adapt to the reduced salinity of the impounded waters?

2. Issue – Food base for birds

The basic issue is what type of changes in the food base for birds of the Sea will occur and how will those changes offset various species of birds.

Will there be qualitative (nutritional values) changes in the food base due to changes in the food chain? If so how will those changes impact the bird life?

Will there be quantitative difference in the food base? Will the food base be sufficient to provide for the bird populations currently present?

Will the foraging behaviors and strategies of birds presently using the Sea be accommodated by the habitat provided within the impoundments?

3. Issue – Disease considerations

Historically, classical type C avian botulism was a significant cause of bird mortality in the deltas of the New and Alamo Rivers. This situation no longer exists, perhaps because of increased salinity. Also, avian botulism was the only disease present for decades. This is no longer true.

a) Will the impoundments revert to environmental conditions that facilitate the occurrence of classical type C avian botulism?
b) Will the impoundments enhance or decrease the potential of bird losses from other diseases currently present?
c) Will the impoundments provide an environment that enhances or decreases the potential for fish disease; either the pathogens currently known in fish such as the parasite Amyloodinium or the bacteria Vibrio, or provide for invasion of new pathogens from fish populations within the drains?

4. Issue – Main body of the Salton Sea

The degradation of the main body of the Sea will involve a continuum of change involving a large area. The outcomes from those changes need to be fully appreciated.

What will be the time sequence for the loss of the fishery and invertebrates currently fed upon by birds?

How long will it be before a new food base for birds such as brine flies and brine shrimp is available?

What outcomes are likely from the large mass of dead fish and algae that will occur?

How will the changing water chemistry affect algal growth and other biological processes within the discarded portion of the Sea?

5. Issue – Salinity levels within the impoundments.

The chemistry of the northern and southern wetlands will be different due to differences in the quality of input waters, the differences in sizes of these impoundments and volume of water flowing into them.

a. What levels of salinity are wanted?
b. Can the desired salinity level(s) be maintained?
c. What are the time sequential changes that will occur in salinity as the impoundments are being created and after they have been completed?
d. What are the biological impacts relative to item c?
e. See disease issue

6. Issue - Recreation/economic development/economic impacts

The smaller sized area available for the activities stated to result in benefits from the proposed project raise a number of questions.

Are the stated use compatible activities with one another and with the level of disturbance tolerated by the species of birds currently using the Salton Sea?

Will bird concentrations within the smaller area available be such that they negatively impact water quality?

Will these impoundments become “contaminant sinks” that result in elevated wildlife body burdens of chemicals that are incompatible with recreational use of the fish and birds?

7. Issue - Flow rates/volume

The hydrology and dynamics of the impoundments will be different than that of the Salton Sea. Significant questions needing to be evaluated include:

a. Sedimentation rates
b. Contaminant loading
c. Water retention time (turnover)
d. Water temperature
e. Circulation
f. Invertebrate population (spatial distribution and abundance by time of year)
g. Fish lifecycle needs
h. Seasonal changes in salinity

8. Issue – Constructed Wetlands

The proposal calls for constructed wetlands for nutrient and selenium reduction to be built in conjunction with the impoundments.

a. How many wetlands of what size and how far from the impoundments?
b. What is the spacing between wetlands?
c. How much water loss will occur as the water passes through those wetlands?
d. Will the wetlands concentrate contaminants in a manner that they are biologically available to the fauna present?
e. What nutrients are to be reduced?
f. Are the wetlands permanent throughout the year or transient?
g. How will these wetlands effect the species present and spatial distribution of numbers of those species?
h. Are these wetlands to be used for recreation, if so what types and how compatible are those uses with current bird usage of the Salton Sea?

9. Issue – Constructed Wetlands

Among other questions that need to be explored the following were identified during our dialogue:

a. What are the fate and transport patterns of selenium within both the constructed wetlands and impoundments?
b. Will movement patterns of desert pupfish be altered in a manner that leads to genetic isolation?
c. Will the impoundments result in habitat changes that enhance or suppress desert pupfish populations?

d. What percentage of the snag habitat used by birds at the Salton Sea will be encompassed within the impoundments? Are there any biological impacts involved?

To assist with the evaluation, the University of Redlands Salton Sea Database Program will provide a map showing the geographic locations for the proposed enclosures. Because Mullet Island is an important nesting island the location of that island will be clearly shown on the map.

The highlights contained in this document were developed from the flip chart pages from our meeting. I have tried to capture the content of our discussion in outline form and hope that this document faithfully reflects that dialogue and places it in appropriate context. All adjustments are welcome.

Milton Friend

Appendix D

Guidance to Focus group and Workshop Members

Dear Evaluator

Thank you for taking the time out of your busy schedule to assist us in the very important task of providing a preliminary evaluation of a proposal for establishing wetland impoundments at the Salton Sea. We have sought your assistance because of your knowledge and because we feel you an objectively apply that knowledge to the task at hand of providing a highly focused evaluation.

The process you are involved with is a first level evaluation leading to the integration of various ecosystem components into a holistic understanding of the probable outcomes associated with the proposed project if built as currently described. That integration will take place during a January 8, 2002 workshop open to the public. The potential for that workshop to achieve its goal of providing a defined understanding of the probable project outcomes is highly dependent upon how well the various small working groups are able to define their subject area outcomes.

The following guidance is provided for your task:

1. Make assumptions during your evaluations to avoid bogging down in unknowns. Assumptions should be reasonable and have a basis for the situation in question. Document the assumptions and basis for them. That will facilitate appropriate adjustments if the integration workshop or additional information at a later time suggests that adjustments should be made.

2. If Michael Cohen is available by telephone, contacts with him may clarify the intent of statements in question within the proposal.

3. Using the project and physical environment descriptive information provided as a basic foundation, evaluate the function and outcomes of the wetland enclosures from a perspective of your working group area (e.g., hydrology, biology, etc.). In doing so focus on the following key aspects:
   a) Develop detail relative to the results of wetland environments that are created (may differ for the different areas) and for the area of the Sea outside of the wetland enclosures. These evaluations are restricted to your group area (e.g., biology-the following groups of birds will…). In doing so, it may be useful to include a comparison with present conditions.

   b) Identify major benefits that may result (e.g., biology-the invertebrate diversity will…).

   c) Identify issues deemed to be important (e.g., water quality-water temperatures will…).

   d) Identify unknowns that may result in significant changes (positive and negative) in project outcomes.

4. Prepare separate lists as key points for each of the categories identified in item 3 above. For each key point, highlight (as additional key points) why the item identified is a key point.

5. Separate lists should also be developed for questions/issues that arise relative to the interface of your work group subject area with that for other subject areas and for items considered, but discarded.

6. An especially difficult area to deal with is the transitions that will occur between current conditions and the proposal being in place if built. The best that can probably be done is to offer general comments of what needs to be considered during that interim period.

7. No formal report will be developed by the working groups. The critical key point lists for each group will serve as the record of discussions. Those same lists will be used by each group presenter as the primary presentation points for the January 8 workshop.

8. Initial thoughts for the January 8 workshop agenda are provided with the enclosed draft. Initial thoughts for the working group presentations at the January 8 workshop are:
   a. Maximum 15-20 minute presentation per group.
   b. Start presentation with identification of the subject area and who the evaluators were. Provide very brief highlights of their specific areas of expertise relative to the subject matter being evaluated.
   c. Follow with a brief overview of the process used by the group.
   d. Identify items considered but discarded, and why.
   e. Conclude by posting pre-prepared flip chart key point lists. Provide handouts for the audience of the same lists. Comment on items that need explanation and to provide additional highlights for specific items but do not comment on items that can be read from the list that do not need further explanation.

9. No questions will be allowed during the presentations or following them. Each group will complete their presentation to provide a posting (and handouts) of all the pieces to provide a framework for the discussions that will follow.

10. Following a break, the panel will begin internal dialogue to interface the information and make adjustments needed. The facilitator will keep the dialogue focused and use his/her discretion when to call upon others known to be in the audience or when to open dialogue on any aspect of the discussion to the general audience.

11. The basic objective of the workshop is to obtain general agreement that the key points identified or as adjusted provide a reasonable representation of the likely outcomes if the proposed project is completed to identify any major areas of disagreements, and to identify and include additional key points that may have been missed during the small working group evaluations.

12. A preselected individual will transform the dialogue of the workshop into a report of findings. That person will also provide a summary of highlights from the day to conclude the workshop. The panel and the Science Advisory Committee will be provided with the report of findings for review. They will provide their comments directly to the preparer of the report who will consider those comments and provide a final report to the Science Office within 45 days following the workshop. The Science Office will post the report on the Bureau of Reclamation website within 10 working days following receipt. The additional time is needed for the Science Office to resolve any questions or seek clarity on statements.

Appendix E

Four Graphical Representations of dike placement and water elevation changes associated with assumed water transfers and implementation of Pacific Institute Salton Sea Restoration Proposal. Maps produced by University of Redlands, Salton Sea Database Program. (Four map graphics follow this page.)

Salton Sea Restoration Project
Dikes at -240 Elevation
No Additional Treatment Wetlands


Salton Sea Restoration Project
Dikes at -240 Elevation
Assuming 6.4% Loss Via Treatment Wetlands
Sand Bars
Johnson Island
West Whitewater Rookery
76th Avenue Powerline
81st Avenue Snags
Oasis
North Shore
Salton Sea State Park Boat Landing
Corvina Estates Boat Launch
Desert Shores Boat Launch
Desert Shores
Salton Sea Beach Marina
Johnsons Landing
Salton City
Bombay Beach Rookery
Bombay Beach
Bombay Marina
Salton Sea State Park
Mallard Road Rookery
Wister Waterfowl Management Area
Ibis Road Rookery
South Ibis Road Blinds
Wister Blinds
Niland
Sonny Bono Salton Sea National Wildlife Refuge (SBSSNWR)
Red Hill Marina
Mullet Island
Old Alamo River Channel
Red Hill Snag Field
Impoundment Area
Obsidian Butte Island
Lack/Lindsey Rookery
Calipatria
Vail Ranch Rookery
New River West Ext
Poe Group C
West Trifolium 1 Drain
New River
Ramer Lake Nor
Test Base Pier
San Felipe Rookery
Salton Sea Test Base
Anza-Borrego Desert State Park
Salt Creek
111
86
78

Salton Sea Restoration Project
Dikes at -245 Elevation
No Additional Treatment Wetlands

Salton Sea Restoration Project
Dikes at -245 Elevation
Assuming 6.4% Loss Via Treatment Wetlands

Appendix F

Draft Hydrologic Modeling of the Pacific Institute Salton Sea Restoration Concept

Pacific Institute Impoundment Proposal

Paul A. Weghorst, PE
Bureau of Reclamation
January 8, 2002

Purpose

- *Characterize hydrologic conditions*
  - **Main Sea**
  - **South Impoundment**
  - **North Impoundment**

(Both impoundments evaluated with dikes constructed at –245 feet)

General Modeling Assumptions

- *Reductions in inflow will occur*
  - **Start at baseline = 1.24 maf/yr**
  - **Future inflow = 1.00 maf/yr**
    - Approximates possible reductions from water transfers
    - Consistent with evaluation of other restoration alternatives
- *Simulation Period: 2000 to 2074*
- *Dike Construction*
  - **Constructed In Water**
  - **Dikes Closed in 2007**

Sediment Load Assumptions

- *Sediment Load Rate = 0.53 tons/af*
  - **From Draft Report:**
    - Sedimentation / Siltation Total Maximum Daily Load for the Alamo River
  - **Assumed same for New, Alamo, and Whitewater Rivers**
- *Sediment Density = 1.2 tons/yd^3*
- *Impoundment trap rate = 100 percent*

Nutrient Load Assumptions

- *Nutrient Loading for 1999 [1/] Prorated According to Annual Inflows*
  - **Total N**
  - **Total P**

1/ Source: Setmire, Jim et al., 2001. Eutrophic Conditions at the Salton Sea. A Topical Paper From the Eutrophication Workshop Convened at the University of California at Riverside, Sept. 7-8, 2000.

Wetlands Assumptions

- *Water Losses = 0.8 * Pan Evaporation [1/]*
- *Surface Area Requirements*
  - **Based on Imperial Wetlands Requirement = 0.012 acres/af**
- *Sediment Removal = 90 Percent [2/]*

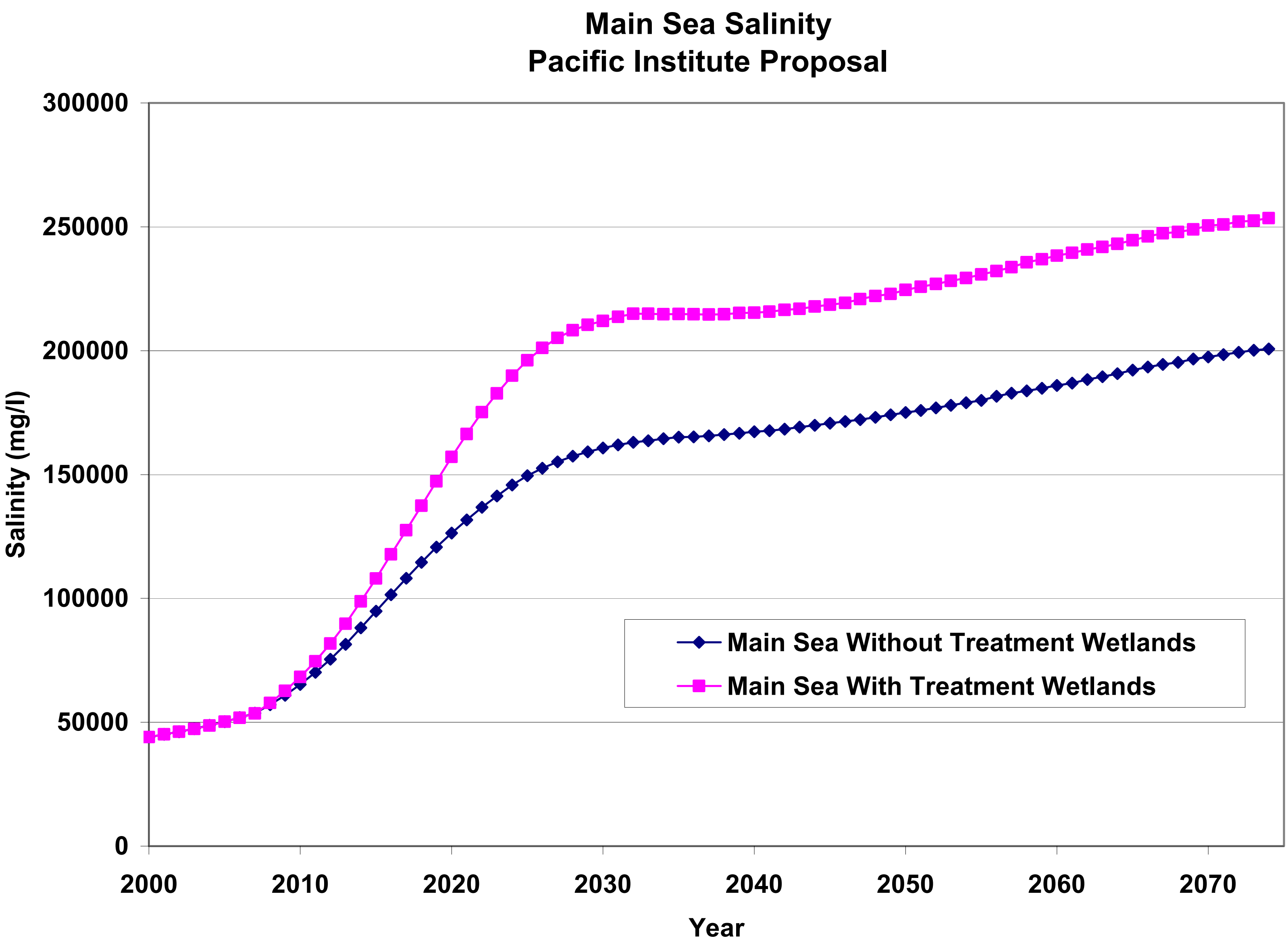
- *Nutrient Removal* [3/]

– **Total N Removed = 34 %**
– **Total P Removed = 11 %**

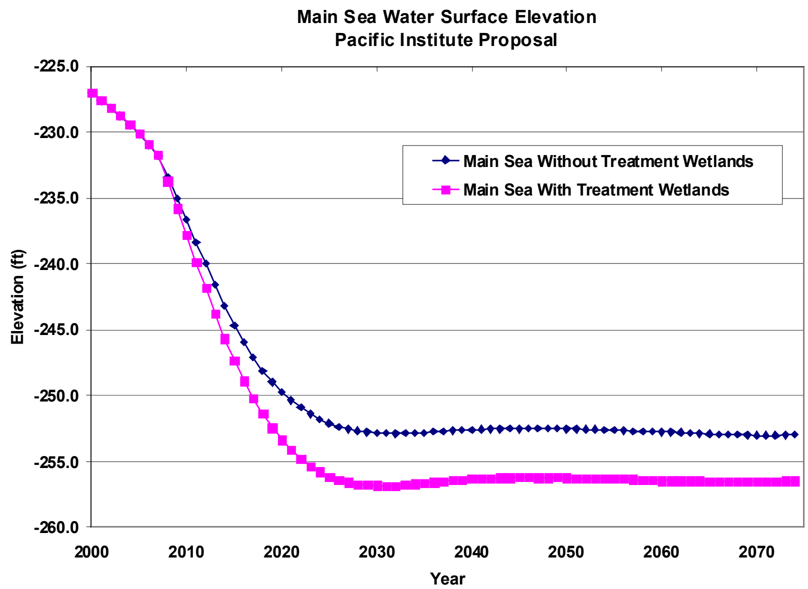
1/ Source: Kadlec, R.H., and R.L. Knight. 1996 Treatment Wetlands. Lewis Publishers, Boca Raton, FL.
2/ General observation of data collected at Imperial and Alamo Wetlands
3/ Personal communication from Jim Sartoris, USGS, Mid-continent Ecological Science Center – unpublished data

Main Sea Simulation Simulation Results

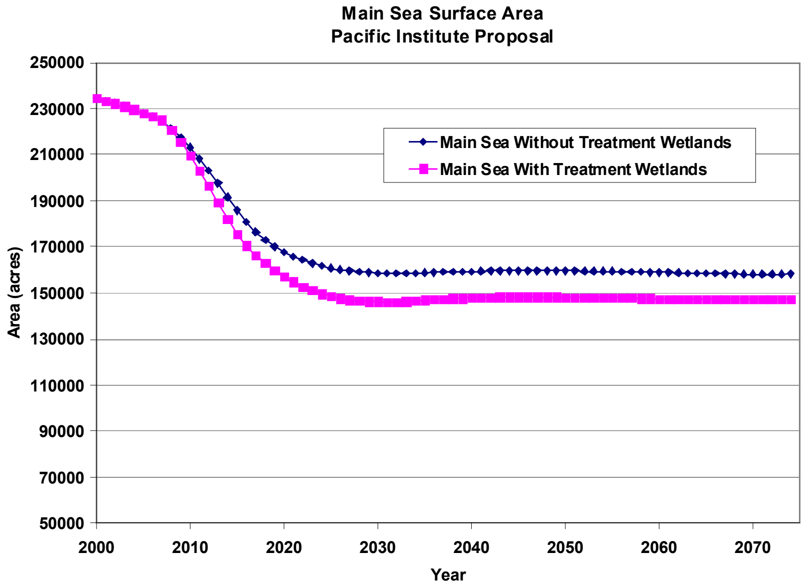
(Based on Application of the Bureau of Reclamation's Salton Sea Accounting Model)



Main Sea Water Surface Elevation

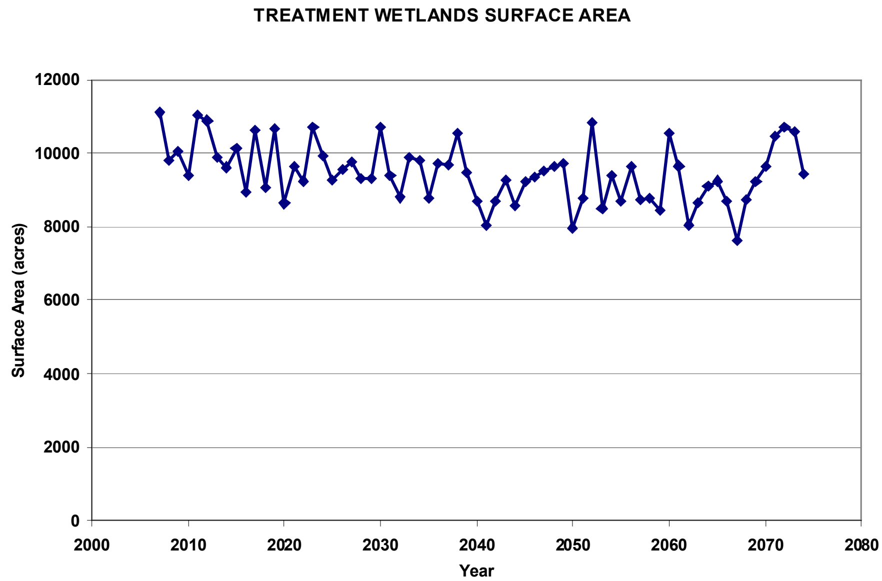


Main Sea Surface Area

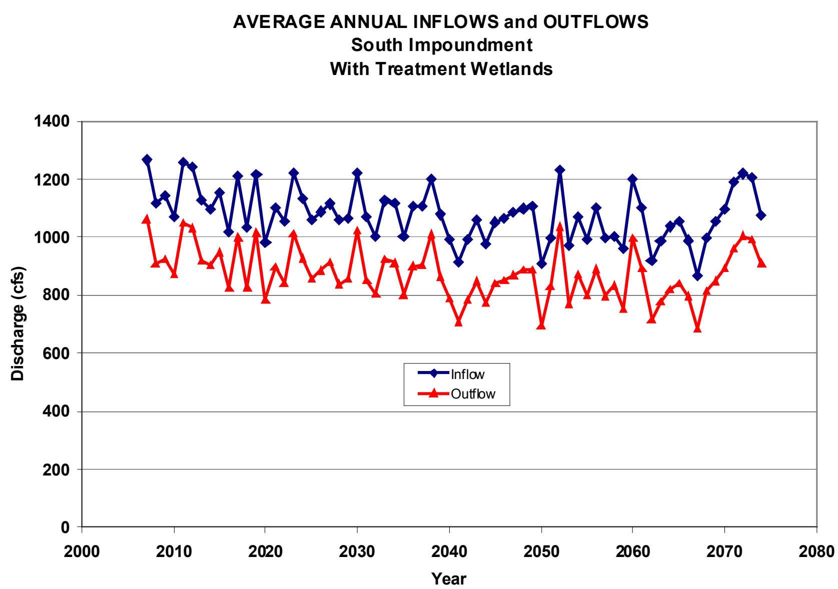


South Impoundment Simulation Results

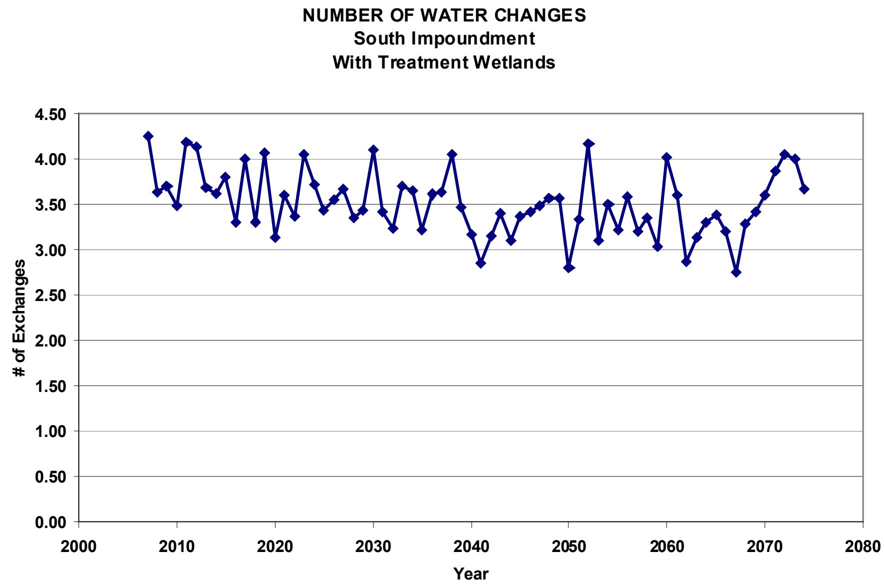
Wetlands Surface Area Requirements



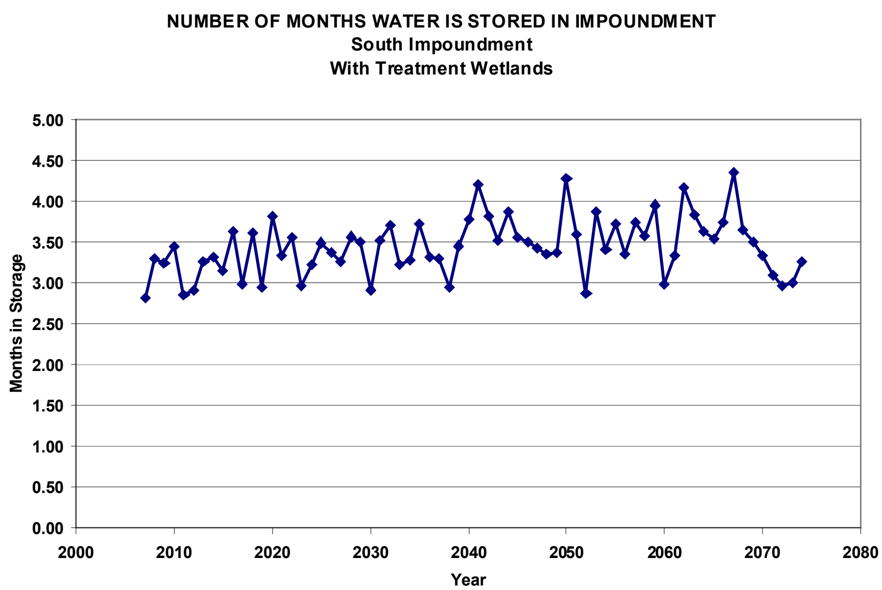
Inflows/Outflows: South Impoundment



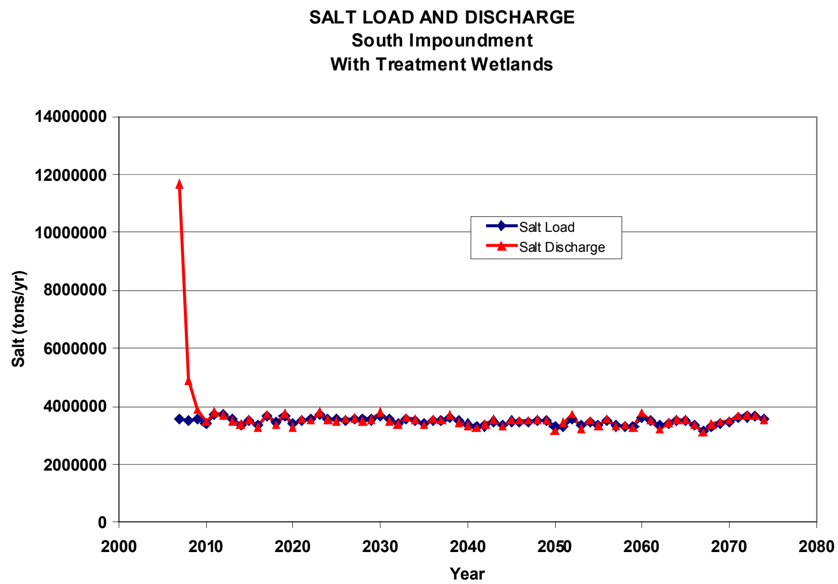
Water Exchanges: South Impoundment



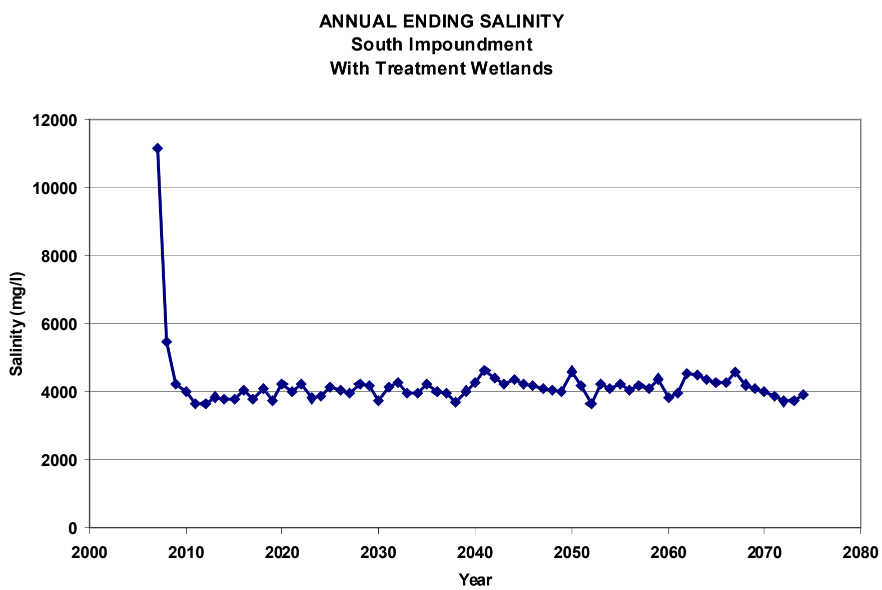
Months in Storage:South Impoundment



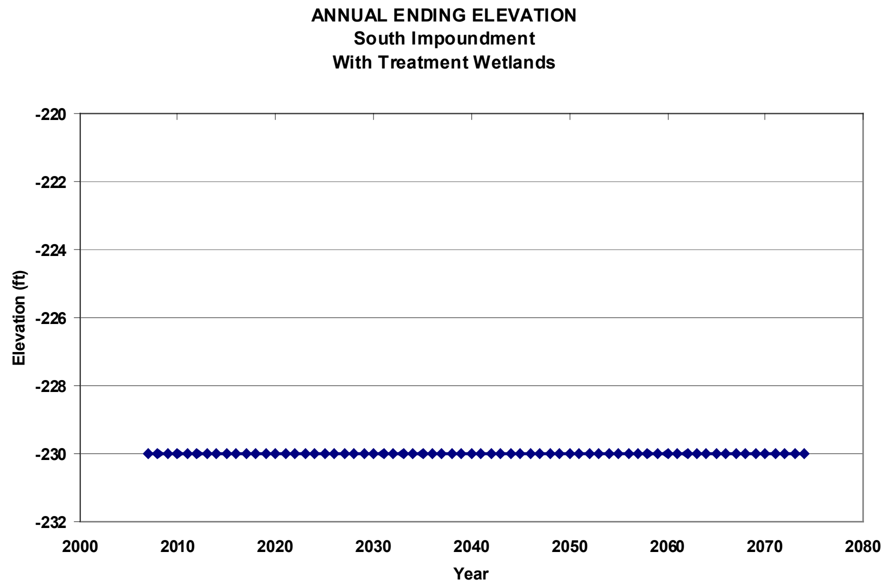
Salt Load and Discharge: S. Impound.



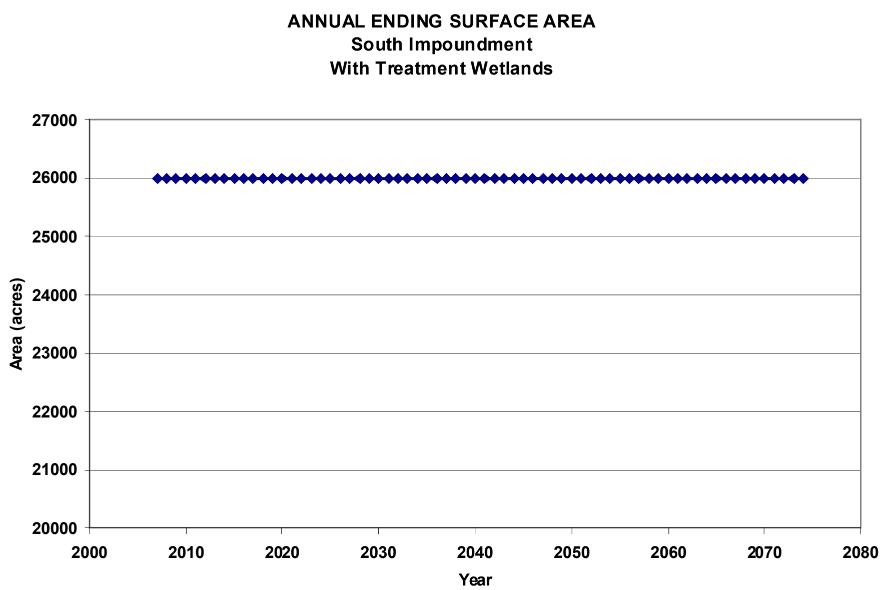
Salinity: South Impoundment



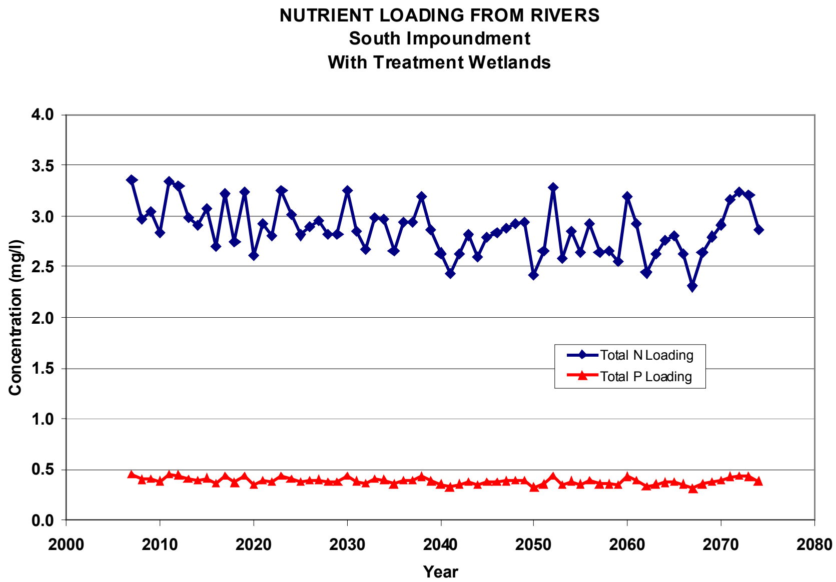
Elevation: South Impoundment



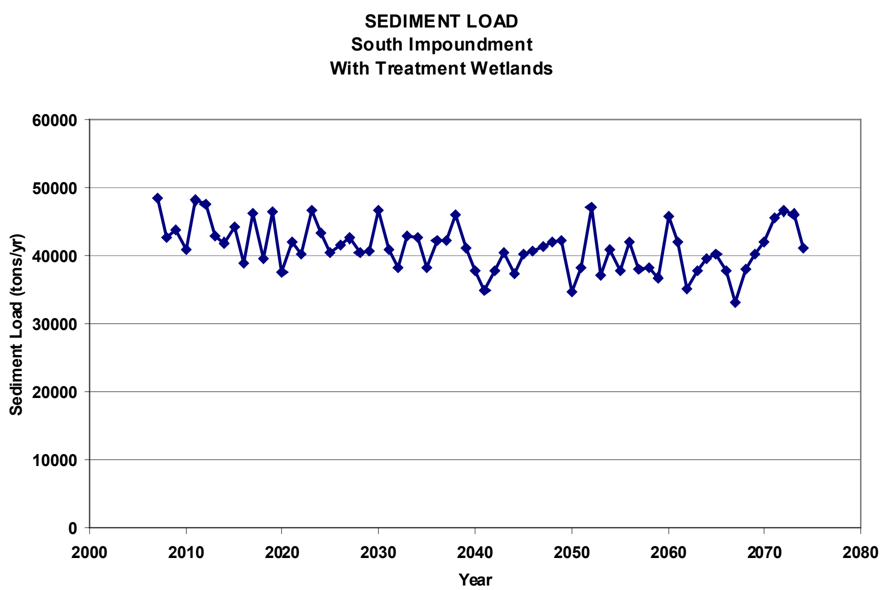
Surface Area: South Impoundment



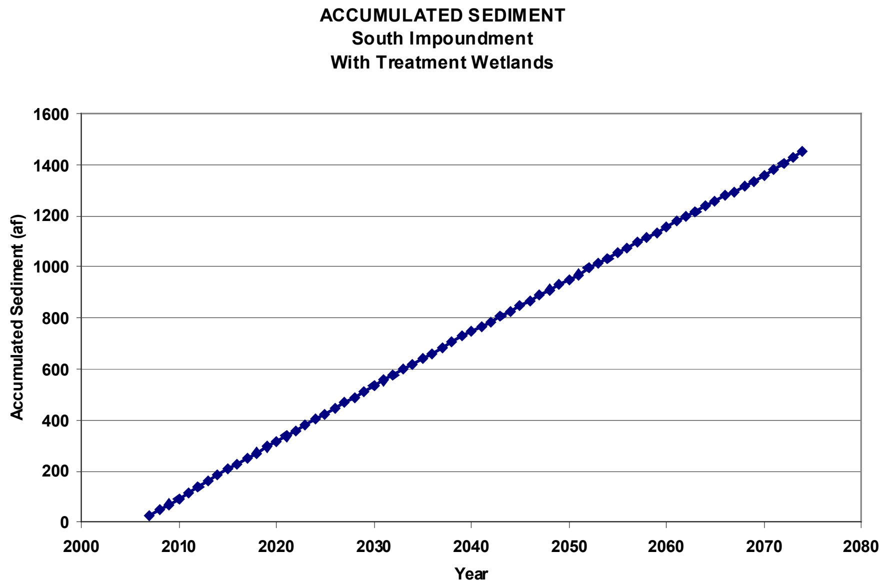
Nutrient Load: South Impoundment



Sediment Load: South Impoundment

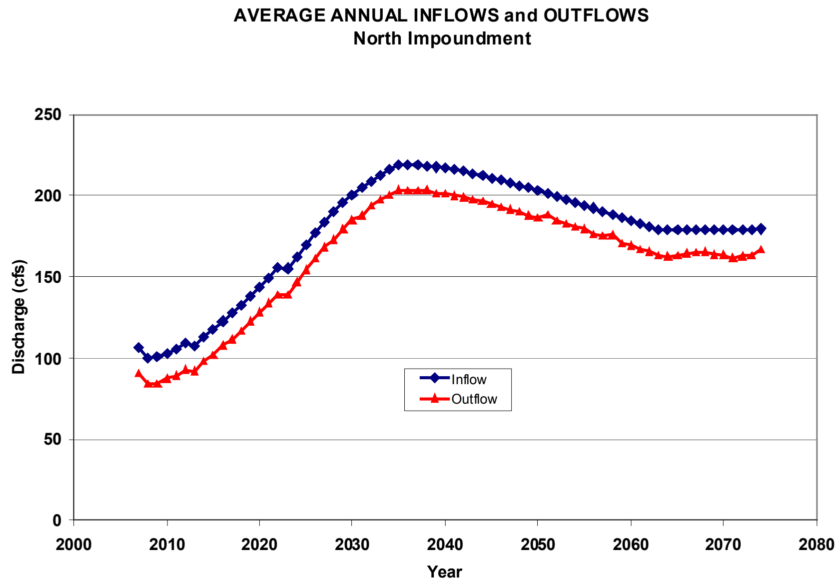


Sediment Trapped: S. Impoundment

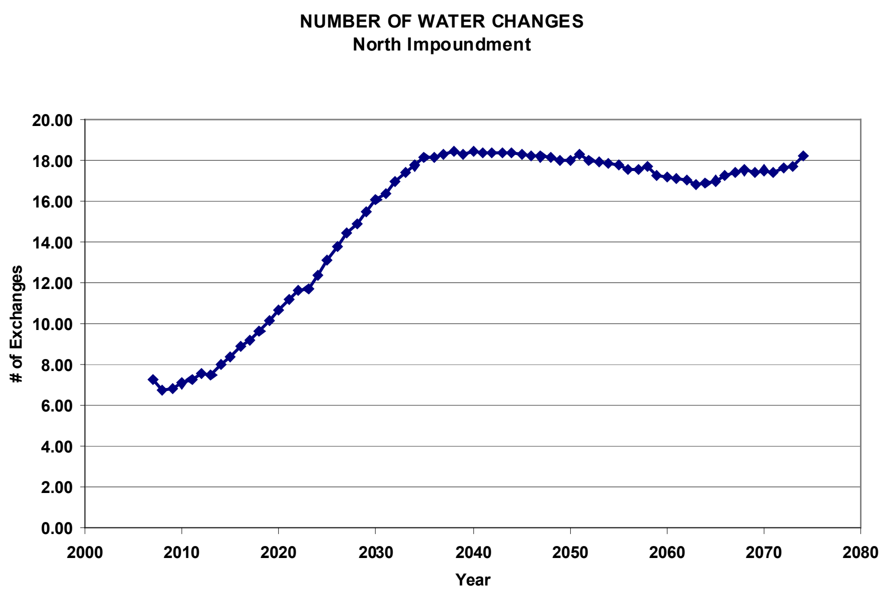


North Impoundment Simulation Results

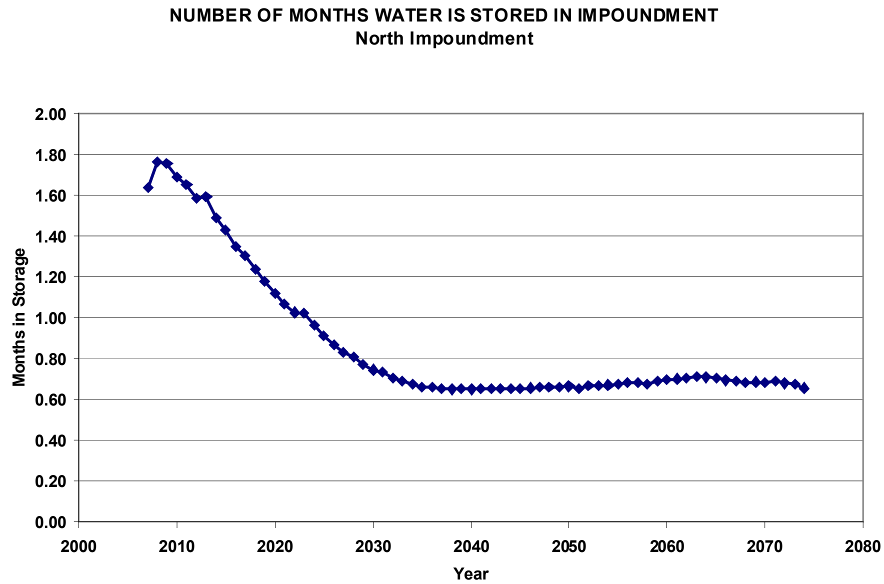
Inflows/Outflows: North Impoundment



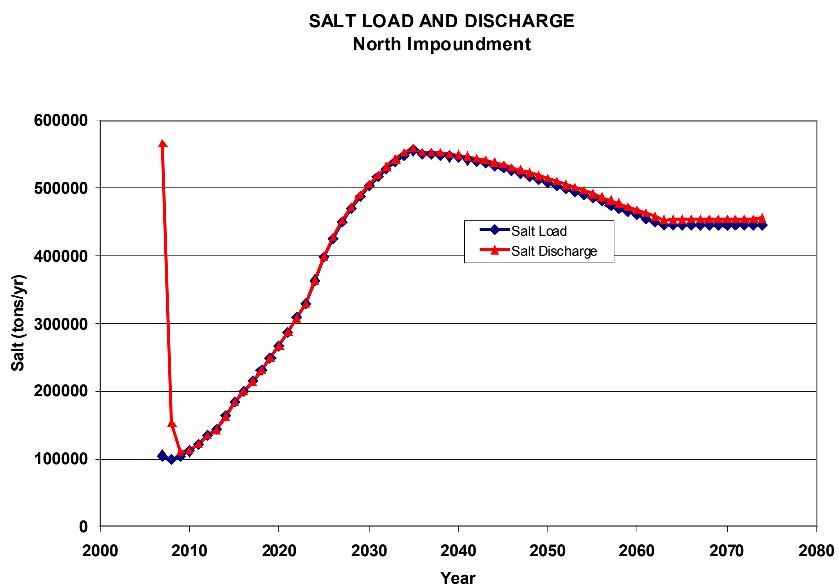
Water Exchanges: North Impoundment



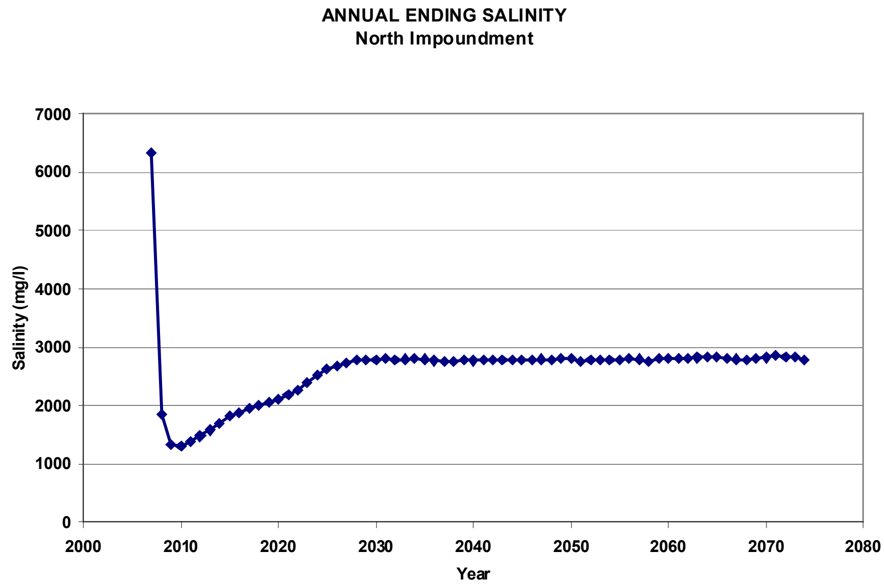
Months in Storage:North Impoundment



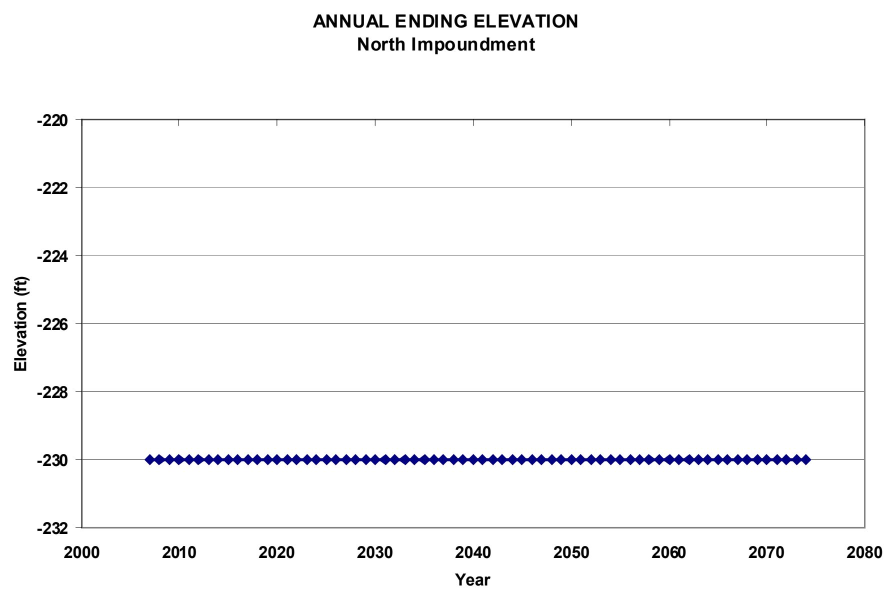
Salt Load and Discharge: N. Impound.



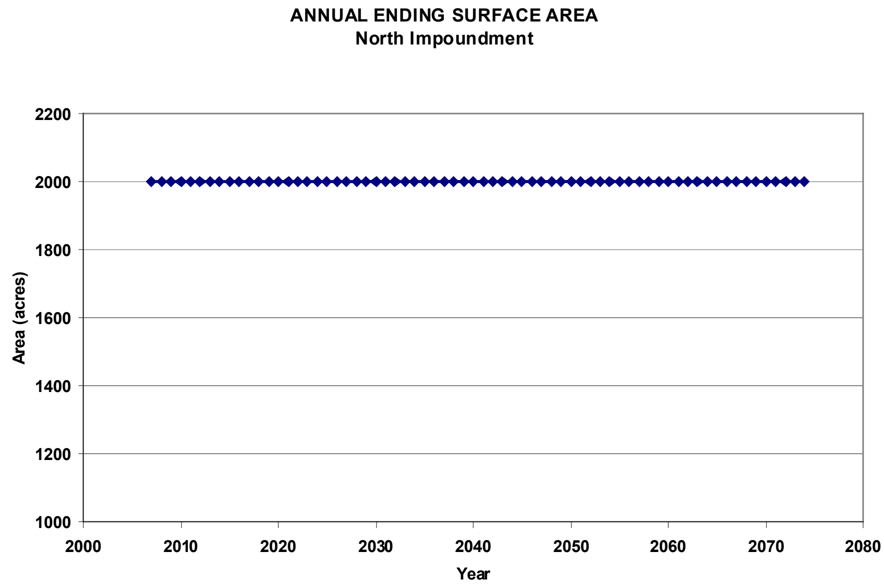
Salinity: North Impoundment



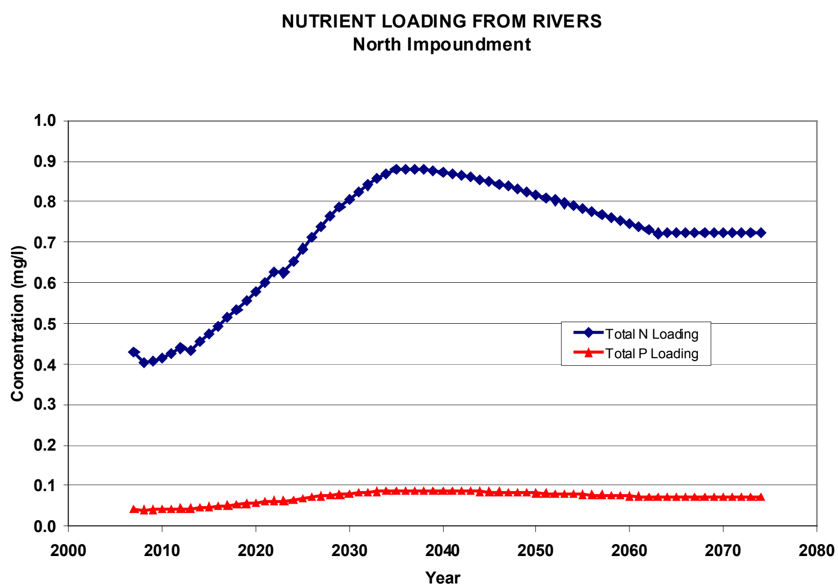
Elevation: North Impoundment



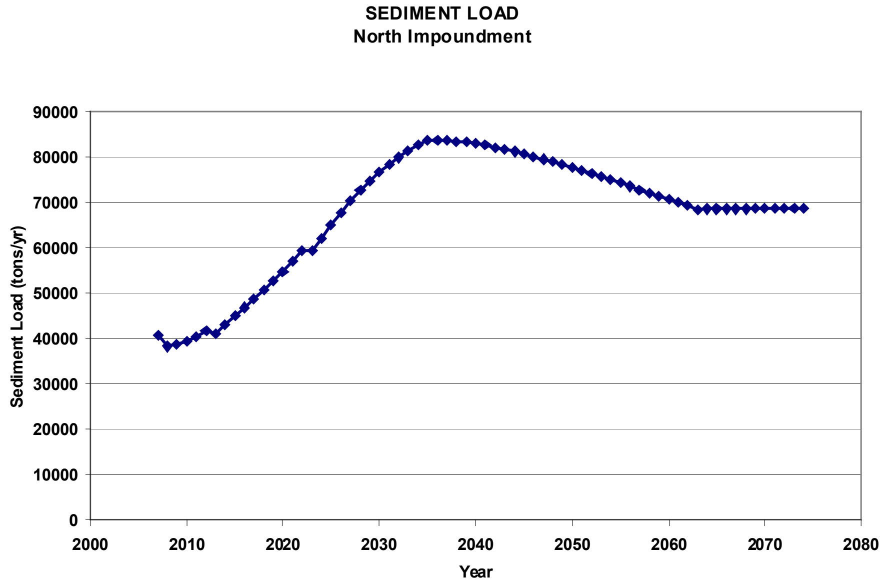
Surface Area: North Impoundment



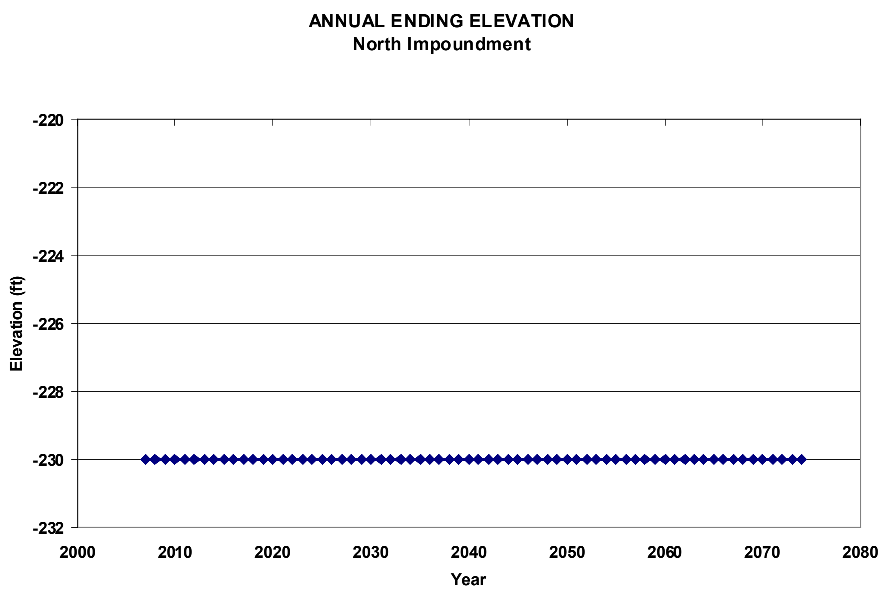
Nutrient Load: North Impoundment



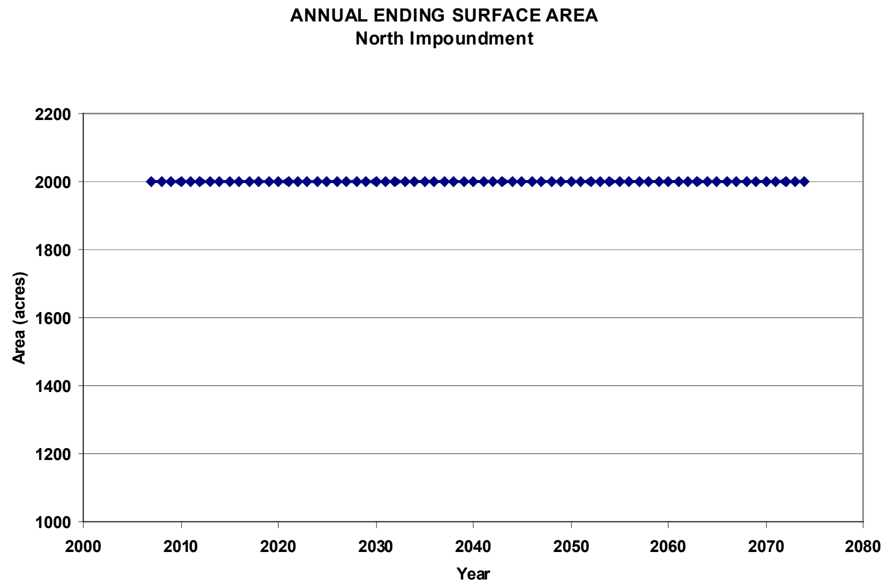
Sediment Load: North Impoundment



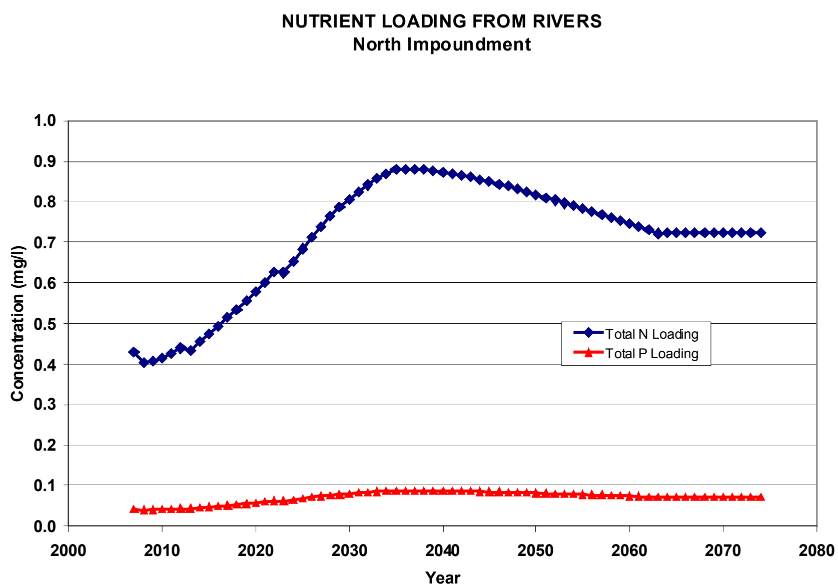
Elevation: North Impoundment



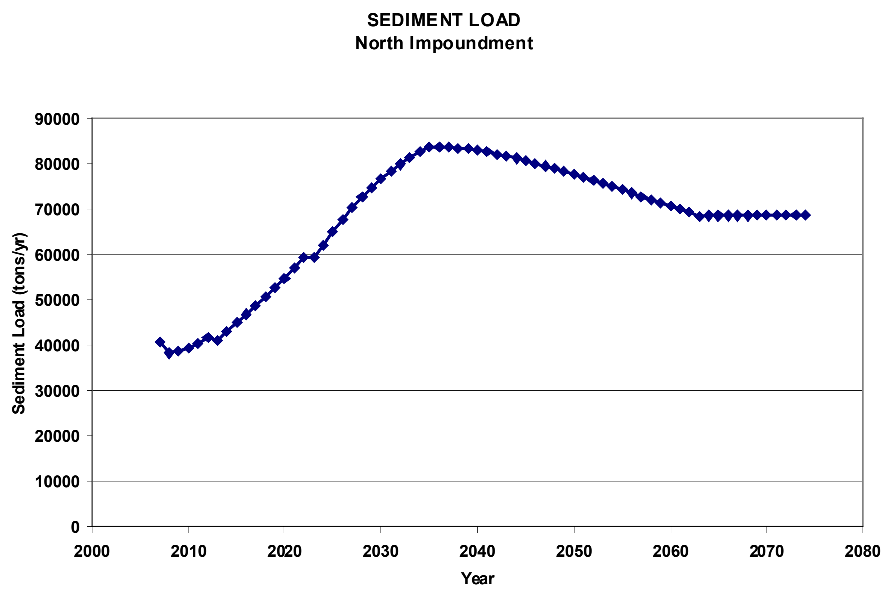
Surface Area: North Impoundment



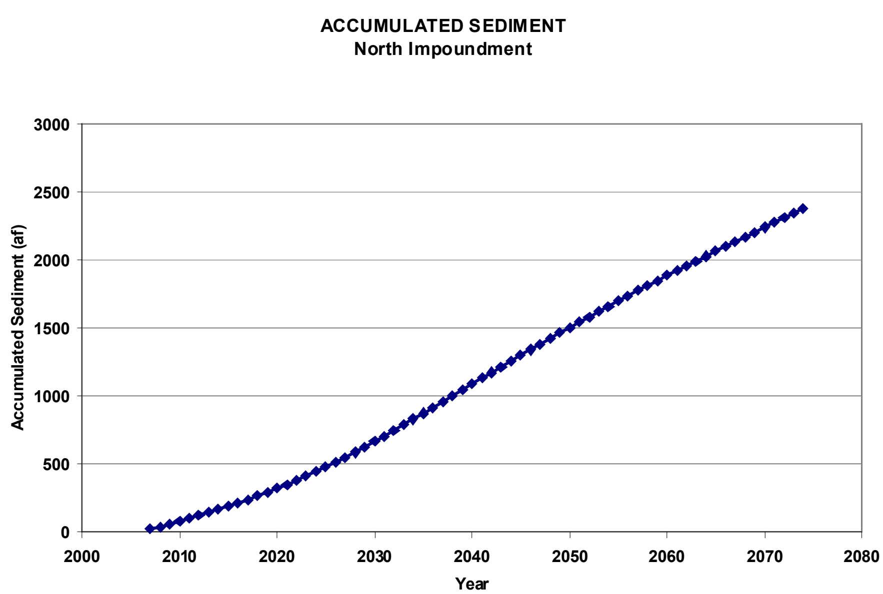
Nutrient Load: North Impoundment



Sediment Load: North Impoundment



Sediment Trapped: N. Impoundment



Appendix G

Predictive Limnology:

The Likely Nature of Impoundment Ecosystems on the Margins of the Salton Sea

An analysis by San Diego State University

Predictive Limnology:
The Likely Nature of Impoundment Ecosystems on the Margins of the Salton Sea

Analysis of a project proposed by the Pacific Institute

Stuart H. Hurlbert, Lucy Caskey, Marie Coe, Joan Dainer, Paul Detwiler, Deborah Dexter, Allen H. Hurlbert, Boris Kuperman, Victoria Matey, Kristen Reifel, Ralf Riedel, Brandon Swan, Mary Ann Tiffany, James Watts and James Zimmer

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17 December 2001
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EXECUTIVE SUMMARY

The impoundment ecosystems proposed by the Pacific Institute would have ecological and recreational values determined primarily by salinity and contaminant levels. As proposed, equilibrium salinities on the order of 3-5 g/L would be quickly (< 6 months) achieved and contaminant levels would be higher than in the current Sea, especially in the impoundment receiving New River waters. Dense submerged and emergent aquatic vegetation would occupy possibly the major part of the impoundments, biting insects would increase in abundance, both fish and birds would be exposed to a greater diversity of parasites, the fishery likely would be poor both for sport fishermen and fish-eating birds, boating would be restricted, and swimming out of the question.

More attractive ecosystem features would develop if salinities of at least 6-8 g/L and lower input of contaminants could be achieved. Salinities of 6-8 g/L might inhibit excessive development of aquatic vegetation. They might limit it to a few forms (e.g. *Ruppia, Najas*) that do not form such dense or as deep-growing beds as do less salinity tolerant potential invaders (e.g. *Hydrilla, Myriophyllum, Typha, Phragmites, Arundo, Schoenoplectus*). Salinities of 6-8 g/L could be achieved by diverting directly to the Salton Sea proper the major portion of inflow waters (> 70 percent, under present hydrologic regimen), including the entirety of the New River flow. Smaller inflows result in longer residence times in the impoundments and hence more evaporative concentration of inflow waters before they overflow into the Salton Sea.

Even with the best design, these impoundments and the eventually fishless Salton Sea proper would together represent much poorer conditions for fish-eating birds, especially the larger ones, and for recreation and economic development than would be provided by a Salton Sea with salinities reduced to 35-38 g/L, even if nutrient inputs were not much reduced.

INTRODUCTION

For roughly 40 years there has been increasing concern for the consequences of the increasing salinity of the Salton Sea, especially for its fish populations and aspects of the natural and human systems partly dependent on them. Analysis of engineering options for dealing with salinity increase and other problems, as well as scientific study of the Sea, accelerated with formation of the Salton Sea Authority (SSA) in 1993 and the establishment in 1997of a U.S. Geological Survey office, now called the Salton Sea Science Office (SSSO), in the region to propose and oversee scientific studies needed for better understanding of the Sea and the consequences for it of different engineering options. Since then many scientific and engineering studies and an analysis of environmental impacts of certain options have been carried out.

In October 2001 a private organization, the Pacific Institute for Studies in Development, Environment and Security, elaborated on earlier comments it had made and put forward "A Proposal to Preserve and Enhance Habitat at the Salton Sea." This has attracted both political and scientific attention because it represents an engineering option with low annual operating costs once built, does not depend on maintenance of current inflows to the Sea, and has some positive ecological aspects.

The essence of the Pacific Institute proposal is to build dikes that will impound low salinity waters at the northernmost and southernmost portions of the Sea and to allow the main body of the lake to become, eventually, a highly saline, fishless lake. At the northern end the dike would be constructed along the –240 ft elevational contour (current depth of about 12 ft), and at the southern end it would be constructed along either the –240 ft or –245 ft (current depth of about 17 ft) contour. These would have maximum depths of 10 ft (northern) and 10 or 15 ft (southern), given a project design that calls for impoundment water levels to be at -230 ft.

According to the Pacific Institute, this project would offer the following benefits:

7. Compatible with water re-allocation efforts
8. Sustainable over the long term
9. Increases diversity of habitats at the Salton Sea
10. Preserves and enhances fisheries in impounded areas
11. Promotes increased recreational and economic development opportunities
12. Compatible with other off-site actions

In November 2001 the Salton Sea Science Office, in response to interest in the Pacific Institute proposal, decided it was desirable to have a formal evaluation of that proposal by independent scientists, and began planning some workshops toward that end. Three principal areas of concern were defined: geological and engineering issues relating to dike construction; likely physical, chemical and biological characteristics of the new impounded ecosystems; and impacts on recreation.

The analysis presented here by SSERG focuses on the second of these areas. We also offer, however, comments on recreation impacts as these will be determined by ecological characteristics of the impoundments and main body of the lake.

This contribution was stimulated by invitations to some members of our group to participate in the SSSO workshops, by the belief that in their general features the nature of the impounded ecosystems are easy to predict on the basis of our collective knowledge, and by SSSO Director Dr. Milt Friend's opinion that such a document could be valuable to the workshop process.

OUR APPROACH

We focus primarily on predicting the general nature of the impoundment ecosystems, recognizing that there would be differences among them due especially to the smaller, shallower, more protected nature of the northern impoundment.

For each of the processes or phenomena involved here, a great deal of additional time could be spent documenting our predictions via literature surveys and small modeling efforts. We do not attempt that here. In general, where we offer an opinion in confident terms, we doubt that more detailed investigation would alter that opinion. We do not attempt many predictions about particular species, about the details of processes, or about short-term (< 6 months post-construction) or fine details of spatial and temporal variations in the system properties. Providing a firm prediction of the 'big picture' is our aim.

We omit value judgments about the overall desirability of the proposed project. Weighing of the pluses and minuses requires attaching of a value to each one of them that is primarily a subjective, non-scientific process.

The sequence in which we treat topics is determined by the fact that the biological components of the impoundment ecosystems will be heavily determined by the physical and chemical properties of those systems.

SOME SYSTEM DIMENSIONS AND FLOWS

At a surface elevation of -230 ft, the Salton Sea would have an area of 233,277 ac and a volume of 6,941,600 ft.

The northern impoundment would include about 2000 ac and 9000 ac-ft of the Sea. These represent about 0.85 percent of the surface area and 0.13 percent of the volume of the Sea, respectively. This impoundment would be fed by the Whitewater River and nearby agricultural drains. Annual inflow from these sources is currently about 80,000 ac-ft/yr with a mean salinity of 2-3 g/L. Residence time would thus be approximately 6 weeks. That is, in 6 weeks the water lost from the northern impoundment, by evaporation and overflow, would be equal to about 6 weeks worth of inflow.

The southern impoundment with a dike at –245 ft would include 26,000 ac and 181,000 ac-ft of the Sea. These represent about 11 percent of the surface area and 2.6 percent of the volume of the Sea, respectively.

With the dike at –240 ft, this impoundment would include 10,500 ac and 47,000 ac-ft. These represent about 4.5 percent of the surface area and 0.68 percent of the volume of the Sea, respectively.

The southern impoundment would be fed by the New and Alamo rivers and nearby agricultural drains. Annual inflow from these sources is currently about 1,100,000 ac-ft/yr with a mean salinity of 2.9 g/L. Residence time would therefore be on the order of 9 weeks for the larger southern impoundment and 2 weeks for the smaller one.

SALINITY

Terminological note: The terms “brackish” and “hypersaline” are terms appropriate for coastal systems where seawater salinity represents a logical standard. In the context of inland waters, however, they have no clear meaning and should be avoided, their popularity notwithstanding.

Salinity will be the single most important factor determining the nature of the impoundment ecosystems. Because of the very short residence times, salinity will drop very quickly, probably within a year after completion of dikes, from Salton Sea salinities (> 42 g/L) to salinities of 3-5 g/L. These will be only slightly higher than salinities of the inflowing rivers.

Exact trajectory for salinity over the first 4-12 months is unpredictable at the moment – and perhaps not of much importance. It would depend a great deal on mixing rates, impoundment configuration, and positioning of outflow points.

Equilibrium salinity (S_e) in impoundments, however, will be a simple function of inflow salinity (S_i), inflow rate (F, ac-ft/yr), and impoundment evaporation rate (E, ac-ft/yr), viz.

$$S_e = S_i F / (F - E)$$

In general this predicts that under likely medium-term scenarios these impoundment systems will have salinities 15-20 percent higher than the waters flowing into them.

For the larger version of the southern impoundment, with an annual inflow of 1,100,000 ac-ft/yr and an evaporation rate of 5.6 ft/yr, equilibrium salinity would be 15 percent higher than salinity of inflows.

If we assume a 200,000 ac-ft reduction in annual inflow, then we would expect equilibrium salinity to be 19 percent higher than that of inflow waters.

For the northern impoundment, with continuation of its annual inflow of 80,000 ac-ft/yr, we would expect equilibrium salinity to be about 16 percent higher than that of inflow waters.

Five factors will tend to produce somewhat higher equilibrium salinities that would be predicted from current inflow salinities.

First, those inflow salinities are likely to increase somewhat as a result of agricultural water management changes already in progress. These include reduction of tailwater runoff, causing agricultural wastewaters to be increasingly dominated by the higher salinity tile drain discharges.

Second, new artificial wetlands and marshes being created along the New and Alamo rivers. These wetlands will be large new surfaces from which water will be lost via evaporation, thus reducing inflow volumes and increasing their salinity.

A third factor would be reduction of input of municipal wastewaters in Mexicali. These have relatively low salinities relative to agricultural wastewaters and eventually are likely to be reclaimed for re-use in Mexico.

The fourth factor will be dissolution of gypsum, or calcium sulfate, that is abundant in the sediments in many places. As the impoundment waters freshen, this will tend to go back into solution, slowing the rate of salinity decline in the impoundment. Gypsum dissolves slowly, however, and much of it is well below the sediment surface where even slower dissolution would occur. Thus gypsum redissolution is not likely to be a large influence on salinity and will probably simply delay slightly the achievement of complete salinity equilibrium in impoundments. During this equilibration period there could be episodes of dissolved gypsum creating high salinity bottom waters that would resist mixing with surface waters. Anoxic, high sulfide conditions lethal to bottom dwelling organisms might develop temporarily. These would be transitional events, however, likely to occur, one would guess, only during the first year or two at the most.

The fifth factor is that evaporation from impoundment surfaces is likely to be higher than from the surface of the Salton Sea. The lower salinity by itself would be expected to increase evaporation by roughly 4 percent relative to that for the present Sea. Greatly increased abundance of shoreline vegetation is likely to result in increased losses from the system via evapotranspiration. Higher surface water temperatures are likely, especially in summer, and these would increase evaporation rates also.

The predicted salinity levels of 3-5 g/L are of particular biological significance. Limnologists conventionally set 3 g/L as the dividing line between fresh and saline waters. This is not entirely arbitrary. Most of the world's fresh waters have a salinity of < 1 g/L and most of its inland saline waters have a salinity of > 5-10 g/L. The nature of lake biota correspondingly changes rather abruptly as one goes from 1-2 g/L to 6-8 g/L. A difference of just a few g/L in this salinity range can cause large changes in the nature of the system, much larger changes than might be produced by going from, say, 8 g/L to 20 g/L.

A corollary of this fact is that temporal variations in salinity in this critical range ideally also need to be taken into account. Imagine two systems one with a salinity more or less constant at 4 g/L, and the other with a salinity that also averages 4 g/L but that fluctuates between 2 and 6 g/L. The biota of these two systems would likely differ markedly. Little information is available to allow even guesses as to how they would differ.

CURRENTS, TURBULENCE AND WAVE ACTION

In the southern impoundment, current speeds, turbulence, and wave action would be greatly reduced relative to present conditions in this part of the Salton Sea. Winds now have a 40 mile fetch over which to exert their influence on water movements in the southern end of the Sea. In the impoundment they would have a fetch of mostly 2-4 miles, at least when coming from the northwest quadrant. Additionally, the high ratio of shoreline (including dike) to surface area would have a dampening effect on current speeds as would the abundant aquatic vegetation (see below). Several consequences would follow from this.

Vertical mixing of the water column would also be greatly reduced in the southern impoundment. This is likely to result in more frequent or more prolonged periods of anoxia in the deeper waters of the impoundment. In the present Sea in summer the nearshore waters generally have higher oxygen levels than do waters at the same depth in the center of the lake. This tendency to poorer vertical mixing will be mitigated to some extent by elimination of vertical salinity gradients. In the present Sea these can be found, especially during calm weather, over southern and southeastern portions of the Sea where the river inflows have flowed out over the top of the higher density saline water. Such density gradients would be non-existent in the new conditions where impoundment waters were only 15-20 percent more saline than inflow waters.

The long, narrow shape of the southern impoundment would tend to increase current speeds in proportion to the degree that inflow and outflow rates were high. Current speed and direction within the lake would be strongly influenced by the number and position of the overflow points. For maximum homogeneity, e.g. of salinity, within the impoundment, overflow points would be located at either end of the lake; for maximum heterogeneity, they would be located on the dike about halfway between the New and Alamo river mouths.

Similar changes would take place in the northern impoundment. They would not be such large ones, however, as this is a smaller, shallower area and usually on the upwind side of the lake.

SEDIMENTS AND SEDIMENTATION

Following construction of dikes all river-delivered sediments would be deposited in the impoundments. At present a large percentage of the fine sediments (silts, clays) carried in can be presumed to be deposited in the deep portions of the Salton Sea.

Retention of fine sediments in the impoundments combined with reduced wave action would likely cause a shift in the nature of shallow water and shoreline sediments from a sandier to a muddier type. Increased abundance of shoreline vegetation, and detritus derived from it, would favor increased organic matter content of nearshore sediments.

Coarse sediments in rivers will continue to be deposited near river mouths, but, especially in the southern impoundment, would be less subject to reworking and redistribution by wave action and currents than coarse sediments are in the present Sea. This may cause the finger deltas of the New and Alamo rivers to build out faster than they are now. By growing toward the dike they would tend to reduce horizontal mixing within the southern impoundment in particular.

ALGAE

Algae would remain an important base of the food webs in the impoundments, though strongly supplemented by production by vascular plants (see below) and with macroalgae assuming a more important role than they have in the present Sea.

Phytoplankton. Phytoplankters that now dominate in the sea are dinoflagellates, diatoms, and raphidophytes. The impoundments would likely be dominated by chlorophytes (green algae) and cyanobacteria (blue-green 'algae'). This shift in composition would result from the fact that few dinoflagellates and raphidophytes tolerate salinities of 3-5 g/L, and the fact that reduced turbulence in the impoundments would make it difficult for diatoms to remain suspended in the photic zone. Their silica frustules make them susceptible to sinking in quiet waters.

Cyanobacteria might have potential for creating blooms toxic to fish and wildlife, as has occurred frequently in other shallow, eutrophic freshwaters but not in waters as saline as the ocean or the Salton Sea. Toxic species of cyanobacteria could appear in the biota without having harmful effects, of course. Indeed some of the cyanobacteria in the present Sea now, as well as some of the dinoflagellates and raphidophytes there, are capable of producing toxins, although there is no hard evidence so far that these have harmed fish or wildlife.

Short water residence times in the impoundments, i.e. high flow-through rates, would seem to diminish the likelihood that toxic species could achieve dense enough blooms to affect fish or wildlife. On the other hand, in embayments of poorly mixed water created by irregular shorelines or bands of aquatic vegetation, the combination of longer residence times, the low ratio of total nitrogen to total phosphorus (TN:TP) in inflow waters, and higher water temperatures (> 35˚C), localized toxic cyanobacterial blooms would be a real possibility.

In the well mixed portions of the impoundments, the short residence times would tend to favor dominance by small phytoplankton species capable of rapid growth. Species present in inflow waters would be especially favored as they would be continuously being inoculated into the impoundments.

Total phytoplankton abundance, measured as biomass per liter, would likely be lower in the impounded areas than in the corresponding areas of the present Sea. At present densities in these shoreline areas are typically much higher than in offshore waters. This would be a consequence of the short residence times and of increased competition for nutrients with macroalgae and vascular plants. In freshwater ponds, large increases in abundance of vascular plants are usually followed by large reductions in phytoplankton abundance.

Macroalgae. Abundance and diversity of macroalgae would be greater in the impoundments than in the present Sea, as a consequence of lowered salinity, reduced wave action, and increased areas of hard substrate. These will include green algae such as *Enteromorpha*, *Cladophora* and other filamentous forms. These would likely form floating mats in quieter areas, attach to solid substrates, including dike faces, and possibly accumulate as drift on shorelines when they die or are pushed there by waves. Stoneworts such as *Chara* or *Nitella,* with rhizoids anchoring them to sediments, may also appear. And microbenthic cyanobacteria would also be able to form thin algal mats on soft and hard substrates just as they do now in the Sea.

Abundance of these macroalgae would likely be controlled by turbidity, which limits the depth of water in which they can grow, by wave action, and by grazing by certain fish, water birds and invertebrates. Reduced current speeds and wave action and reduced phytoplankton abundance would cause turbidity levels to be lower than present ones. Turbidity may be the factor which now limits the existing *Cladophora*, *Chaetomorpha*, and *Enteromorpha* populations to the shallowest waters.

Faces of the new dikes would presumably be of rock or concrete and their great extent would tremendously increase the abundance of attached macroalgae. In the southern impoundment the inner side of the dike generally would experience much less strong wave action than do the dikes along the present southern shoreline of the Sea, allowing larger masses of macroalgae to develop on this inner side.

Periphyton. This term refers to the small algae of various sorts that are found growing on the surfaces of aquatic vascular plants, loosely or tightly attached to them. Such algae represent a food supply for a variety of invertebrates that cannot feed on the vascular plants themselves. Though inconspicuous thesesmall algae can take up nutrients rapidly from the water, thus competing with phytoplankton and the vascular plants themselves. If abundant on plants in the impoundments they would thus tend to have a clarifying effect on the water column by reducing phytoplankton densities.

VASCULAR PLANTS AND VEGETATION

Vascular plants would become much more abundant in the impoundments and along their shorelines than they are along the edges of the present Sea. These would contribute large amounts of plant detritus to the shoreline ecosystem and new habitat for birds in particular. These plants would probably boost overall production of the system and represent an increased food supply for decomposers and detritivores. The detritus would also increase the organic matter content of sediments making them softer and muddier and more subject to anoxia.

Vascular plants are a group especially sensitive to salinity variations in the vicinity of the 3 g/L dividing line between fresh and saline systems. Many species that can thrive at 2-3 g/L cannot tolerate 5-6 g/L. Thus precise prediction of the new assemblages of vascular plants would require precise prediction of impoundment salinities and a thorough review of the literature on the ecophysiology of aquatic vascular plants in the region.

Four distinct categories of vascular plants would be involved in this increase: submerged, floating, emergent, and terrestrial. These are discussed in turn.

Submerged vegetation. These are plants that are rooted in sediments and have all or most of the plant body beneath the water surface. Among species likely to colonize the impoundments would be those in the genera *Ruppia*, *Potamogeton*, *Zannichellia, Hydrilla*, *Najas*, and *Myriophyllum*. *Ruppia* and *Potamogeton* serve as food for some waterfowl species. *Ruppia* beds occurred in the Sea a few decades ago and were favored habitat of the sargo. Submerged vegetation serves as a substrate often colonized by microalgae and by invertebrates. It also provides structural complexity that provides invertebrates and smaller fish some protection from predation by larger fish.

Some submerged species can root in sediments tens of feet deep and thrive there if turbidity is low enough and light levels sufficient. They may produce stands of vegetation that extend only a couple of feet above the sediments or the stands may extend all the way to the surface. By slowing currents and competing with phytoplankton with nutrients, the presence of such plants tends to reduce turbidity thus favoring their occupation of even deeper-lying sediments.

Invasion of the impoundments by the fast growing exotics *Hydrilla verticillata* or *Myriophyllum spicatum* (Eurasian watermilfoil) might occur and would have drastic consequences if it did. *Hydrilla* is reported to grow in salinities up to 7-10 g/L, and *Myriophyllum* in salinities up to 15 g/L. Doubtless neither species grows very well at the upper end of their salinity range.

In clear water systems both species can root at depths greater than 30 feet and form dense stands extending to the surface, as *Hydrilla* did in Lake Murray in San Diego twenty years ago. Both species occur in waters in the Coachella, Imperial and Mexicali valleys, though *Hydrilla* is scarce after years of successful control with grass carp. The California Department of Food and Agriculture and U.S. Department of Agriculture have a program to try to eradicate *Hydrilla* from the state, as it arrived only a few decades ago. If either species established in the proposed impoundments, it likely would be possible to eradicate it, given the size of the impoundments.

Detailed predictions are not possible at this point, but given the predominance of shallow water areas in the proposed impoundments, it is likely that large portions of them, and perhaps even their entirety, would be colonized by submerged vegetation with all the consequences that would follow. Increase in impoundment water clarity resulting from upstream removal of sediments in artificial wetlands would facilitate facilitate invasion of the deepest portions of the impoundments by submerged vegetation.

Floating vegetation. This is likely to be the least significant of the four types of new vegetation that will develop in the impoundments. In quieter areas, tiny floating plants such as duckweed (*Lemna*) and aquatic ferns (*Azolla, Salvinia*) could abundantly cover the surface if salinity is satisfactory. They are probably most important as food for some types of ducks.

Emergent vegetation. Emergent aquatic plants are those that are rooted in the lake bottom or on damp shorelines and whose photosynthetic and reproductive structures extend well above the water surface. Common types are cattails (*Typha*), bulrush (*Schoenoplectus*), common reed (*Phragmites*), and giant reed (*Arundo*). Some such plants can grow in water more than 10 ft deep, if they can get established, can extend more than 10 ft above the water surface, and can grow so densely as to form impenetrable thickets separating open water from upland habitats. *Schoenoplectus* growing in the margins of Lake Miramar in San Diego County is rooted in sediments at a depth of 12 ft. The emergent vegetation that grows along the edges of the lower portions of the New and Alamo rivers is in water often 5-6 ft deep.

Now restricted to the immediate vicinity of the deltas and other inflow points of rivers and streams, emergent vegetation would soon colonize all shoreline areas with sandy or muddy substrates in the impoundments once their salinities were near 3 g/L. These vegetation beds would then tend to expand into deeper water, in large part by vegetative reproduction. This would probably be a slow process that went on for years before plants reached some depth beyond which they could not grow.

It would be likely that this emergent vegetation would come to occupy large portions of both impoundments, making them marsh ecosystems as much as lake ecosystems. The history of Cienaga de Santa Clara in the Mexican portion of the delta gives an idea of what might happen. Once a barren saline depression periodically inundated by ocean water, the whole northern end of the Cienaga became a densely vegetated marsh of *Typha*, *Schoenoplectus*, and *Phragmites* once large volumes of 3 g/L wastewaters from Arizona agriculture began being diverted into this basin. Of course, this is a much shallower system, with maximum water depths on the order of 3 ft, than would be the Salton Sea impoundments.

Development of emergent vegetation in the impoundments would tend to displace submerged aquatic vegetation via competition, most likely for light.

Terrestrial vegetation. The shoreline of the Salton Sea is mostly devoid of terrestrial vegetation, exceptions being those shorelines near points of surface or groundwater inflow. The primary reason for this undoubtedly is the high salinity of soils and soil porewaters near the lake's edge.

Once impoundments were created their fresher waters, together with the infrequent rainfall events of the region, will greatly reduce soil salinity along the shores of the impoundments. This would lead to great increases in the abundance of terrestrial vegetation, which would abut or intermingle with the emergent aquatic vegetation developing in adjacent shallow water areas. Various grasses (e.g. *Distichlis*) and shrubs (*Salicornia*, *Atriplex*, *Pluchea, Baccharis*) would colonize these shore habitats. Salt cedar (*Tamarix*) likely would be the tree species that would most successfully establish in these freshened areas, but other trees such as cottonwood (*Populus*) and willow (*Salix*) might succeed in some areas as well, especially if planted.

Taken together, the submerged, emergent and terrestrial vegetation that would develop along the impoundment shorelines would represent a great 'greening' of the shoreline ecosystem. There would be increased abundances of some invertebrates and birds that can use this vegetation as physical habitat for roosting, nesting, or hiding, as food, or as a place in which to find food. On the other hand, these beds of vegetation displace other elements of planktonic and benthic food webs that are perhaps even more important for good fish production.

INVERTEBRATES

In the impoundments, the species-poor invertebrate assemblage of the Salton Sea would be quickly replaced by a much more diverse assemblage. Key elements of the present food chain, such as the pileworm (*Neanthes*) and barnacle (*Balanus*) would disappear completely, while a few elements might persist, e.g. the copepod (*Apocyclops*), the rotifers (*Brachionus, Synchaeta*), and the amphipod (*Gammarus*).

Large numbers of new species of crustaceans, insects, oligochaete worms, mollusks, flatworms, rotifers and nematodes would colonize the water column, the sediments, and the surfaces of aquatic plants. A long species list could be compiled from studies of other marshes and lakes in California or the Southwest with salinities of 3-5 g/L. But the absolute and relative densities of these new invertebrate species would not be possible to predict. They would depend in part on complex food web interactions, such as predation on invertebrates by fish and bird populations in the new ecosystem.

Increases in the abundance and diversity of shoreline vegetation would be accompanied by large increases and diversity in the abundance of terrestrial invertebrates, especially insects and other arthropods (e.g. spiders, mites), relative to what now can be found along the mostly barren shorelines. Some of these arthropods may feed directly on green plant tissues. Others may be detritivores. Detritus produced by this vegetation will create shallow water sediments and shoreline soils rich in organic matter, and this can serve as the base for detritus-based modules of the overall food web.

The impoundments likely would increase abundance of biting insects in the vicinity of the Sea. These could include mosquitoes (Culicidae), biting midges (Ceratopogonidae), and horse flies (Tabanidae). The aquatic larvae of virtually all mosquitoes are intolerant of salinities as high as those of the Salton Sea and are also very susceptible to fish predation in open waters. But salinities of 3-5 g/L are tolerated by many species of mosquitoes, including *Culex tarsalis,* which is common in vegetated water bodies in the Salton Sea region and a vector of western equine encephalitis.

The structural complexity provided by the stems and foliage of submerged and emergent vegetation would provide mosquito larvae and other invertebrates significant refuge from fish predation. In general fish-inhabited marshes are major breeding grounds for mosquitoes, both in coastal and inland areas.

Biting midges and horseflies breed in damp soils with moderate to high levels of organic matter, often near the margins of bodies of fresh water. Their increase would seem highly probable, but it is not possible to predict whether or not this would be to levels representing a significant nuisance to persons visiting or living near the impoundment areas.

FISH

New Assemblage. The fish assemblages that would develop in the impoundments would be radically different from the present one in the Sea. Corvina, sargo, bairdiella, and long-jaw mudsucker would disappear. Mozambique tilapia would persist as would threadfin shad, mosquito fish, mollies and mullet. Almost all of the freshwater exotics found in the Coachella, Imperial, and Mexicali valleys would eventually find their way into the impoundments and establish permanent populations. These include common carp, catfish, largemouth bass, sunfish, Zill's tilapia, and shiners. The triploid sterile grass carp used for weed control in agricultural drains could also invade though they should not be able to reproduce. It might be predicted that the fish assemblage would be dominated by the tilapias, threadfin shad, carp and catfish, as these feed predominantly near the bottom of the food web. Large mouth bass would become one of the most popular sportfish, if its populations thrived.

The abundances of the different species would exert strong influences on each other and on other components of the impoundment ecosystems via predation, disturbance of the sediments, and, in the case of carp and Zill's tilapia, grazing of macroalgae and aquatic vascular plants.

Fish production on a *per unit area basis* would likely be lower in the impoundments than in the corresponding portions of the present Sea, and very much lower if aquatic vegetation came to occupy more than a minor portion of the impoundment area (e.g. > 20 percent). The major reason for this is that fish presently in these nearshore areas are recipients of food supplies, e.g. plankton, that are produced over the entire area of the Salton Sea. During the warmer half of the year, these food supplies are not consumed in the central 80 percent of the lake because almost all fish move into the nearshore areas.

On the other hand there are some factors that would tend to offset the above to some extent. These would be the greater variety of fish present, and hence of foods utilized, feeding modes, and microhabitats utilized, the lower physiological stress caused by salinity, and perhaps more regular reproductive and recruitment success.

Total fish production *for the region* (excluding aquacultural production) would be drastically reduced as the proposed impoundments would represent, at most, only 12 percent of the area of the present Sea.

Desert pupfish would likely colonize at least the margins of the Salton Sea proper once the other fish were mostly gone. Though stressed by the salinity, the pupfish would have their glory days in the region, perhaps even for a few decades, before even their salinity limits were reached.

Parasites and Disease. At present the fish in the Sea are known to host only a single metazoan parasite, a monogenean fluke (*Gyrodactylus*), and this only rarely. A few microbial ectoparasites (*Amyloodinium*, *Cryptobia*, *Ambiphrya*) are known to infest large percentages of fish, especially juvenile tilapia, at certain times of year. On rare but significant occasions, botulism has been found in moribund tilapia, often associated with *Vibrio* infections.

In the proposed impoundments, all fish would likely be much more heavily infested with metazoan parasites (flukes, cestodes, roundworms, crustaceans). The life cycles of most of these parasites require an intermediate host, usually an insect, crustacean or snail. Few species of such invertebrates are found in the present Sea, but many-fold more would establish populations in the impoundments. This would lead to greater numbers of kinds and perhaps higher infestation rates of parasites on and in impoundment fish. The lower salinity water itself might also improve survival of the free-swimming stages that some of these parasites have.

For example, the introduced Asian fish tapeworm *Bothriocephalus acheilognathi* has been found in shiners and mosquito fish in creeks draining into the Sea. This tapeworm is a harmful parasite of commercial and recreational significance. It uses freshwater copepods as an intermediate host, spreads rapidly, and can cause high mortality of juvenile cyprinid fish.

There is no reason to think, however, that parasite loads would be heavier than they are in these same fish species where they occur in other freshwater or near-freshwater ecosystems in the region.

We cannot predict how the types or degrees of infestation by microbial parasites might change in the impoundments relative to the Sea. The three genera mentioned above are all known to occur in freshwater habitats, aquaria and aquaculture operations. Many other species of microbial parasites may be capable of tolerating a salinity of 3-4 g/L and could appear in the impoundments as well.

Contaminants. Concentrations of contaminants of significance to humans and wildlife would likely be higher in fish in the new impoundments than they are in fish of the present Salton Sea. Principal contaminants of concern would be selenium, pesticides, industrial pollutants, and pathogens. Each contaminant would have its own behavior, and there are many uncertainties, but the big picture seems clear.

In the present system, contaminants entering the Sea at specific points are quickly distributed by currents over and diluted by the whole volume of the Sea. Most fish in the Sea are thus bathed in water and feeding on organisms in water where contaminant concentrations range from extremely low to undetectable. Nevertheless significant levels of selenium, arsenic, and DDE are present in Salton Sea fish.

In the impoundments the fish and their food organisms would be spending their entire lives in what would amount to undiluted, sluggish extensions of the New, Alamo, and Whitewater rivers. Most of the new fish species moreover could move between the rivers and the impoundments, whereas the Mozambique tilapia is the only common species likely to do that now. Fine river-borne sediments on which pesticides might be adsorbed would all be deposited in the impoundments and not distributed over the whole Sea. New species of bottom-feeding fish, such as carp and catfish, thus would be exposed to higher levels of these and any other contaminants that tended to accumulate in sediments. Over time such bottom feeding fish could also bring back into circulation in the food web shallowly buried contaminants that were deposited in prior decades. The occasional pesticide spills (perhaps usually illegal discharges or dumping) upriver that now kill fish mostly only in the rivers, would likely cause mortality in the impoundments as well.

Whereas fish now in the Salton Sea are exposed to water column levels of selenium on the order of 1 ug/L, those in the impoundments would be exposed to the same levels as found in the rivers, viz. 3-6 ug/L. The Pacific Institute proposal acknowledges that selenium-related problems for birds might be exacerbated by resuspension of sediments during dike construction. This, however, would seem a less important mechanism for increased selenium exposure of birds than would be the accumulation of higher selenium levels in the impoundment ecosystem after the dike was completed.

It thus seems certain that fish in the impoundments would have generally higher levels of contaminants than do fish currently in the Sea. This would cause them to pose greater risks to both fish eating birds and to sport fishermen than do the present Salton Sea fish.

In principle, contaminants in inflow waters could be reduced by altered water management practices, both on farm and at wastewater treatment plants, and by constructed wetlands. Exactly what sorts of reductions would be feasible are unknown. Even marked improvements in inflow water quality could occur, of course, and still leave contaminant levels in impoundment fish higher than those now in Salton Sea fish.

AMPHIBIANS AND REPTILES

Soft-shelled turtles have been seen in the New and Alamo rivers and doubtless would colonize the impoundments. Bullfrogs occur in the region, used to be collected for food in the Rio Hardy when it was in better conditions. The African clawed frog is now widespread in southern California and doubtless would colonize the impoundments. Toads and tree frogs might use them for breeding. Abundance of amphibians would be closely tied to the nature of aquatic vegetation present, as this would be needed as critical refuge from piscine and avian predators.

BIRDS

New Assemblage. The avifauna of the Sea would be markedly affected by creating the impoundments and letting the rest of the Sea rise in salinity until all fish disappeared from it. Some types of birds would become more abundant, others less abundant. Changes would reflect changes in habitats and food supplies available. We focus on predicting changes for four major categories of birds.

Users of shoreline vegetation. The predicted large increases in shoreline and shallow water vegetation would lead to large increases in bird species that can use that for nesting, roosting, or feeding. These would include especially rails, bitterns and blackbirds, wrens, and warblers . Once tall salt cedar stands had developed, various herons and egrets would be likely to nest in them. Passerines that glean insects from the foliage of such vegetation would also increase. Ducks, coots, and even geese that can feed on submergent aquatic vegetation would also be more abundant.

Aerial feeders. Production of insects with aquatic larvae and aerial-terrestrial adults is now essentially zero in the Sea. This production would likely be very high in the impoundments. Adults of non-biting midges (Chironomidae) and perhaps mosquitoes (Culicidae) would be especially abundant and likely to attract more swallows, swifts, and nighthawks to the skies above the impoundments.

Feeders on aquatic invertebrates. We distinguish three categories: wading shorebirds (e.g. avocets, stilts, dowitchers, godwits, etc.), beach runners (e.g. sandpipers, plovers), and open water feeders (eared grebes, Wilson's phalaropes, shovelers, ruddy duck, etc.).
We would expect to see reduced abundances in the impoundments of the first two categories as the open shoreline and mudflat areas they utilize would eventually be taken over by dense shoreline vegetation. The open water feeders would probably also be less common as we would predict that the diverse fish assemblage in the impoundments would result in lower overall density of macroinvertebrates of the types these birds feed on.

At least some of these feeders on aquatic invertebrates would be likely to find greatly increased food supplies in the main body of the Sea that would be left to becomes fishless. Once fishless, the dominant invertebrates there would be copepods (*Apocyclops*), water boatmen (*Trichocorixa*) and brine flies (*Ephydra*). Only after salinity became high enough (> 80 g/L?) to eliminate the copepods and waterboatmen would brine shrimp (*Artemia*) become abundant, as the first two are predators on the latter.

Fish-eating birds. In general these would become very much less abundant in the region, even though some individual species might come to have higher densities in the impoundments than they do in the current corresponding portions of the Sea. Fish-eating birds, such as egrets and herons, that like quiet water and are willing to use vegetated marshy areas might become more abundant in the impoundments than they are now along the Sea's southernmost and northernmost shorelines.

The double-crested cormorant and the two pelicans would be likely to become much less abundant even in the areas to be impounded, once the main part of the Sea became fishless. As indicated above, fish production in the areas to be impounded likely will decline. Also, these are open water birds. They cannot swim where there is much submerged vegetation, and at least pelicans generally stay well away from dense emergent shoreline vegetation of any sort, presumably as a way of avoiding predators. The white pelican feeds while swimming in groups in shallow water, and most such shallow waters might have dense submerged vegetation. Areas that the pelicans currently use for loafing – small islands, sand spits, etc., though not Mullet Island – may be colonized by emergent vegetation.

Greater abundance of small fish – mosquito fish, shiners, mollies, and young of the numerous larger species – would likely represent increased food supplies for smaller fish-eating birds, such as terns, black skimmers, and western grebes. They thus might become more abundant. Much would depend on the balance among species and size classes maintained by predation of the larger fish present, such as large mouth bass.

Parasites and Disease. The greatly increased number of invertebrate and fish species in the impoundments that could serve as intermediate hosts for parasitic helminths would likely increase infection rates of birds by those parasites. The importance of this to the health of the bird populations is difficult to judge, however. Most birds would be exposed to these parasites in many of the other aquatic systems they visit for food during the course of a year.

Prediction of changes in the bird disease scenario is difficult. Botulism might be expected to become more frequent as a result of fresher, quieter waters, increased levels of sediment organic matter, higher summer water temperatures, and lower oxygen levels. On the other hand, extensive occupation of shallow water areas by emergent vegetation could work against this.

Contaminants. As indicated above, contaminant levels likely would be higher in fish and invertebrates in impoundments than in fish and invertebrates now in the Sea. Fish-eating and invertebrate eating birds feeding in impoundments thus would be expected to accumulate those contaminants to higher levels than they do now, to the degree that the impoundments would represent their principal source of food over significant parts of the year.

The potential problems in this area are dependent on many unknown factors and would be different for each bird species. Factors include possible improvements in quality of inflow waters, possible tendency of some bird species to cease using areas once they are impounded, possible increased use of impounded areas by other bird species, the specific fish and invertebrate assemblages that develop in the impoundments, the specific behaviors of different contaminants, and so on.

RECREATION

Birdwatching. This is an activity engaged in at the Sea by many thousands of individuals a year, especially at the southern end of the Sea. Construction of the proposed impoundments would not likely have any negative impacts on the quality of the impoundment areas for birdwatching. Positive effects that might be expected would include: increased diversity of birds as a result of development of shoreline vegetation and greater variety of prey populations (invertebrates and fish) in the impoundments; and better access to the shorelines via dikes, especially at the northern end where access is poor.

Along shorelines outside the impoundments and in the Sea's open waters, the diversity of birds would decrease with the disappearance of fish-eating birds. Much larger numbers of invertebrate-eating birds than are there now might be attracted to the Sea, however. Such birds also could remain at the Sea longer during the year because of enhanced invertebrate food supplies.

Since the Salton Sea is already an excellent, nationally recognized location for bird-watching, it would not likely experience even greater popularity in that regard even if certain bird species did become more abundant there.

Fishing. Fishing could be quite good in the impoundments for tilapia, largemouth bass, sunfish, carp and catfish, though it is unpredictable just which of these would establish good numbers of good-sized individuals. Special attractions might include the fact that tilapia sport fisheries do not exist elsewhere in the state and the possibility that largemouth bass would reach record sizes in the impoundments.

That sort of fishery, except for the tilapia, can be found in many other waterbodies in the region and in southern California, however, and fewer fisherman would be willing to travel long distances to take advantage of it. It will no longer be a special, unique fishery capable of generating tales of 30 lb corvina that got away. Rather it would become known as a fishery where contaminant levels were higher than elsewhere for the same species. The accurate perception that the impoundments were sluggish extensions of wastewater drains would probably discourage fishing for many years even after contaminant levels had been reduced – if that ever happened.

Boating and swimming. Boating in the impoundments, because of reduced current speeds and wave size, would probably be safer than in the current sea, and the entirety of the impoundment areas would be accessible to smaller boats. On the other hand lower fish production, invasion by aquatic vegetation, and the considerable number of obstructions (rocks, tree trunks, old man-made structures) in the shallow northern and southern ends of the Sea would render the impoundments much less attractive to boaters in general than is the present Sea. There would be no need for pontoon boat tours for birdwatchers, such as the State Recreation Area currently conducts. Persons with larger, faster boats interested in a quasi-oceanic boating excursions would no longer be attracted.

Swimming would probably be non-existent in the impoundments. Potential bathers would be put off by softer sediments, aquatic vegetation, absence of beaches, and pathogen levels almost certainly higher than those in the present Sea. There are dozens of human pathogens that historically have been detected in the New River, especially near the U.S.-Mexico border. A pathogen not reported from the rivers but that might become of special concern in the summer is the protozoan *Nagleria fowleri* . This enters the nasal passages, travels to the brain, and causes primary amebic meningoencephalitis, a rare but nearly always fatal disease. This ameba does well in fresh waters at very high temperatures. We have heard that cases of this have occurred in the Mexicali valley in summer when young children in agricultural areas use the drainage ditches and other shallow waters as places to play and cool off.

Another deterrent to swimming might be swimmers' itch, a rash caused by penetration of the skin by larval stages (cercariae) of bilharzia-type flukes or trematodes. These flukes have snails as intermediate hosts. The freshened, high calcium waters of the impoundments and the abundant aquatic vegetation would be heaven for several types of snails.

The above contrasts with the present situation. Though swimming in the Sea is less common than it once was along the exposed, sandier shorelines of the present Sea, this has more to do with irrational fears of algal blooms and resultant turbidity and inaccurate press reports than it does with the reality of the situation. Naturally on those specific occasions when there is a moderate to large fish kill nearby or washing up on shore, or when there is a bloom of the surface film-dwelling alga *Pleurochrysis* in progress or when heavy waves have stirred up sediments, swimming is not an attractive option. But most of the year the present Salton Sea is an excellent place for swimming. You can keep your legs still, hold a beer in each hand, and still not sink.

The main part of the Sea where salinity would be allowed to increase over time would remain suitable for both boating and swimming for some decades, though of course boating fishermen would not be interested in it.

Camping. There is a fair bit of both tent camping and mobile home camping around the edges of the Salton Sea, and much of this is associated with birdwatching, desert nature study, scientific excursions by university classes, and just relaxation under the desert stars. More than fishermen and boaters come to the Sea. Very little of this camping takes place along the shorelines of the areas to be impounded, and in general the impoundments – by increasing the abundance of biting insects as well as on non-biting insects likely to swarm to campsite lighting fixtures – would make these areas even less attractive than they are now for camping, unless campsites were a considerable distance – perhaps hundreds of yards - from the water's edge.

Camping on shorelines of the main part of the Sea would still be attractive to visitors not primarily interested in fishing. Great recession of the shoreline would make these areas less attractive.

New camping areas, or general centers of recreational activity, established near where impoundment dikes intersected the shoreline could enhance recreational values. These could provide easy access of boaters, birdwatchers or fishermen to both impounded areas and the open Sea, especially if means easy transfer of boats over or around dikes were available. These would be areas of high biotic diversity. Those on the west side of the Sea could be tranquil sites free of the hooting and rumbling of nighttime freight trains that run along the east side of the Sea.

ENGINEERING OPTION: EXCLUSION OF NEW RIVER INFLOWS

There are two key negative aspects of the proposed impoundment ecosystems with respect to fishing and other recreational activities associated with them. These are: 1) the taking over of the impoundments by aquatic vegetation well-adapted to the projected salinities, and 2) the high levels of contaminants likely to be present or to develop in the waters and sediments of the impoundments.

For the southern impoundment, the problems arising from these two aspects could be considerably mitigated by diverting all New River flows and a portion of Alamo River flows so that they enter the main body of the Sea directly. This could reduce contaminant inputs to the impoundments and increase equilibrium salinity levels in them so as to inhibit excessive development of aquatic vegetation. Salinities on the order of 6-8 g/L perhaps would be sufficient to do this. They would also be consistent with healthy populations of most, if not all, of the fish species that would be present at 3-5 g/L. Higher equilibrium salinities, e.g. 8-12 g/L, easily could be engineered and might necessary to prevent invasion of *Myriophyllum* in particular. These higher salinities, however, might also eliminate a few of the freshwater fish from the impoundments.

The system described is not unlike that of Laguna Macuata (a.k.a. Laguna Salada; southwest of Mexicali) when it is fully flooded. At those times it supports at least catfish, tilapia, largemouth bass and even small-scale commercial mullet fisheries, and no aquatic vegetation except at its southernmost end where it receives the floodwaters of the Rio Hardy.

Under the current inflow regime, diversion of the New River directly to the Sea would result in a southern impoundment salinity only 35–40 percent higher than that of the New River and other inflows. This salinity increase likely would be insufficient for the objective. If we wanted impoundment salinity to be roughly double inflow salinity then we would have to reduce total inflows to the impoundment to 290,000-300,000 ac-ft/yr. This would be more than a 70 percent reduction of current inflows to this southern shoreline. Hence, the need to consider partial diversion of Alamo River flows directly to the Sea also, perhaps via a pipeline connection to the New River.

The best diversion structure for the New River would be a channel along the southwest shoreline of the southern impoundment. A modest dike or concrete retaining wall built in shallow (4-6 ft deep) water could form one side of the channel and the existing shoreline the other. This channel would extend until it emptied into the Sea proper at or a short ways north of the intersection of the main impoundment dike with the shoreline somewhere south of the old Navy Test Base.

An attractive ecological feature of this diversion structure would be that the shoreline side of the channel would become heavily vegetated with terrestrial, emergent, and, in wider slow-flow areas, even emergent vegetation, just like the banks of the current New River. It would be good habitat for birds and other wildlife, including birdwatchers.

A problematic aspect of allowing essentially only Alamo River water entry into the southern impoundment is that its selenium concentrations seem to be higher than those of the New River, possibly because municipal wastewaters (from Mexicali) make up a higher proportion of total flow in the New than in the Alamo. Not having undergone the evaporative concentration experienced by agricultural wastewaters, or passage through soil, these municipal wastewaters presumably have selenium concentrations on the order of those of the Colorado River. A thoughtful comparison of how the risks associated with the two rivers compare is called for. Of course, if selenium becomes a serious problems for wildlife, it seems most likely to do so in the shrinking main body of the Sea and the invertebrate-eating birds that would use it. In that regard, it would perhaps make little difference which river was the main or only supply for the impoundment. All the selenium of both rivers, most likely, would end up in the Salton Sea proper.

There would also be ways to engineer partial diversion of northern inflows directly to the Salton Sea in order to create northern impoundment salinities on the order of 6-8 g/L.

EVALUATION OF PROPOSED BENEFITS

We quoted at the beginning the benefits that the Pacific Institute claimed for the proposed impoundments, and they are repeated below, with our comments on each. We recognize that the intent of the Pacific Institute was, in part, to put these forward as benefits only relative to benefits (or costs) associated other proposed projects, such as those involving major evaporation facilities and input of additional low salinity waters. Our comments take into account, however, that the proposed benefits will be taken on their face by many as being net benefits claimed in some more absolute sense.

1. **Compatible with water re-allocation efforts.** The impoundments will be compatible with these. But then so would complete desiccation of the Salton Sea and the Colorado River. There is an underlying presumption here that these "re-allocation efforts" are a positive thing or at least a political inevitable. Many of the authors of this review think they are neither and that they will have high environmental and social costs.

2. Sustainable over the long term. This is true in the sense that once constructed, annual maintenance and operation costs will be much lower than those for possible projects to restore the entire Sea involving evaporation and replacement waters. It is false in that government policies favoring continued high rates of population growth will prohibit guarantees of any flows into the Salton Sea in the long term. The writing is on the wall. The MWD and CVWD have already filed requests to be given rights to 40 percent of current Salton Sea inflows.

3. **Increases diversity of habitats at the Salton Sea.** This is true but that does not make it good. Those numbed by the rhetoric of political correctness may be pardoned for having forgotten that diversity per se is not a positive – not in society and not in ecology. Putting in 100 acres of date palms on Refuge lands would also increase habitat diversity at the Salton Sea. Convince us that is good!

   The main question to be answered with respect to our re-engineering of habitats at the Sea is what problems would it likely pose to those bird species that have come to rely on the Sea in a major way? This document does not attempt to address that important question.

4. **Preserves and enhances fisheries in impounded areas.** This might be more accurately stated as "Creates new fisheries in impounded areas", as neither preservation or enhancement of what exists now is involved. From the point of view of sport fishermen or fish-eating birds the impoundment fishery would be inferior to the existing fishery. A very large scale, unique fishery would be replaced by a small scale, common type of fishery. Some fishery is preferable to no fishery, of course.

5. **Promotes increased recreational and economic development opportunities.** Yes, small lakes with fish plus a large one without fish offers more such opportunities to the region

than does one large fishless lake. On the other hand, the proposed project would result in a large net *loss* of such opportunities relative to those provided by a Salton Sea restored to lower salinities.

6. **Compatible with other off-site actions.** This is true of other possible restoration projects for the Sea, as well as of the no project alternative, and does not constitute a benefit.

Appendix H

Summary Presentations submitted by working focus groups on engineering, hydrology, water quality, biology, wildlife disease and contaminants

Hydrologic Modeling: Pacific Institute Impoundment Proposal

Paul A. Weghorst, PE
Bureau of Reclamation
January 8, 2002

Purpose

- Characterize hydrologic conditions
  – Main Sea
  – South Impoundment
  – North Impoundment

(Both impoundments evaluated with dikes constructed at –245 feet)

General Modeling Assumptions

- Reductions in inflow will occur
  - Start at baseline = 1.24 maf/yr
  - Future inflow = 1.00 maf/yr
    - Approximates possible reductions from water transfers
    - Consistent with evaluation of other restoration alternatives
- Simulation Period: 2000 to 2074
- Dike Construction
  - Constructed In Water
  - Dikes Closed in 2007

Sediment Load Assumptions

- Sediment Load Rate = 0.53 tons/af
  - From Draft Report:
    - Sedimentation / Siltation Total Maximum Daily Load for the Alamo River
  - Assumed same for New, Alamo, and Whitewater Rivers
- Sediment Density = 1.2 tons/yd^3
- Impoundment trap rate = 100 percent

Nutrient Load Assumptions

- Nutrient Loading for 1999 [1/] Prorated According to Annual Inflows
  - Total N
  - Total P

1999 Alamo River Total P Loading	0.574	mg/l
1999 Alamo River Total N Loading	7.08	mg/l
1999 New River Total P Loading	0.66	mg/l
1999 New River Total N Loading	4.96	mg/l
1999 Whitewater River Total P Loading	0.053	mg/l
1999 Whitewater River Total N Loading	1.03	mg/l

1/ Source: Setmire, Jim et al., 2001. Eutrophic Conditions at the Salton Sea. A Topical Paper From the Eutrophication Workshop Convened at the University of California at Riverside, Sept. 7-8, 2000.

Wetlands Assumptions

- Water Losses = 0.8 * Pan Evaporation [1/]
- Surface Area Requirements
  - Based on Imperial Wetlands
    Requirement = 0.012 acres/af
- Sediment Removal = 90 Percent [2/]
- Nutrient Removal [3/]
  - Total N Removed = 34 %
  - Total P Removed = 11 %

1/ Source: Kadlec, R.H., and R.L. Knight. 1996 Treatment Wetlands. Lewis Publishers, Boca Raton, FL.

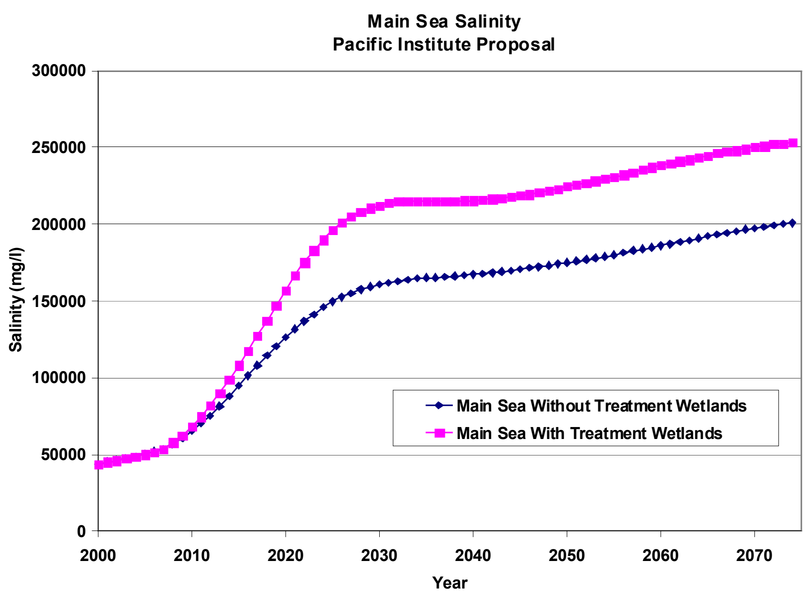
2/ General observation of data collected at Imperial and Alamo Wetlands

3/ Personal communication from Jim Sartoris, USGS, Mid-continent Ecological Science Center – unpublished data

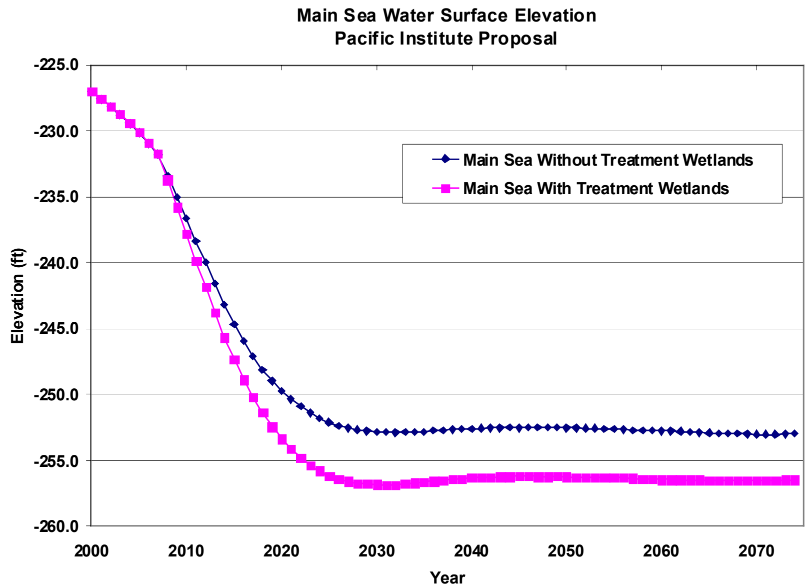
Main Sea Simulation Simulation Results

(Based on Application of the Bureau of Reclamation's Salton Sea Accounting Model)

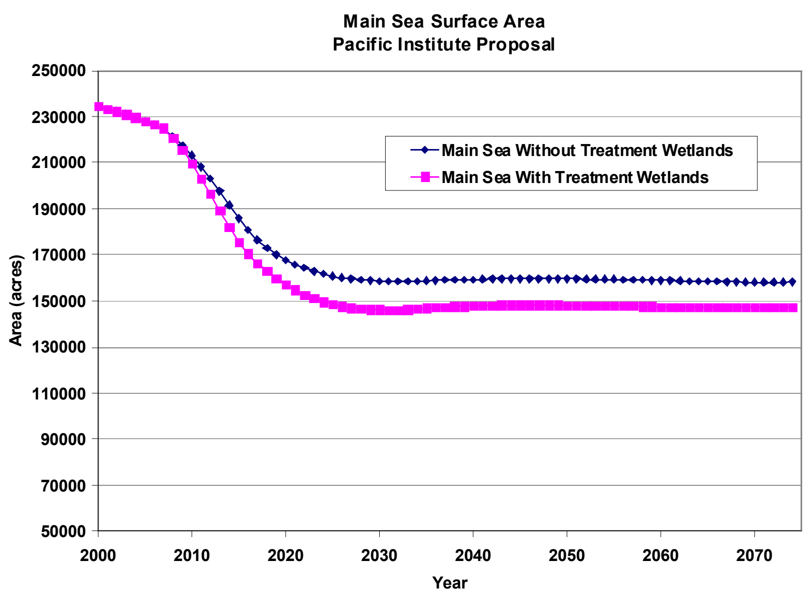
Main Sea Salinity



Main Sea Water Surface Elevation

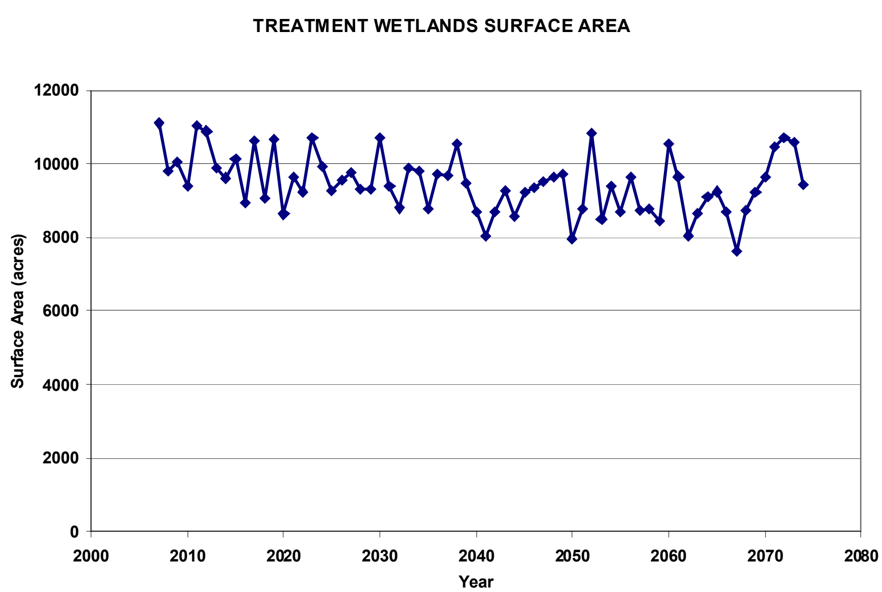


Main Sea Surface Area

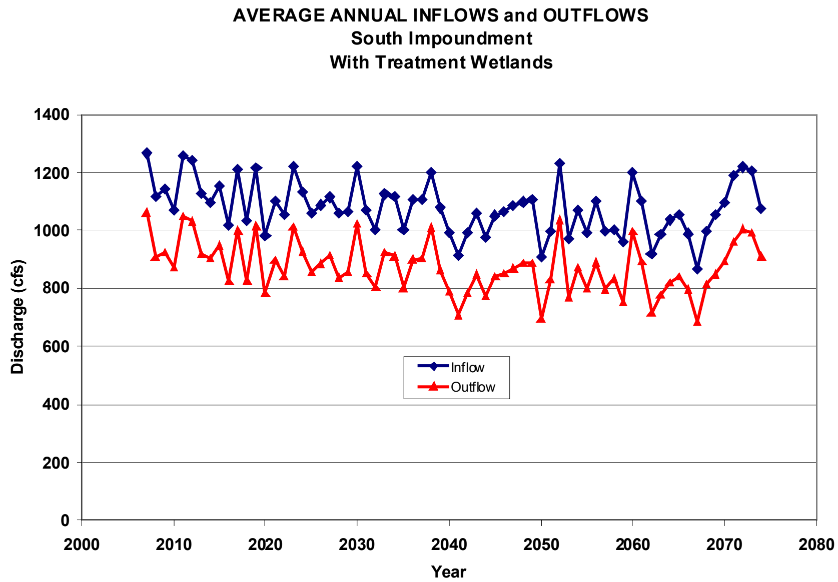


South Impoundment Simulation Results

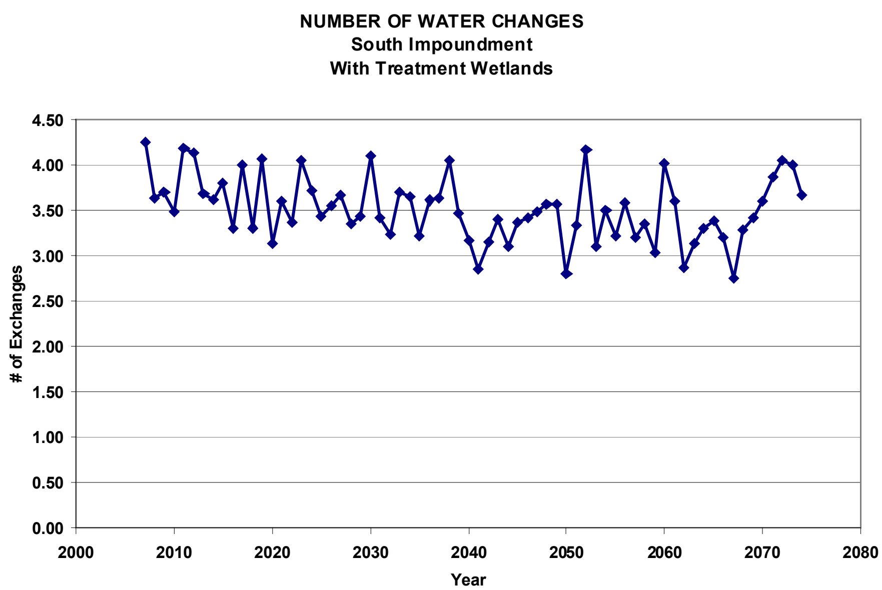
Wetlands Surface Area Requirements



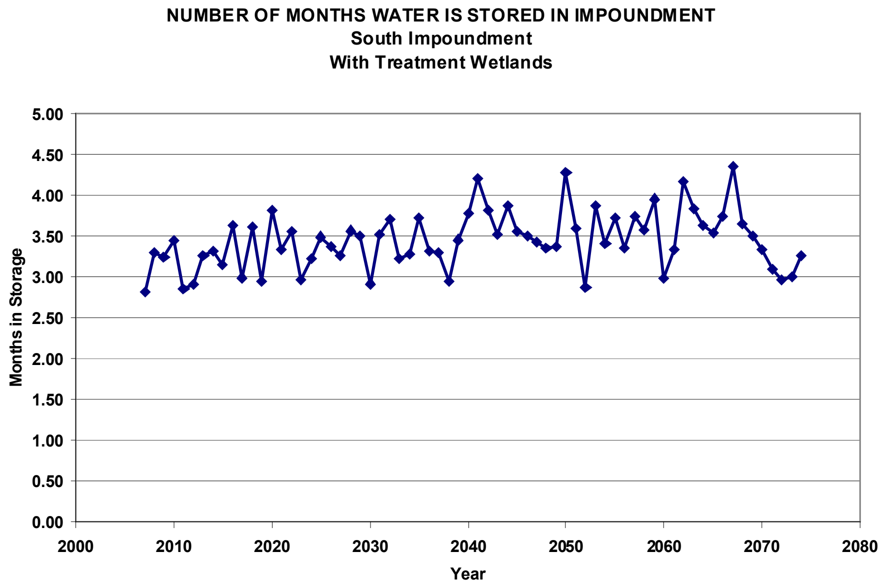
Inflows/Outflows: South Impoundment



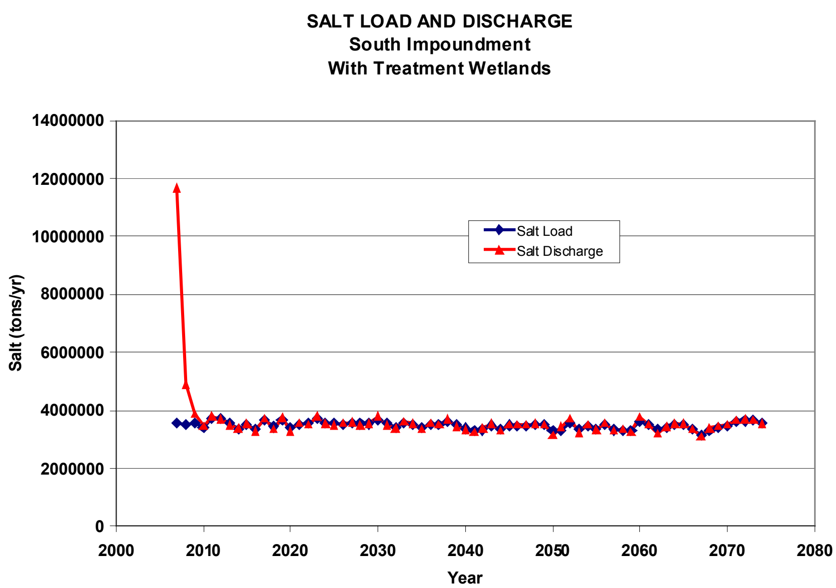
Water Exchanges: South Impoundment



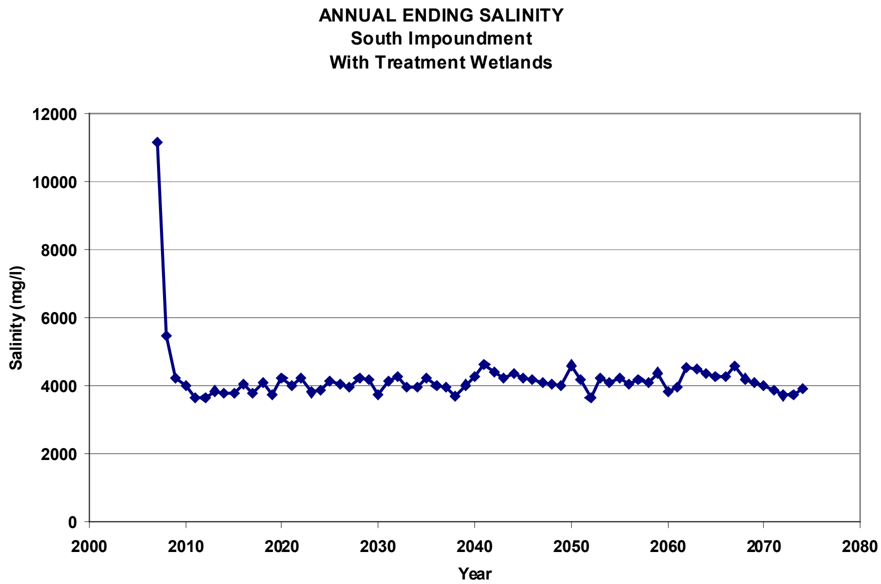
Months in Storage:South Impoundment



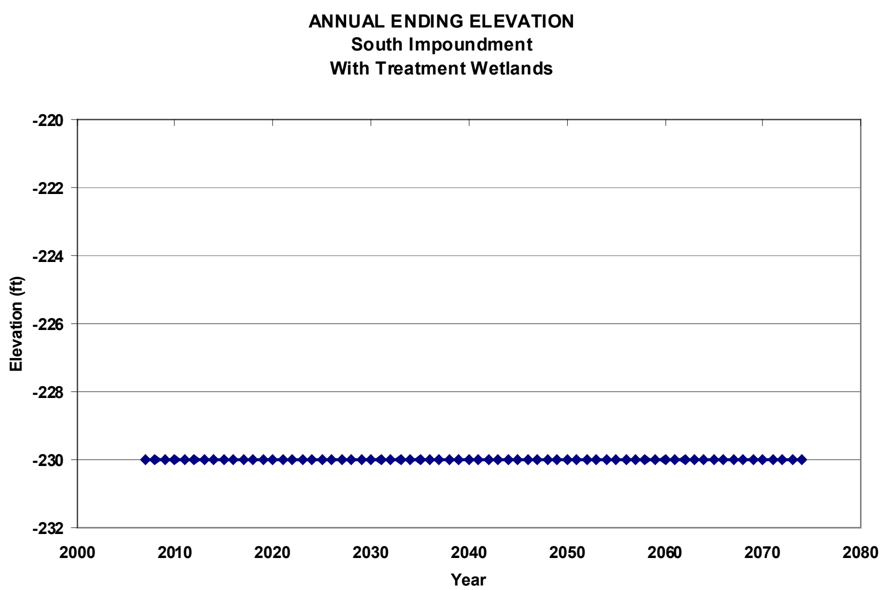
Salt Load and Discharge: S. Impound.



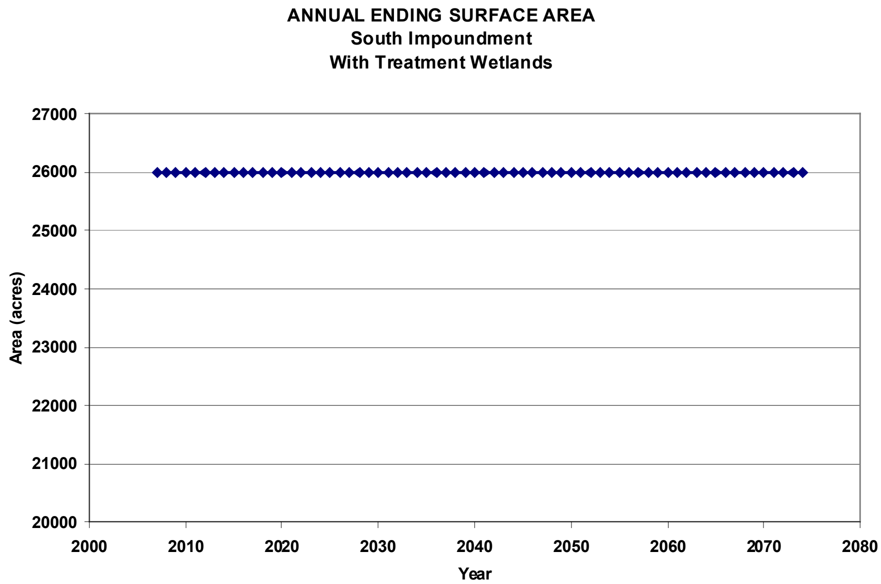
Salinity: South Impoundment



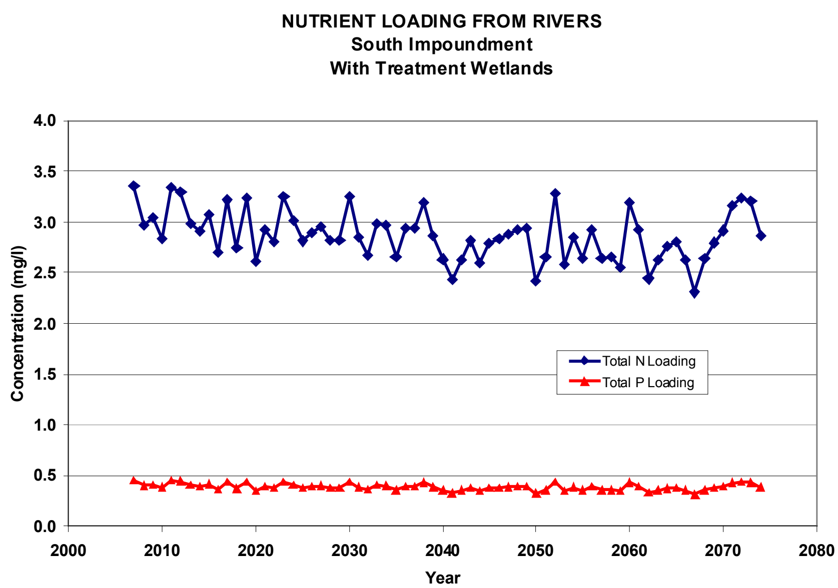
Elevation: South Impoundment



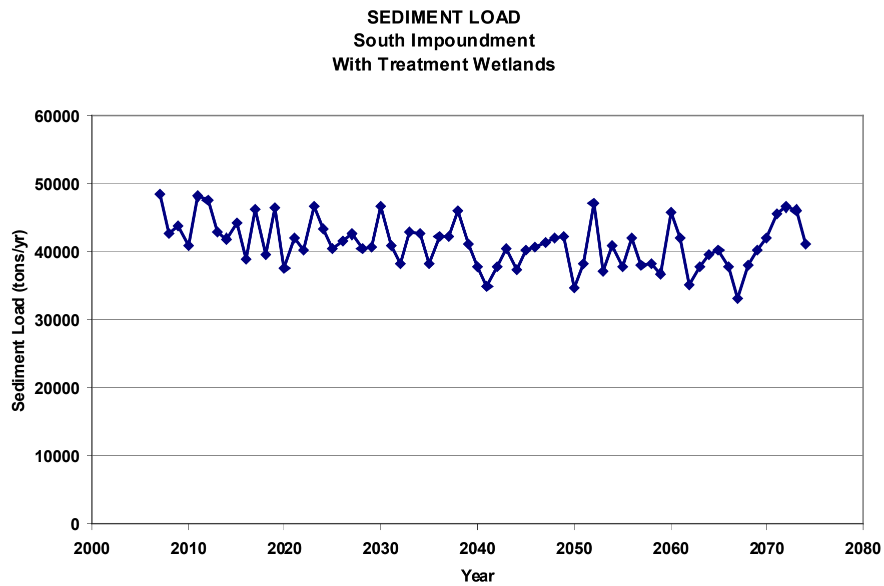
Surface Area: South Impoundment



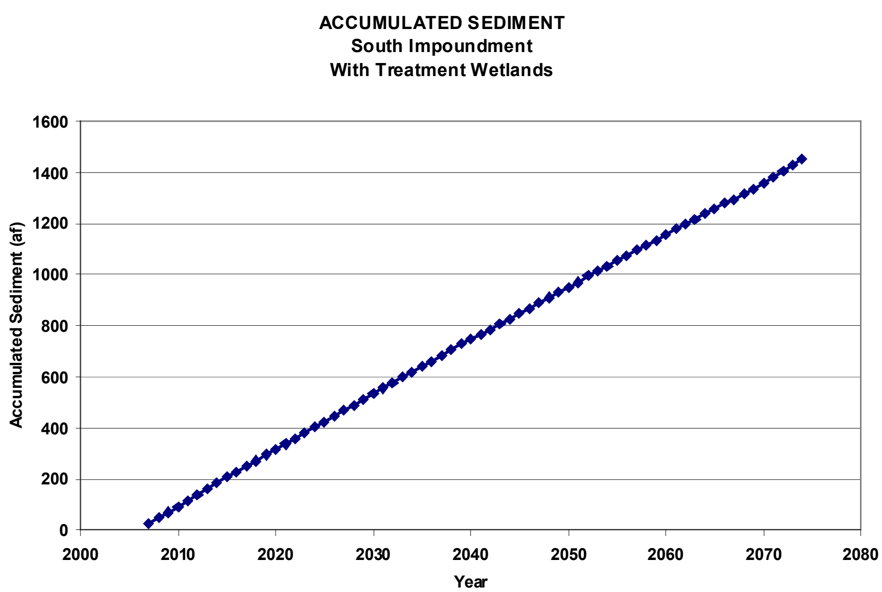
Nutrient Load: South Impoundment



Sediment Load: South Impoundment

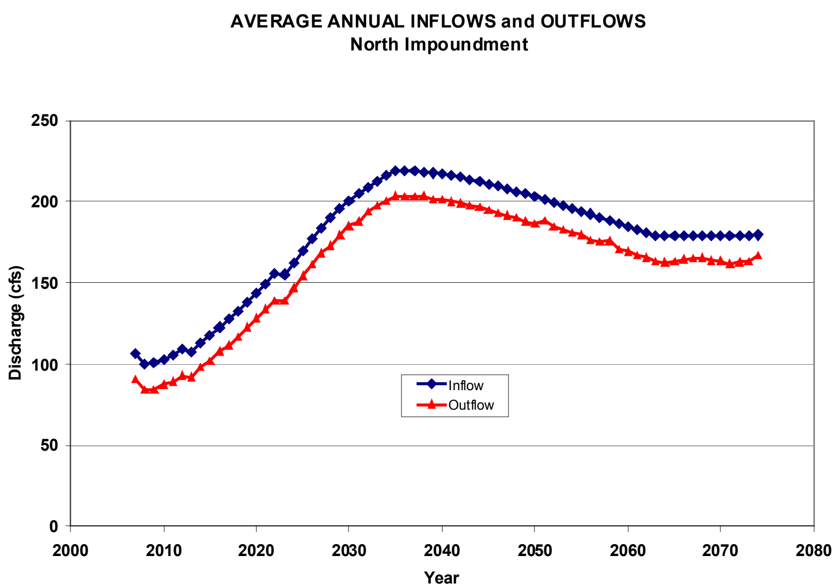


Sediment Trapped: S. Impoundment

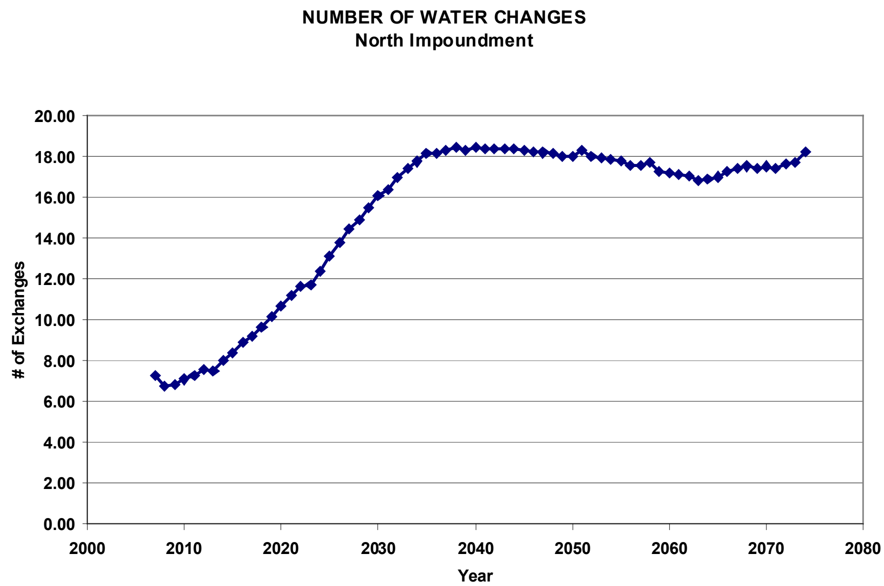


North Impoundment Simulation Results

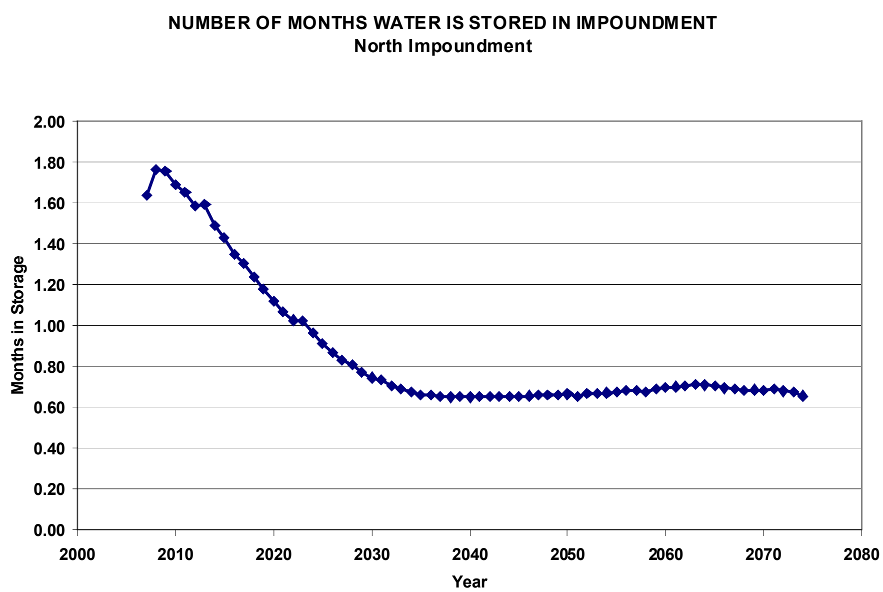
Inflows/Outflows: North Impoundment



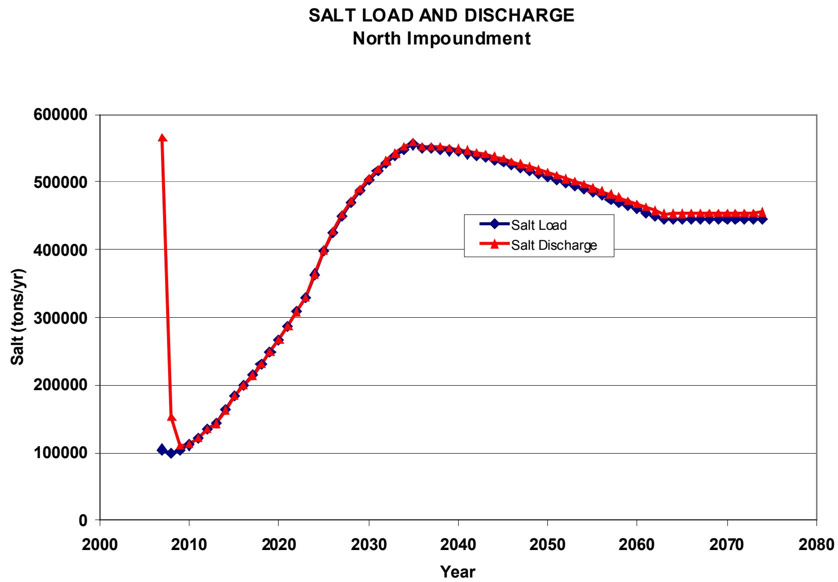
Water Exchanges: North Impoundment



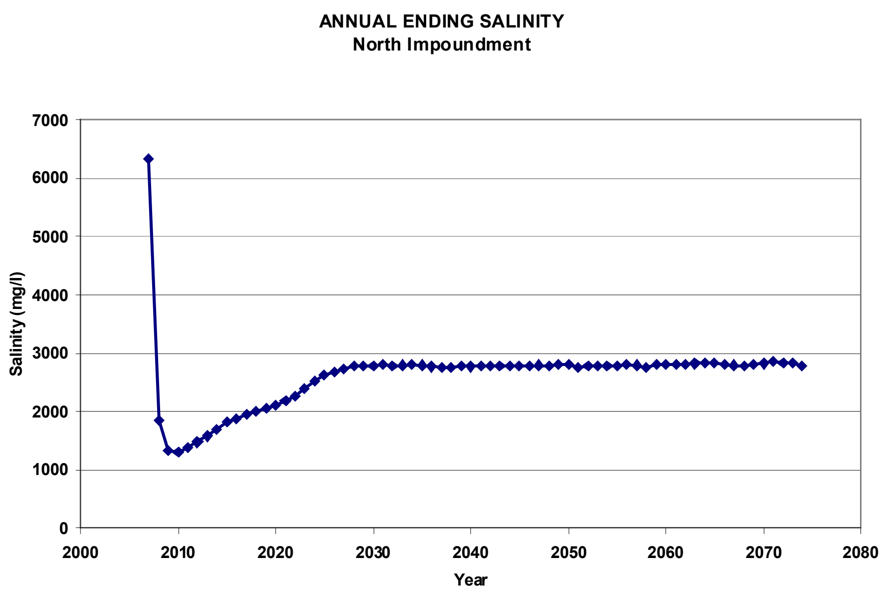
Months in Storage:North Impoundment



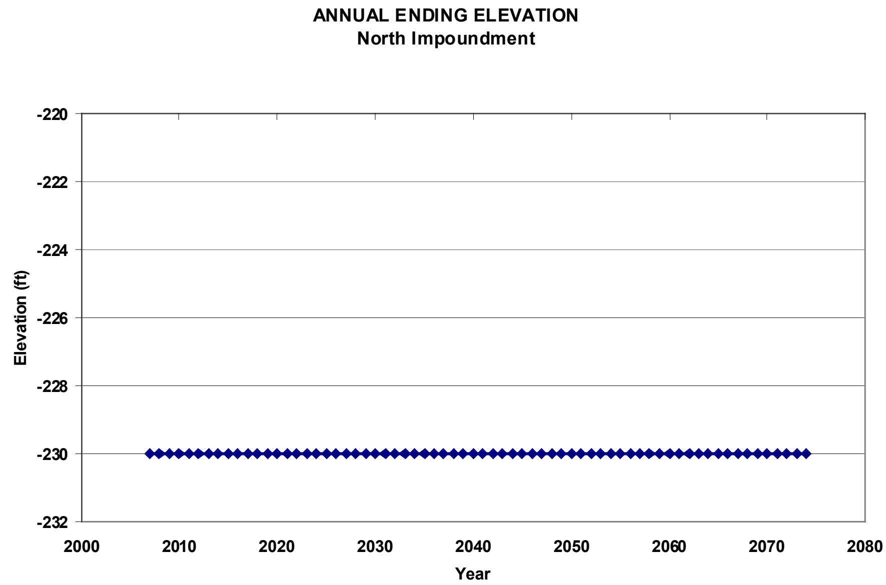
Salt Load and Discharge: N. Impound.



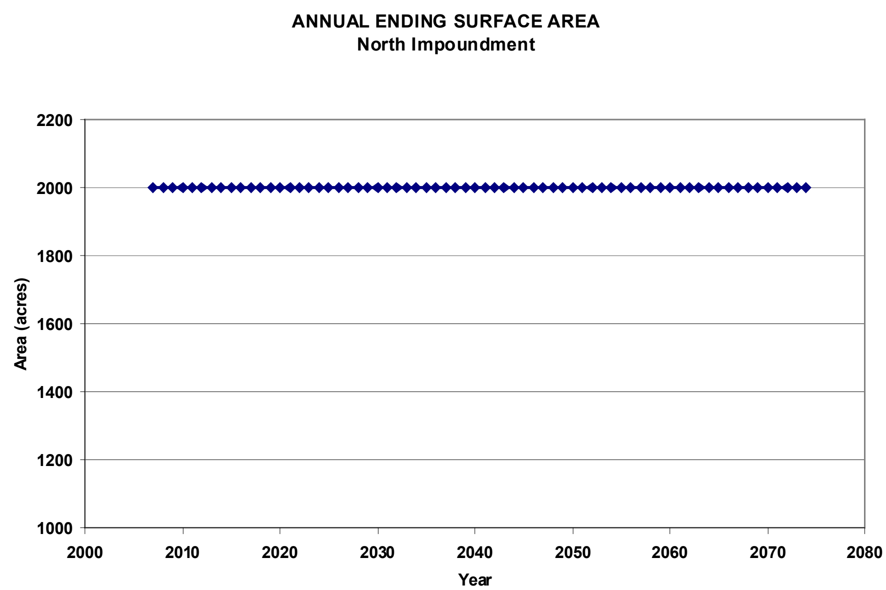
Salinity: North Impoundment



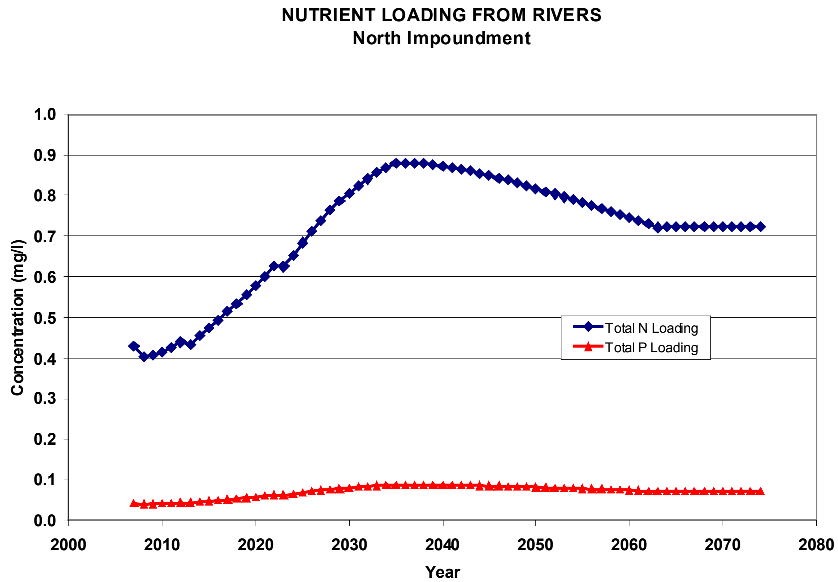
Elevation: North Impoundment



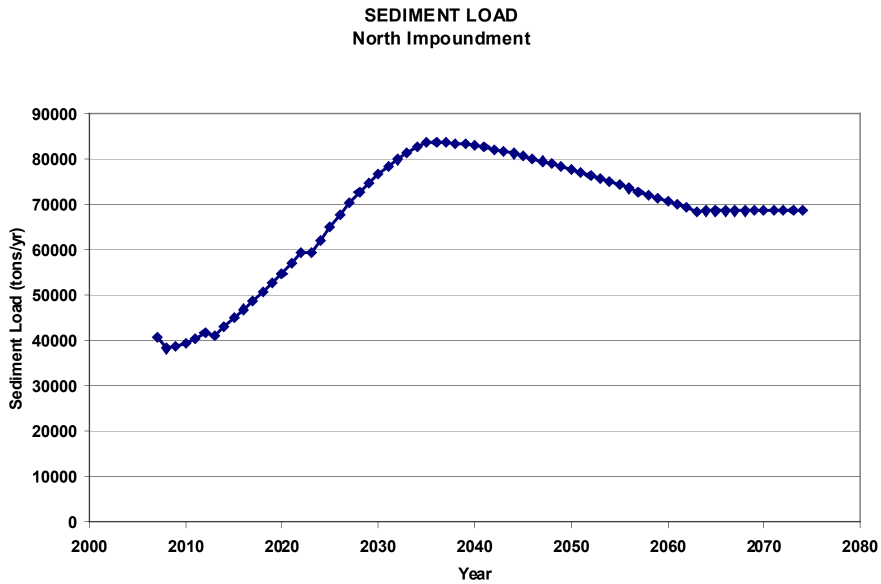
Surface Area: North Impoundment



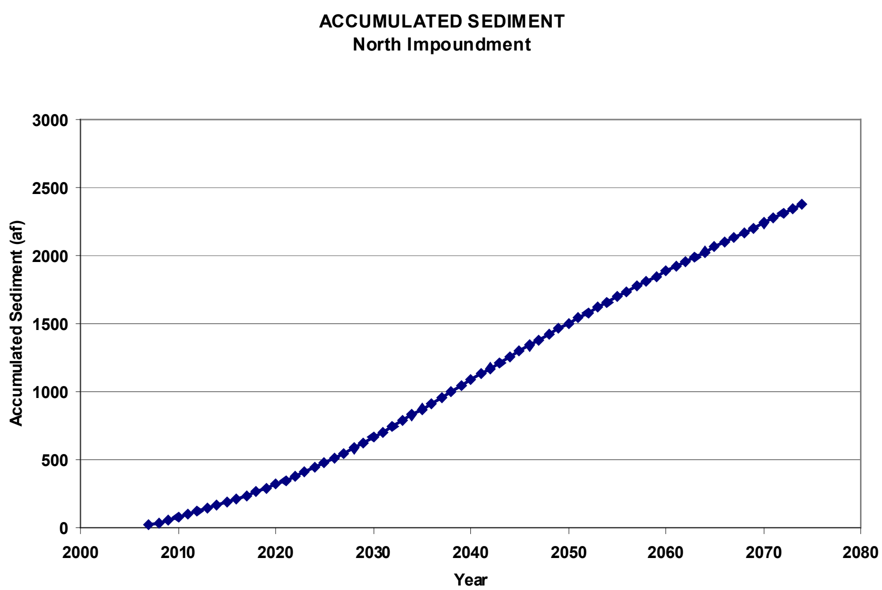
Nutrient Load: North Impoundment



Sediment Load: North Impoundment



Sediment Trapped: N. Impoundment



Pacific Institute Impoundment Proposal

Engineering Assessment
8 January 2002

Agenda

- Contributors
- Design Considerations
- Engineering Issues
- Cost

Contributors

William Brownlie, PE, PhD	Senior Vice President, Registered Civil Engineer Tetra Tech, Inc.
Elston Grubaugh, PE	Supervising Engineer - Water Resources Imperial Irrigation District
Leo Handfelt, PE	Vice President, Registered Civil and Geotechnical Eng. URS Corporation
William Thompson, PE	Senior Design Engineer, Registered Civil Engineer U.S. Bureau of Reclamation
Paul Weghorst, PE	Principal Hydraulic Engineer, Registered Civil Engineer US Bureau of Reclamation
Dick Wiltshire, PE	Principal Embankment Engineer, Registered Civil Eng. U.S. Bureau of Reclamation

Design Considerations

- Greater than 50 acre-feet and more than 6 feet in height ➡ dam
  - Likely be considered as dams by the California Division of Safety of Dams
- Levee exclusion if primary purpose to control floodwaters probably does not apply

Design Considerations

- Dams
  - – Dam safety a major concern
  - – Need to pass project flood
  - – Need spillway or weirs and channels to convey water to the new Sea
  - – Dam break risk analysis required
  - – Design for seismic stability

Seismicity

- One of most highly seismic areas in CA
- Imperial and Coachella Valley Segment of San Andreas Faults
- Possible embankment failure
  - – Catastrophic slump/slope failure
  - – Liquefaction and slumping of crest
  - – Several minutes to an hour or more
  - – Zipper effect when water spills through breach

Embankment Design

- Underwater uncompacted construction
- Poor hydraulic barriers
- Possible failure from internal erosion by seepage after Sea elevation falls
  - Similar to Teton Dam failure
- Added cost for improved hydraulic and seismic design

Flooding Issues

- South impoundment need to handle project flood
  - Spillway or multiple weirs
  - Costs would need to be considered
- North impoundment need to pass ~80,000 cfs Whitewater R. project flood
  - Spillway or other means to pass flood

Wetlands

- About 9,000 acres estimated to be needed
  - Available area in the river bottoms estimated at 2,000 acres
  - Areas on bluffs difficult to use
  - Limited area at river mouths
- Difficult to treat drains that discharge into the Sea

Siltation

- IID has existing dredging program
  - In channel near mouth
  - No dredging in delta
- Need to continue dredging to keep delta areas from clogging
- Dikes would interfere with circulation
  - Exacerbate dredging problem

Agricultural Drains

- Complex plumbing for drains at the south end
- May need to reconfigure/extend some across exposed area to impoundment

Cost

<u>**Dikes/Berms (north & max. south)**</u>	<u>**Cost**</u>
Uncompacted underwater berm design	$370,000,000 to $450,000,000
Sheet pile design for seismic and hydraulic protection	$1,040,000,000
<u>**Wetlands**</u>	
Wetlands (9,000 acres X $50,000/acre)	Up to $450,000,000
<u>**Total**</u>	$820,000,000 to $1,490,000,000

Water quality Impacts of the Pacific Institute's Proposal to Preserve and Enhance Habitat at the Salton Sea

Evaluation Meeting on December 17, 2001 at the University of Redlands

Panelists:

Milt Friend, Ph.D. – Chief Scientist, Salton Sea Science Office

Chris Amrhein, Ph.D.– University of California at Riverside, Professor of Soil and Water Science

Jim Sartoris – USGS on detail to USBR, Civil Engineer, MS, Certified Professional Wetland Scientist

Jim Setmire – USGS on detail to USBR, Hydrologist

Water-quality evaluation

Goal: **determine the QW in the impoundments and the potential implications of that water quality on biota/beneficial uses.**

Underlying premise:

> **QW in impoundments is directly correlated to inflowing river quality – no target salinity**

Tacitly settled on southern impoundment at –245 contour to begin evaluation

Southern impoundment at –245 ft contour

QW controlled by inflowing New and Alamo Rivers plus drains discharging directly to Sea along southern shore

Distinct water quality differences across the impounded water - Mouths of rivers 12 miles apart – minimal mixing of water from Alamo River with water from New River

Constituent	New River at Outlet	Alamo River at Outlet
TDS	3,000 mg/L	2020 mg/L
N total	8 mg/L	10 mg/L
P total	0.4 mg/L	0.2 mg/L
Se dissolved	4 ug/L	8 ug/L
Suspended sediment	510 mg/L	590 mg/L
Pesticides	na*	na*
Flow	500K acre-ft/yr	600K acre-ft/yr

Selenium

Selenium conc. in Salton Sea currently is 1 ug/L

Southeastern part of impoundment will be 8 ug/L Se

Southwestern part of impoundment will be 4 ug/L Se

EPA criterion for protection of aquatic life is 5 ug/L, but lower limits such as 2 ug/L are being considered for areas having significant bioaccumulation and magnification

Entire loading annual loading of 7 tons of Se to the Salton Sea will be concentrated in 11 % of the Sea's volume – the impoundment

Currently, this Se is entombed in the deeper sediments of the Sea where it is not available to the biota

Selenum – cont'd

Role of Se in current disease issues and reproductive success is unknown, but is at levels of concern

The southern end of Sea where impoundment is to be located contains major shorebird feeding areas as well as feeding areas for many other waterfowl and waterbirds – Se currently is 1 ug/L in water and <1mg/Kg in bottom sediments of these areas.

There is significant concern that increasing the Se conc. from 1 ug/L to 8 ug/L in selected areas of the impoundment along with decay and deposition of the algae will alter the existing biological system causing major reproductive impairment.

Se has been found at 3 ppm in filamentous algae in the Imperial Wetland

Se cont'd

Worst case scenario –

All of Se load deposited in impoundment

Sufficient time for algae to grow, die and deposit in bottom sediment of impoundment

In future – if tailwater and operational loss are conserved to provide source water for water transfer – Se in Alamo and New Rivers could increase by 30 % - lead to 10 to 12 ug/L Se in Alamo River and eastern portion of impoundment;

6 ug/L Se in New River and western portion of impoundment

If water for transfer obtained by fallowing poorer quality land (saline soils) might reduce Se conc by 10%

Nutrients

Salton Sea is strongly P limited – entire load of N and P will be deposited in an area that represents only 11 percent of the current Salton Sea

Algal blooms in the impoundment will be incredible

High nutrient loading will translate to supersaturated DO during daylight, causing increased pH and could lead to increased conc. of unionized ammonia

Sulfate ppt and calcite formation which removes P in the Sea will not occur in the impoundment

Will be significant internal loading of P from decaying algae and release of P to water column fueling the algal cycle in the impoundment producing dark green water

Nutrients cont'd

Primary productivity in the impoundment will be higher than currently in the main body of the Salton Sea.

Michael Anderson from UC Riverside used BATHTUB to make some tentative water quality simulations for the –240 and –245 ft impoundments.

Model predicts that total N, total P, and chlorophyll *a* levels will be very high in the impoundment leading to hypereutrophic conditions.

Chlorophyll a = 75-94 mg/L

Secchi Depths = 0.4m

TP = 0.3-0.4 mg/L

Nutrients cont'd

Two possible ecological states:

- **Turbid algal dominated system**
- **Clear macrophyte dominated system**
- **Presence of carp will push toward algal system**

Topic interfaces with biological evaluation

Impact of Constructed Wetlands

- **90-95% reduction in sediment loads going to impoundment**
  - **DDE associated with fine sediments will deposit in wetlands**
  - **Other sediment adsorbed compounds will be removed**
- **Underlying assumption that wetlands will remove nutrients from inflowing water**
  - **Wetlands generally are a sink for nitrogen, so nitrogen loading to the impoundment will be reduced**
  - **Wetlands are not effective at phosphorus removal –**
  - **Some depositional loss of refractory sediment associated P**
  - **Hemet wetlands averaged between 5-11% P removal**

Impact of Constructed Wetlands

Selenium – total load will likely decrease, but concentration will stay the same

Selenium uptake by plants, algae, and sediments plus possibility of Se volatilization as dimethylselenide

3 ppm Se found in filamentous algae in Imperial Wetland

Water loss in wetland due to evapotranspiration – about 8%

Northern Impoundment

30 years to come to equilibrium – built at –240 ft

Short residence time – quick turnover

Overdraft of aquifer feeding northern end of Sea will cause changing QW in drainwater feeding impoundment

Impoundment will have lower dissolved solids and suspended sediment concentrations than southern impoundment

Same high productivity as the southern impoundment

Changes in QW of Main Body of Salton Sea

External loading of nutrients will be eliminated

Algal blooms should cease

Clarity will increase

Sulfate reduction will continue with some H_2S production

Intense calcite precipitation in sediments and co-precipitation of P

P will remain in sediments, but rate of sequestration will be reduced

Questions & Summary

How much P will be in bird excrement of the southern impoundment?

What is impact of this P on impoundment?

South impoundment at –240 ft would provide the worst QW impacts

South impoundment at –245 ft is better

North impoundment is different, high exchange rate, long time to equilibrium

Hydrology Working Group

- Michael Anderson—Ph. D. from Virginia Tech, 1990. At UC Riverside 11 years; now Associate Professor, Department of Environmental Sciences. Nutrient studies at sediment-water interface in Salton Sea.
- Paul Weghorst—Registered professional engineer with Bureau of Reclamation, Denver. Salinity and elevation modeling for the Salton Sea.
- Roy Schroeder—Ph. D. from Scripps Institution of Oceanography, 1974. Salton Basin selenium and New River contaminants studies since 1988.

Overview of Our Process

- **Review of proposal and instructions**
- **Descriptive maps—U. Redlands**
- **Hydrologic modeling—Reclamation**
- **Key points developed for:**
  - Impoundments
  - Main Salton Sea
  - Transition (construction phase)
- **Met with water-quality group**

Key Hydrologic Features

- Residence time (turn-over rate)
- Mixing time (circulation rate)
- “Reaction rates”

- South impoundment
  - Residence time is 3 to 4 months
  - Salinity about 4,000 mg/L

- North impoundment
  - Residence time drops from 7 to 3 weeks
  - Salinity increases from 1,200 to 2,800 mg/L

- Mixing
  - Wind more important than advection

Other Key Points

- Multiple outflows to prevent stagnation
- Transition rapid as closure nears
- Must dredge rivers and cut drain channels
- Suspended mineral matter retained
- Turbidity greater than in main water body
- Temperature range greater
- Wet and salty land between dike and Sea
- Need cumulative depth vs. area graph
- No longer a temporal imperative

Biological Evaluation of the Pacific Institute's Proposal for the Salton Sea

Panelists

Dan Anderson, Ph.D., Professor of Wildlife Biology, UC Davis
Eugenia McNaughton, Ph.D., Environmental Scientist, US EPA
Stuart Hurlbert, Ph.D., Professor, Professor of Biology, Director, Center for Inland Waters, San Diego State University
Albert Johnson, Ph.D., Professor Emeritus of Biology, San Diego State University
Kathy Molina, Avian Ecologist, Natural History Museum of Los Angeles County
Make Saiki, Ph.D., Research Fishery Biologist, USGS
Rey Stendell, Ph.D., Senior Scientist, USGS
Joan Dainer, graduate student, San Diego State University
Lucy Caskie, Fish and Wildlife Biologist, USFWS
Doug Barnum, Ph,D., Science Coordinator, Salton Sea Science Office

HABITAT TYPES CONSIDERED

- **High salinity (the open sea)**
- **Impoundments (at the river deltas)**
- **Wetlands (rivers and sea)**
- **Mud and salt flats**
- **Rivers**
- **Uplands**

HABITAT	EXPECTED CHANGES
Open Sea	Increasing salinity > less biodiversity > fish > brine flies > brine shrimp
Mud – Salt flats	Different habitats within the area > some stagnant conditions > more biodiversity
Impouded areas	Lower wind and circulation impact > decreasing salinity > freshwater vegetation
Rivers	Lower flow > exposed river channel > no change in diversity
Wetlands	Increased acreage > sediment traps > freshwater vegetation
Uplands	No change

ASSUMPTIONS

- Impoundments at -245 ft with wetlands
- Wet habitat will be reduced by 10%
- No infrastructure
- No management
- Impoundments to provide open water habitat

PHYSICAL CHANGES THAT WILL AFFECT THE BIOLOGY

- Lower salinity (3-5ppt)
- Lower sediment load
- Lower turbidity
- Less wind/current effect
- Creation of stagnant conditions
- Anoxic conditions

THE OPEN SEA

- Introduced marine and salinity-tolerant fish populations will not be able to reproduce
- Pelicans and grebes (fish eaters) will lose wintering habitat
- Invertebrate species will dominate
  - Brine flies and water boatmen at first
  - Brine shrimp in very high salinity conditions

IMPOUNDED AREAS

- Submergent and emergent vegetation
- Likely exotic species invasion
- Tilapia
- Desert pupfish habitat and escape routes compromised
- Periphyton and epiphyton replace phytoplankton
- Snag habitat lost
- Snowy plover breeding area may be lost
- Amphibian habitat created

SALTON SEA PUPFISH HABITAT

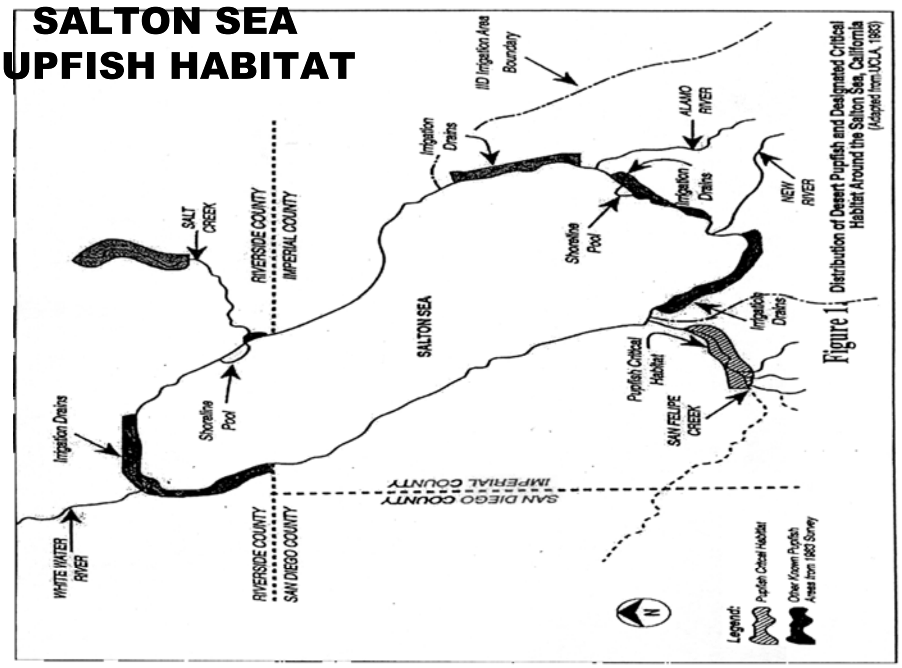


Figure 1. Distribution of Desert Pupfish and Designated Critical Habitat Around the Salton Sea, California (Adapted from UCLA, 1983)

MUD and SALT FLATS

- Not completely dry
- Patches of salty areas
- Shorebird habitat relatively unchanged
- Less flow to refresh remaining shallow areas
- Potential for tamarisk invasion
- Vegetation will bring habitat changes

RIVERS

- Lower flow
- Lower turbidity
- Exposed river channel
- Little aquatic species change
- Vegetation (tamarisk) to water's edge

THE ALAMO RIVER

WETLANDS

- Similar to impoundments
- Ducks, geese, rails, cormorants
- Emergent vegetation
- Small fish and tilapia
- Mosquito habitat in stagnant areas

NEW RIVER WETLANDS
IMPERIAL SITE

NEW RIVER WETLANDS
BRAWLEY SITE

UPLANDS

- Egrets, ibis, curlew in fields
- Raptors
- Impoundment levies
  - nesting habitat for some bird species
  - predator pathway

GENERAL PREDICTIONS

- Biota will be qualitatively different
- Biomass will be less abundant
- Plant productivity will increase per unit area
- Plants will invade the impoundments within 5 years
- Plants will change the aquatic community
- More habitat for amphibians

RECOMMENDATIONS

- **Management program is needed**
  - **Impoundment infrastructure for water movement and depth manipulation**
  - **Vegetation control**
  - **Fish and wildlife habitat**

CONTAMINANTS AND DISEASE

CONTAMINANTS

- Selenium is major concern because of 1) its ability to bioaccumulate in the food chain, 2) the narrow window between the amount that is nutritionally beneficial and the amount that is toxic (i.e., a steep dose-response curve), 3) its effect on reproduction in aquatic birds and fish including congenital anomalies (teratogenesis), 4) and its potential effects on human health.
  - Past use of large-scale biological treatment technologies (e.g wetlands, evaporation ponds) for selenium removal elsewhere has generated serious ecological problems and hazardous selenium waste.
  - With diking proposal, entire selenium load from New and Alamo Rivers will be concentrated within impounded area (including wetlands).
  - Impoundments could become a problem of increasing proportions over time for selenium not removed by wetlands; conversely, wetlands could become a problem if they are efficient in removing selenium.

- Food web exposure is the main route of transfer, and predators, rather than prey, are most sensitive to selenium contamination. Efficiency of bioaccumulation and trophic transfer will depend on food chain that results in wetlands and impoundments, but accumulation in tissues and eggs is likely to increase. Depressed immune system , mass wasting, and winter stress syndrome also are effects attributable to excessive selenium.
- Selenium volatilization may occur as a mechanism for selenium loss from the system but is unlikely to be a significant factor.

CONTAMINANTS

- Organochlorine pesticides: most entering the New and Alamo Rivers will be removed by wetlands due to sedimentation. A temporal decline in organochlorine pesticides in wetlands will occur as the finite amounts deposited within the agriculture fields continues to be removed; same situation will also probably occur within impoundments.

- Heavy metals: Concentrations in impoundments will increase over present concentrations in the sea due to less dilution.

- Microbial contaminants (e.g. fecal coliforms, viral pathogens): Loading within the impounded area will increase over that present in the Sea due to the concentration of waters in a more limited area.
  - Wetlands will remove 90-99% of microbial contaminants depending on their efficiency, however there will be a significant level of microbial contaminants in the impoundments because of the large numbers entering the system.

- Without wetlands, the full load of microbial contaminants would likely be concentrated within the impoundments; the use of the impoundments for recreational activities would be unlikely.

- The Imperial and Coachella Valleys are areas of known activity of St. Louis encephalitis and western equine encephalomyelitis virus activity in birds, although currently, human disease is rarely reported.
  - Both the impoundments and wetlands pose a potential to facilitate SLE and WEE transmission to humans by increasing mosquito habitat, primarily in the south. Water less than 1 foot in depth with emergent vegetation provides the best habitat for the primary mosquito vector, Culex tarsalis; freshwater to brackish water is best. The expected fluctuation in water level in the southern impoundment will flood into shoreline areas providing ideal breeding areas for Cx. tarsalis.
  - Increased recreational opportunities will provide opportunities for increased interactions between mosquitoes, birds and humans, so the probability of human exposure to arboviruses will increase.

- The potential expansion of West Nile Virus into California is an added concern of increasing mosquito habitat with the proposed impoundments and wetlands.

FISH DISEASE

- Infections of both Vibrio sp. and the parasite *Amylodydidium occelatum* in fish will greatly decrease due to the decreased salinity in impoundments.

- Heavy nutrient loads and high temperatures in impoundments will increase algal growth and the potential for toxic algae which could result in large fish kills.

- Impoundment fish would likely be heavily infected with such metazoan parasites as flukes, tapeworms, and roundworms due to more established populations of their intermediate hosts (snails, crustaceans, and insects).

- A harmful fish parasite, the Asian tapeworm *Bothriocephalus acheilognathi*, that already has been found in fish in creeks draining into the Sea will likely become a major parasite of Cyprinids of the impoundments.

- Trematode parasites will likely become well established within impoundments because the freshwater and vegetation will facilitate snail intermediate hosts.
    - Swimmers itch is likely to develop as a human disease (schistosomiasis) resulting from the snail-fish-bird life cycle of the causative fluke.
    - Trematode infections in fish, such as “black spot disease”, will be evident in the flesh of sport fish, making them less desirable for human consumption.

AVIAN DISEASE

- An evaluation of current diseases resulted in the following projections for those diseases within the compound.

Classical type C avian botulism	⇧	due to increased numbers of waterfowl, environmental conditions and maggot cycle.
Type C avian botulism in fish eating birds	??	dependent upon fate of pelican and tilapia populations.
Avian cholera	⇧	due to increased numbers of waterfowl, the primary source of disease carriers in wild birds.
Salmonellosis	⇧	due to freshwater environment and likely increased concentrations of colonial nesting species within impoundments.
Algal toxins	⇧	due to high nutrient loads and shift to blue-green and green algae.
Newcastle disease	??	dependent on cormorant use of dikes as ground nesting areas.
Grebe mortality	??	cause is unknown, therefore, projections cannot be made.

- Under certain environmental conditions, salt encrustation and other problems may eventually occur if birds use the highly saline shallow areas of the main Sea for roosting or in escaping disturbances within the impoundments.

CONTAINMENTS AND DISEASE WORKING GROUP

Dr. Milton Friend	Former Director, USGS National Wildlife Health Center and Adjunct Professor, Department of Animal Health and Biomedical Sciences, University of Wisconsin, Madison
Dr. Tonie Rocke	Epizootiologist, USGS National Wildlife Health Center
Hugh Lothrop	Associate Specialist, Center for Vector-borne Disease, University of California, Davis
Dr. Victoria Matey	Adjunct Professor, Center for Inland Waters, San Diego State University
Dr. Boris Kuperman	Center for Inland Waters, San Diego State University
Dr. Rex Sohn	Wildlife Disease Specialist, USGS National Wildlife Health Center
Dr. Theresa Presser	Research Chemist, U.S. Geological Survey, Water Resources Division, Menlo Park, California
Dr. Rick Gersberg	Professor of Environmental Health, Graduate School of Public Health, San Diego State University

Appendix I

PREDICTED WATER QUALITY IN THE SOUTHERN IMPOUNDMENTS

Michael Anderson
UCR

PREDICTED WATER QUALITY IN THE SOUTHERN IMPOUNDMENTS

Michael Anderson
UCR

I conducted a couple of quick water quality simulations for the –240' and –245' southern impoundments with the BATHTUB model (Walker, 1996). I used the data presented in the Table in the Pacific Institute's proposal for the volumes and areas for the impoundments created by placing of dikes at –245' to Bombay Beach and –240', along with mean nutrient concentrations presented in Setmire *et al.* (2001) (Table 1). Total annual flow was assumed at 1 maf, consistent with Weghorst (2001).

Table 1. Flow and influent water quality to southern impoundment.

Source	Flow (maf)	TP (mg/L)	SRP (mg/L)	TN (mg/L)	IN (mg/L)
Alamo R.	0.554	0.719	0.408	9.20	7.68
New R.	0.488	1.110	0.697	8.20	7.27

An annual evaporation rate was put at 1.5 m/yr and rainfall was assumed to be about 0.15 m/yr. The BATHTUB model uses a series of empirical sub-models to predict the annual nutrient budgets and productivity levels in the water body; there is some latitude here in terms of which model is used. For the following calculations, the 2nd-order, available N and P sedimentation models were used, while the P-N-light-T model for chlorophyll was used.

Results for the two proposed impoundment scenarios (without treatment wetlands) are shown in Table 2.

Table 2. BATHTUB-predicted mean annual water quality in the two proposed impoundment configurations (without wetlands pretreatment).

Property	Units	South –245' (no wetlands)	South –240' (no wetlands)
TP	mg/L	0.292	0.430
TN	mg/L	4.030	5.836
Chl a	µg/L	74.8	92.8
Secchi Depth	m	0.4	0.4
Retention Time	yrs	0.192	0.047
% P Retained	-	81.1	70.2
% N Retained	-	67.7	49.7

As one can see, very high total P, total N and chlorophyll levels are expected for both impoundment scenarios. For comparison, the TP and TN concentrations in the Salton Sea average approximately 0.07 and 4.0 mg/L (Holdren, 1999).The larger, deeper impoundment formed by placing the dike on the –245' contour (mean depth 2.1 m) had better water quality than the shallower –240' impoundment (mean depth of 1.36 m), even though this impoundment had a much shorter hydraulic residence time (0.192 vs. 0.047 yrs, respectively). P removal within both impoundments is predicted to be quite effective, with 81.1% of the influent P removed in the –245' impoundment and 70.2% in the –240' impoundment (Table 2).

Similar calculations could be performed for the above impoundments with wetlands at the front end with some specific assumptions about the extent of nutrient removal within the wetlands. Although I did not do the simulations, with P removal rates around 10% in the wetlands as discussed, it seems that water quality will not be substantively improved. An additional use of model would be to solve the inverse problem, that is, estimate what level of nutrient removal within the New and Alamo Rivers (e.g., via alum addition, wetlands, etc.) is required to achieve an "acceptable" water quality condition in the impoundment(s). Anyway, while a more careful analysis is probably warranted, these preliminary calculations suggest water quality consistent with our expectations of hypereutrophic conditions in these shallow, highly nutrient-loaded systems

Appendix J

Integration workshop notice with goals and key points

WORKSHOP NOTICE

EVALUATION OF PACIFIC INSTITUTES SALTON SEA WETLAND PROPOSAL

January 8, 2002

Miramonte Resort

Highway 111 – Indian Wells

8:30 a.m. – 4:30 p.m.

The workshop purpose is to describe the environment of the Salton Sea and the impounded wetlands that will be created if the proposal the proposed dikes are built. This workshop is oriented at determining likely outcomes relative to the stated project goals and will focus on identifying major benefits that may result, issues that need to be considered and major questions that need to be resolved for sound judgments to be made about the merit of this project.

A panel comprised of individuals that previously focused on selected components such as hydrology, engineering, biology and other major considerations will report on their focal group evaluations. Those individuals will discuss the integration of that information into a more holistic composite of the probable outcomes. A meeting facilitator will maintain the focus for the workshop and the flow of dialogue among the panelists and others in attendance.

Appendix K

Jan 9, 2002 Workshop attendance list
(list of persons choosing to sign in, therefore not a complete list of attendees)

Salton Sea Impoundments Proposal Workshop

Jan 8, 2002 – Miramonte, Indian Wells, CA

Attendees

	NAME	ORGANIZATION	ADDRESS	PHONE	EMAIL
1	Ted Deckers	Chamber of Commerce	Desert Shores	760-395-0056	saveoursea2000@aol.com
2	Norm Niver	County Planning	Salton City	760-394-4664	saltye1@saltonpseas.com
3	Dale Roberston	USGS	Middleton, WI	608-821-3867	drobert@usgs.gov
4	Joan Dainer	SDSU	San Diego	619-594-0359	jdainer@sunstroke.sdsu.edu
5	Deborah Dexter	SDSU	San Diego	619-594-6379	ddexte@sunstroke.sdsu.edu
6	Vickie Doyle	IID	Imperial	760-339-9446	vdoyle@iid.com
7	Danielle Healey	SDSU	San Diego	858-483-7541	Healey92@hotmail.com
8	Marie F Coe	SDSU	San Diego	619-594-2887	mcoe@sunstroke.sdsu.edu
9	Roy Schroeder	USGS	San Diego	858-637-6824	raschroe@usgs.gov
10	Tim Krantz	U Redlands	Redlands	909-335-5268	krantz@uor.edu
11	Rey Stendell	USGS	Ft Collins	970-226-9499	rey_stendell@usgs.gov
12	Richard Vogl	HydroGeo Consultants	Costa Mesa	949-650-8604	ravhydrogen@aol.com
13	Pauline Nol	USGS/NWHC	Madison	608-270-2753	pauline_nol@usgs.gov
14	Chris Holdren	USBR	Denver	303-445-2178	children@do.usbr.gov
15	Tonie Rocke	USGS/NWHC	Madison	608-270-2451	Tonie_rocke@usgs.gov
16	Rex Sohn	USGS/NWHC	Madison	608-270-2447	rsohn@usgs.gov
17	Bill Brownlie	Tetra Tech	Pasadena		
18	Branlia B Lothrop	Coachella Valley MVCD	43-420 Tracker Place	760-342-8287	bbl5@cvhved.org
19	Hugh L Lothrop	UC Davis, center for Vectorborn Dis	One shields Ave Davis CA 95616	760-342-8287	hughlothrop@ispwest.com
20	Jeri Taylor	C-VAG	POB 1095-Indio 92202	760-342-8081	
21	Michael Cohen	Pacific Institute	948 N St. Ste 7 Boulder 80304	720-564-0651	mchoen@pacinst.org
22	Jim Kenna	USBLM	POB 581260, N Palm Springs 92258	760-251-4803	jkenna@ca.blm.gov
23	E McNaughton	US EPA		415-972-3411	mcnaughton.eugenia@epa.gov
24	Francisco Costa	SWRCB			
25	Nadim Zhynar	CARWQCB	Palm Desert	760-776-8942	
26	Audra Schrader	USGS/NWHC	Madison	608-270-2443	

27	Chris Amrhein	UC Riverside	Dept Env Sci	909-787-5196	
28	Ken Linthrim	CA Dept of Health		909-937-3443	klinthic@dhs.ca.gov
29	Orylle Abbott	retired	76004 Frank Sinatra Rm B160, Palm Desert	760-345-4770-2542	
30	Bern Shanks	USGS	909 1st Ave Seattle 98104	206-220-4610	

	NAME	ORGANIZATION	ADDRESS	PHONE	EMAIL
31	Gil Stuart	BIA	2036 Iowa Ave Riverside92595	909-276-6627x251	
32	Mike Massingill	Kent Seatech	11125 Flintkote Ave Ste J San Diego 92121	858-452-5765	
33	Renjie Hu	CA Health Services	2151 Convention Way Ste 218B Ontario 91764	909-937-0705	
34	Todd W Walker	CA Health Services	2151 Convention Way Ste 218B Ontario 91764	909-937-3447	twalker@dhs.ca.gov
35	Les Ramirez	Torres-Martinez Desert Cahuilla Tribe	POB 4546 Albuquerque NM	505-254-7817 FAX:225-6955	leswramirex@netscape.net
36	Kenneth Althiser	SSDP- U Redlands	Redlands	909-335-5268	althiser@cem.uor.edu
37	Fred Cagle	Audubon			Fred.cagle@sdsu.edu
38	Sylvia Oey	ARB	POB 1258 Sacramento 95812		
39	Carol Roberts	US FWS			
40	John L Scott	MWD			
41	Robert Robinson	CVWB			
42	Charles Keene	DWR			
43	Jose L Angel	CRWQCB (7)			angj@rb7.swrcb.ca.gov
44	Teresa Newkirk	CRWQCB (7)			newkt@rb7.swrcb.ca.gov
45	Mike McDermid	GEI Consultants	2191 Palomar Apt Rd Ste 160, Carlsbad 92009	760-929-9136 x18	mmcdermid@geionsultants.com
46	Carla Scheildinger	Agrarian	162 E line Ste G Bishop 93514	801-376-0033	Carla@agrarian.org
47	Frank Stradling	Agrarian	162 E line Ste G Bishop 93514	801-376-3300	frank@agrarian.org
48	Laura Fujii	Region 9 US EPA	75 Hawthorne St CMD-2 San	415-972-3852	Fujii.laura@epa.gov

			Francisco		
49	Paul Weghorst	USBR			
50	Mike Walker	USBR			
51	Douglas Barnum	USGS			
52	Stuart Hulbert	SDSU			
53	Jim Setmire	USBR/USGS			
54	Milt Friend	USGS/NWHC			
55	Rick Gersberg	SDSU	San Diego		
56	Jo Clark	Clark Consulting	Denver		

Appendix L

Integration Workshop Agenda

WORKSHOP AGENDA

SALTON SEA IMPOUNDMENTS PROPOSAL

January 8, 2002

8:15 a.m. – 5:30 p.m.

Miramonte Resort – Indian Wells, CA

- Welcome and Announcements — M. Friend
- Introductory Comments — M. Friend

    Background, evaluation process, workshop goals
- Pacific Institute Proposal — M. Cohen

    Overview, goals, objective, concepts, and general considerations
- General Baselines
    - Physical Description of Affected Area — T. Krantz

        Computer depiction of diked area and associated information
    - Hydrologic Modeling — P. Weghorst

        Basic assumptions and model results of physical conditions within impounded areas.
- Reports of Working Groups

    General findings from preliminary evaluations
    - Engineering — B. Brownlie

        Construction, operation and maintenance considerations.
    - Hydrology — R. Schroeder

        Water movement and other aspects of the hydrology of the impoundments and other affected areas within the system.
    - Water Quality — J. Setmire

        Evaluation of physical and chemical aspects of water quality within the impoundments and other affected areas within the system.
    - Biology — E. McNaughton

        Changes in biota within the impoundments and other affected areas within the system.
    - Contaminants and Disease — T. Rocke

Evaluation of likely conditions within impoundments and other affected areas within the system.

BREAK

- Integration of Working Groups Reports — Facilitator (to be announced)

  Facilitated dialogue to describe physical conditions likely to exist within the impoundments, associated wetlands and Salton Sea area outside of the impoundments.

LUNCH

- Integration (continued) — Facilitator

  Focus on describing biota and health status considerations.

BREAK

- Open Forum — Facilitator

  Facilitated input and comments from the audience for consideration for the expert panel relative to evaluations being made.
- Highlights — S. Hurlbert

  Summary of conclusions reached and divergent opinions among panel, major issues to be resolved, unknowns that could have major impacts on outcomes and other pertinent comments.
- Panel Response — Panel Members

  Facilitated response to adjust highlight statements as reported by meeting summarizer.
- Closing Statement and Adjournment — M. Friend

Appendix M

Commentary on the Science Office Review of the Pacific Institute Proposal

Mike Cohen

Commentary on Proposal Evaluation
by Michael Cohen, Pacific Institute

The Pacific Institute greatly appreciates the effort and expertise of those involved in the review of the "Proposal to Preserve and Enhance Habitat at the Salton Sea." This review very helpfully indicates areas where the proposal could be improved. We are encouraged that the Salton Sea Science Office expects future iterations of the review process to refine and produce a more workable proposal.

The evaluation's Executive Summary notes that the review "did not attempt to separate out those effects due to a water transfer from those due to development of freshwater impoundments." For example, the evaluation notes that under the proposal, some 89 square miles of lakebed would be exposed. Yet the IID water conservation and transfer program draft EIR/EIS (p. 3.1-120) projects that the combination of the water transfer and other future actions would expose approximately 103 square miles of lakebed. Relative to current conditions, the exposure of 89 square miles of lakebed would argue strongly against adoption of the proposal. Yet relative to the potential baseline exposure of 103 square miles of lakebed, the proposal looks far more reasonable.

One of the key objectives of the Pacific Institute proposal was to preserve as much avian habitat as feasible, in the face of likely reductions in the volume of water flowing to the Salton Sea. The objective was not an improvement relative to current conditions, but rather an improvement relative to what would likely exist at the Sea without any habitat preservation plan. Unfortunately, no adequate description of future baseline conditions exists.

The Pacific Institute urges the Salton Sea Science Office to coordinate the development of such a baseline, drawing from the expertise of those who contributed to this review and others familiar with the Salton Sea. Such a baseline might include the three inflow scenarios used in the Salton Sea Restoration Project draft EIR/EIS (of 0.8, 1.0, and 1.3 MAF/year) and various explicit assumptions (such as the adoption of the Regional Water Quality Control Board's TMDLs and Upper Basin selenium control programs), with the depth of analysis performed by this evaluation. This baseline appraisal would provide an objective basis for comparing future iterations of the Pacific Institute proposal and other proposals that may be considered, and would inform the preparation of the Salton Sea Authority's restoration plan. Such a baseline would also be an informative document in its own right.

One of the underlying themes that emerges from the evaluation is that a larger impoundment could minimize many of the potential problems arising from the relatively low salinity of the proposed impoundment. Presumably, a higher impoundment salinity could limit the viability of emergent wetland vegetation and many disease vectors. The challenge of creating a larger impoundment lies in the construction and design of the impoundment structures themselves: locating the structures in deeper water could increase costs almost geometrically (to address the hydraulic head on the impoundment side), particularly across the broad southern base of the Sea. Potentially, a structure could be build across the middle of the Sea where it narrows, at Bombay Beach or northwest of there, but the feasibility of constructing such a structure within the water has been questioned.

Toward developing a common, transparent set of assumptions for the assessment of revised versions of the proposal, we offer the following comments on Science Office's evaluation. We regret that the proposal itself did not state its assumptions more explicitly.

Dikes vs. Dams

The evaluation notes that the California Division of Safety of Dams would likely classify the proposed impoundment structures as dams rather than dikes, tripling the estimated cost of these structures. Given that the potential failure of these structures would be unlikely to threaten human life or property, the hope is that an exemption from standard dam construction requirements could be secured for such structures.

As noted by the evaluation, a benefit of the impoundments is that they would offer a ready source of water for dust abatement programs, such as sheet flooding and revegetation efforts. Given that fugitive dust emissions have been identified as a potentially significant impact of the proposed water transfer, this could prove to be a valuable benefit.

Treatment wetlands

The evaluation assumes that "Approximately 9000 acres of [artificial] wetlands would be needed to meet the objective of removing >90 percent of the silt load" of the New and Alamo rivers. The proposal itself does not list this as an objective; sediment removal is simply listed as a corollary function of the wetlands. Nor does the proposal suggest that enough wetlands be constructed to improve water quality to the standard achieved by the existing pilot wetlands; it says that "The resulting impounded areas behind the dikes would be coupled with treatment wetlands, to reduce nutrient and selenium loading, and with the implementation of management practices to reduce nutrient loads from agricultural, municipal, and industrial sources."

The evaluation also notes that only ~2000 acres of suitable river bottom lands are available for wetland construction. The evaluation unreasonably assumes that the proposal calls for the construction of 7000 acres of wetlands on unsuitable land. It might be reasonably assumed that some of the existing, suitable bottom land would not be available for wetland construction; let's assume that half of the existing bottom land could be leased or otherwise made available. As extrapolated from Paul Weghorst's hydrologic modeling, assuming 1000 acres of treatment wetlands, the rate of sediment accrual in the south impoundment would be roughly 220 acre-feet per year, into an impoundment with a total volume in excess of 180,000 acres. (The evaluation apparently uses the sediment loading rate of 20 af/y that assumes 9000 acres of wetlands.) Note that the Regional Water Quality Control Board's (RWQCB) numeric target for sediment could reduce the Alamo River's sediment load by more than 1/3 by 2011. On-farm conservation improvements associated with the proposed IID water conservation and transfer program would also be expected to reduce sediment loadings to the Salton Sea.

The evaluation estimates capital costs for the wetlands at $50,000/acre, based on the per acre cost of the Brawley and New River pilot projects. Conversations with Desert Wildlife Unlimited suggest that economies of scale will reduce the costs of their proposed wetlands by at least a factor of three, suggesting that the actual cost of 1000 acres of constructed wetlands would be less than $20,000,000.

Disease vectors

The evaluation notes the challenge of predicting the abundance of particular species, given the uncertainty inherent within projecting complex physical and biological interactions. The evaluation notes that wave action along the southern shoreline would likely be reduced from current levels, but "would still be sufficient for significant waves to be generated. Shoreline wave action and near shore turbulence action are significant factors influencing . . .

establishment of aquatic vegetation." Yet several pages later the evaluation predicts that "vascular plants would become abundant in the impoundments and along their shorelines," leading to the projection of a large increase in the abundance of invertebrates within these vegetated areas, including biting insects that could be disease vectors. From the evaluation, it is unclear to what extent the predicted wave action would limit the establishment of aquatic vegetation. Additionally, at the January 8 workshop on the proposal, the participants expressed uncertainty as to whether the impoundments would convert to algal or macrophyte systems, though more seemed to think that it would become a turbid algal system. This too would tend to limit submergent and emergent vegetation, further reducing habitat for biting insects. The uncertainty about the abundance of such habitat could be made more explicit in the evaluation.

As noted during the workshop, the Coachella Valley Water District has an on-going mosquito abatement program, to address mosquito problems on the Sea's northern shore. A similar program could be adopted by IID, perhaps in conjunction with the National Wildlife Refuge, to control the populations of biting insects within the southern impoundment. Although the problem of disease vectors would be an unwelcome byproduct of the impoundments' lower salinity, the problem could be managed with existing methods.

The evaluation also notes the increased potential for transmission of botulism and avian cholera, due to increased bird density. Ideally, the continuation of the Refuge's disease monitoring program could limit the transmission of these diseases, by physically removing sick and dead individuals from the wild.

Phosphorus and Nitrogen

The evaluation notes that nutrient loadings to the Sea could be reduced by improved management of tailwater drainage and improved municipal wastewater treatment. Such improvements are likely to result from the proposed water transfer and improved wastewater treatment capacity within the City of Mexicali, as well as from the adoption of TMDLs within the Imperial Valley. The development of an independent baseline appraisal would inform such analysis, and might show that future nutrient inputs to the Sea (and impoundments) will be greatly reduced from current levels.

Selenium

The increase in selenium concentrations within the impoundments may be the single greatest negative impact of the proposal. Potentially, a combination of the efforts listed by the evaluation (Upper Colorado River basin source reduction programs, fallowing of Imperial Valley farmlands reporting disproportionately high salt and selenium loadings, and sediment settling basins) could reduce selenium concentrations in the impoundments below EPA's existing criterion for the protection of aquatic life, and possibly as low as the potential new EPA criterion of 2 μg/L. Agrarian Research and Management Company, Ltd. has reported significant reductions in selenium concentrations with the use of constructed wetlands, affording additional reason to believe that this impact may be mitigable.

Conclusion

The evaluation highlights a number of challenges facing the proposal as written, and the need for clarification and revision. The Pacific Institute welcomes the suggestions and recommendations of reviewers (and others) on methods to improve the proposal and address the challenges noted in the evaluation. Future iterations would benefit from the development of a reasonable baseline, which could assist reviewers in making comparisons and would inform the continuing policy-level debate on the future of the Salton Sea.