CHAPTER IV

Alternatives Retained

Chapter IV

ALTERNATIVES RETAINED FOR FURTHER EVALUATION

This chapter describes the alternatives that survived the elimination process and will be subjected to further evaluation. For each alternative, available information is provided on each of the evaluation criteria.

4.0 INTRODUCTION

Fifty-four alternatives for addressing issues at the Salton Sea have been proposed (see Table 11). All but five alternatives were eliminated from further consideration because they failed to meet one or more of the elimination criteria. Alternatives that did not meet the elimination criteria and the reasons why are presented in Chapter V.

Each of the five alternatives that survived the elimination process are described in this chapter. In order to select a preferred alternative from among these five, each was evaluated against the criteria described in Chapter III. Information is provided in this chapter which allows application of evaluation criteria in a way that results in a priority ranking of the five alternatives. That ranking process is presented in Chapter VI.

In Table 11, the alternatives are organized, in general, by the method used to reduce salinity. Since alternatives came from a number of different sources, the degree to which they address salinity of the Sea vary. Some would directly reduce salinity; some would not, of themselves, reach salinity goals. For the purpose of classification, alternatives were divided into those that addressed salinity by separating the Sea by diking, by pumping water and its salt load out of the Sea, by combinations of various methods, by removing salt before it reaches the Sea, by importing good quality water into the Sea, and by other various methods. Each alternative has been placed into one of those categories.

4.1 EVALUATION LIMITATIONS

Alternatives presented in this report originated from numerous sources. Some came from previous work that was done at a fairly detailed level. Others had no previous analyses and were presented with only minimal data. In addition, available data may have come from studies ranging in age from more than 20 years old to ongoing investigations. In some cases, study results have not been published.

SALTON SEA ALTERNATIVES

Table 11 - Elimination Summary

DIKED IMPOUNDMENTS

1. 50 mi^2 - South or North End
2. 40 mi^2 - South End
3. 127 mi^2 - North 1/3
4. 47 mi^2 - In-Sea Evaporation Basins
5. Phased Impoundment
6. 30 mi^2 with pumping *(4)*
7. 30 mi^2 max pump *(4)*

13. 190 mi^2 - Plastic Curtain *(3)*
14. Various Sized Impoundments - Plastic Curtain *(3)*

PUMP-OUT

8. Onshore Evaporation Ponds *(4)*
9. Enhanced Evap/Solar Pond/Power *(4)*
10. Dry Lake Bed (Palen, Clark, or Ford) *(4)*
11. Pipeline to Pacific Ocean/Camp Pendleton *(4)*
12. Navigable Waterway/Mexicali Seaport *(4)*

15. Canal/Dam to Base of Chocolate Mountains *(1)*
16. Diked Impoundment to Gulf of CA *(4)*
17. Frontier Aquadyne Enhanced Evaporation *(3,4)*
18. Solar Still Desalt/Colorado River Replenish *(3)*
19. SNAP Technology *(3)*
20. Aquaculture/Evaporation Ponds *(1,2)*
21. Pump to Gulf of CA (415K AF) *(4)*
22. Pump to Laguna Salada/Gulf of CA (415K AF) *(4)*
23. Pumped Storage Canal to Gulf of CA *(4)*
24. Solar Membrane Distillation *(3)*
25. Disposal of Reject Stream to Yuma *(1,2)*

COMBINATION

26. Impound/EvapPond/Pipe to Gulf of CA/YDP *(4)*
27. Impound/Power Generation/Wetlands *(4)*
28. Freshwater Shore/Pumped Storage/Wetlands *(4)*
29. Solar Power/Pumped Storage/Wetlands with Laguna Salada Disposal *(4)*

REMOVAL OF INFLOW SALT

30. Move Yuma Desalting Plant to Sea *(2,4)*
31. Poplar Tree Constructed Wetlands *(1,2)*
32. Special Pre-Treatment Reservoirs *(1,2,3)*
33. U.S. Filter - New River Desalting *(1,2,4)*
34. Groundwater Pump for Selenium Mgmt *(1,2)*

WATER IMPORTS

35. Freshwater Blending - Calexico *(2)*
36. Replenish - Colorado River Surplus *(2)*

OTHER

37. Venturi Air Pump *(1,2)*
38. Foraminifera Studies (Research) *(1,2,3)*
39. Potential Use Study Ponds (Research) *(1,2,3)*
40. Injection Well Salt Disposal *(4)*
41. Air Diffusion/Ultraviolet Ozone System *(1,2)*
42. Surface Aeration *(1,2)*
43. Gravel Berm *(1,2)*
44. Sea Water Filtration *(1,2)*
45. Enzyme-Activated Removal *(1,2)*
46. Power/Freshwater Cogeneration *(1,2)*
47. Water Conservation *(1)*
48. Drainage Water Reuse or Blending *(1)*
49. Pulsed Plasma *(3)*
50. Hydropower/Filtration System Resort *(3,4)*
51. Slow Sand Reverse Osmosis Filtration *(1,2,4)*
52. Electrochemical Extraction *(2,3)*
53. Mexican Cleanup of New River *(1)*
54. Land Speed Racetrack *(1,2)*

Note: Alternative titles in RED show an alternative as RETAINED for further consideration. If an alternative is shown in black, one or more of four criteria were used to remove it from further consideration. The applicable criteria is indicated by the italic number(s) following the title as follows:

Because of the prohibitive cost of completing detailed designs and cost estimates for each of the alternatives submitted, analyses were done at an appraisal level without collecting additional field data. Many alternatives were submitted as conceptual ideas or anecdotal possibilities; therefore, in order to evaluate the alternatives on as equal a basis as possible, an attempt was made to develop missing data and to bring quantitative data to an equivalent time period. For the most part, data contained in this chapter are preliminary and have been developed at a reconnaissance or appraisal level. Previous analyses conducted at more detailed levels were used to the extent possible.

Normally, at the reconnaissance or appraisal level of analysis, only existing data are used. Consequently, assumptions that may have significant effects on analysis outcomes often must be made. General assumptions used in this report are discussed in this section; assumptions specific to each alternative are discussed in the section for that alternative. While the use of these assumptions is adequate for the purpose intended here—appraisal analysis of multiple alternatives—these assumptions must be revisited before being used in a more detailed analysis of a preferred alternative.

An example of the use of assumptions is in the area of salinity improvement. For most alternatives, data on the time to reach certain salinity levels is based on unsophisticated models that, while providing a fairly accurate picture of salinity changes, do not provide the precision necessary to do final sizing and design. Therefore, a more rigorous operating model will need to be developed for the preferred alternative in order to complete designs, develop operational parameters, and determine project effectiveness. Additional assumptions are made in the areas of costs, construction methods, project features, and certain wildlife impacts.

4.2 GENERAL ASSUMPTIONS

Some of the alternatives that were submitted contained cost estimates. For the most part, these costs were assumed to be accurate and were used without alteration except for indexing to make all costs current.

Of the five alternatives that survived the elimination process, all involved separating the Sea with dikes. It was assumed that the construction method and material was the same for the dike in each of these alternatives. In addition, it was assumed that the unit cost (cost per cubic yard) was the same irrespective of the location or configuration of the dike. This was done because locations and configurations were still somewhat conceptual and have not been established to the point where cost distinctions could be made. Development of the unit cost used for all diking alternatives is presented under Alternative 1.

If a proposed alternative contained sketches, drawings, tables, charts, and supporting data, and no cost information was given, only the supplied material was used to develop the cost of the proposal. If a proposal required pumping or evaporation, quantities of water pumped or evaporated were taken at face value. If a proposal stated the specific quantity of water needed to be pumped from one location to another, it was assumed that this quantity would provide the required objectives of salinity management. The actual quantity of water required to be pumped and the distance and lift required for a specific alignment were generally not questioned. For alternatives that included pumping water out of the Sea, no calculations were performed to check pipe or canal sizes, pump number or sizes, or the location of pumping plants or conveyance facilities.

4.3 INDEXING COSTS

Many of the alternatives were developed years ago, and their costs may no longer be accurate. In those cases, the costs were updated to account for inflation and changes in material costs and labor rates. Updating provides a cost in today's dollars and allows a cost comparison among alternatives whose costs were developed at different times. For this report, costs developed in the past were updated to January 1996.

Updating was done by applying indices developed periodically to account for changes in costs. In this report, costs were indexed using composite cost trends updated quarterly and published annually by the Bureau of Reclamation. These composite cost trends are primarily used in cost indexing Reclamation projects, but they can be applied to commercial projects as well because the composite cost trends closely follow cost trends as published by the *Engineering News Record, McGraw-Hill Construction Weekly* for labor and materials.

A composite index combines all labor and material cost changes over time for a broad range of civil works into one number. If a road, dam, or pumping plant cost is estimated in 1980, for example, a composite index would be used to obtain a current cost estimate. Composite cost indices are assumed to apply to all major construction features.

If an alternative was eliminated from further consideration because of non-cost parameters (that is, salinity control, elevation control, or an unproven technology), costs were not relevant and no time was spent developing new costs or indexing prior cost estimates.

4.4 ALTERNATIVE DESCRIPTION ORGANIZATION

As pointed out previously, alternatives have been grouped in accordance with the method they use to control salinity.

Table 12 lists each alternative by group. The number of alternatives by group is shown below:

TABLE 12
ALTERNATIVE DESCRIPTION ORGANIZATION

Type of Salinity Control	Number of Alternatives
Diked Impoundment	9
Pump-out	16
Combination	4
Salt Removal	5
Water Importation	2
Other	18
Total	**54**

Discussion of the alternatives, with alternatives retained for further evaluation beginning on the next page and alternatives that have been eliminated beginning in Chapter V, are organized by group. This was done so that discussion that applies to all alternatives within a group is presented in general sections for the whole group and does not have to be repeated for each individual alternative. Each individual alternative is then described, and information that applies to that individual alternative is covered in that section.

DIKED IMPOUNDMENTS

INTRODUCTION

Managing salinity with a diked impoundment is based on the concept of providing the Sea with an outlet into an evaporation pond. For alternatives in this group, the evaporation "pond" is an impoundment within the Sea itself. Under this concept, the main body of the Sea is separated from an evaporation section. This "within-the-Sea evaporation pond" concept distinguishes the diked impoundment group from the pump-out group.

The impoundment concept works because water flowing into the impoundment area carries a heavy salt load, while inflow to the main body of the Sea from the Alamo River, New River, and other sources carries a smaller salt load, thereby decreasing the salt concentration of the main body of the Sea. Over the years, a number of in-Sea impoundment proposals have been made (Reclamation and Resources Agency of California, 1969 and 1974; Aerospace Corporation, 1971; Coachella Valley Water District, undated report). Variations of the impoundment concept continue to emerge. Detailed engineering and geologic studies, dialogue with local residents, and water conservation developments in Imperial Valley will, in all likelihood, result in further adjustments in impoundment size, location, configuration, and design.

Unless inflows decrease in volume, an in-Sea impoundment would change the elevation of the Sea very little. Although the surface area of the main body of the Sea would be reduced by the impoundment, the total surface area of the Sea would be essentially unchanged. Some minor changes in elevation would occur because evaporation rates in the impoundment and the main body of the Sea would be affected by salinity and temperature changes that would occur as the main body became less saline and the impoundment became saltier. Surface evaporation rates decline as salinity increases because saltier water absorbs more heat—thus reaching a higher temperature before evaporating—than fresher water. Impacts on elevation due to dissimilar evaporation rates are unknown because evaporation rates applicable to the impoundment alternatives for the Sea have yet to be determined.

A diked impoundment, as a means of reducing salinity, was first formally proposed by the United States Department of the Interior and the Resources Agency of California (Reclamation and Resources Agency, 1974). The impoundment would receive water from the main body of the Sea through inlets, concentrate it through evaporation, and store the removed solids from the Sea for an indefinite period of time. Eventually, the impoundment would become full of salts, and salt disposal would be necessary.

Most comparisons between in-Sea diked impoundments and onshore evaporation ponds have shown that evaporation ponds on land are not economical because the combination of large land requirements and the high value of land surrounding the Sea result in excessive land acquisition costs (Reclamation and Resources Agency, 1969). However, advances in solar pond technology have included enhanced evaporation systems that significantly reduce land requirements and, therefore, land cost. Such a system is included in an alternative under the pump-out group.

In a diked impoundment alternative, an inlet structure in a dike separating the main body of the Sea from the evaporation section would allow water to flow from the Sea into the impoundment. The length of time required for the main body of the Sea to reach some predetermined salinity level would depend upon the size of the impoundment and, thus, the amount of water flowing between the Sea and the impoundment. If a target salinity level in the main body of the Sea is set higher than the impoundment system's natural equilibrium level, flow into the impoundment would eventually have to be reduced, or some method of transporting salt from the impoundment back into the main body would have to be employed in order to maintain the target level.

While water in the main body of the Sea would become less saline until it reaches an equilibrium level, water in the impoundment would become more concentrated over time. Salt concentrations would eventually reach saturation, at which point precipitation as a solid would occur. Precipitated salts would occupy volume in the impoundment, but impacts on elevation and useful project life would be minimal, except in the case of small impoundment sizes. In those cases, impoundment water would reach saturated levels relatively quickly, and impoundment volumes would be small enough that salt build-up could noticeably impact project life. The lifespan of the impoundment configuration that is selected will be affected by the rate of inflow. Decreased inflow rates will result in a longer effective life due to deposition of less salt.

Unlike some other alternatives, a pure diked impoundment alternative would not require pumps or other electro-mechanical features. Because of its "low-tech" nature, the impoundment concept would offer simplicity, low O&M effort, and high reliability. Construction techniques for building a dike are well established and would offer the opportunity for substantial employment of local labor.

Except for alternatives with dikes connecting specific portions of shoreline, impoundments could be placed anywhere within the Sea. Environmental considerations, construction costs, and public opinion would be the major factors in determining location of those impoundments.

A number of methods for dike construction have been considered in *A Value Engineering Evaluation of Salton Sea Alternative Dike Structures* (Reclamation and TAC, August 1995). Results of that analysis indicate that, while there are a number of other possibilities, an earthen dike would provide the most reliable structure at the lowest cost. Therefore, costs given in this chapter assume earth dike construction.

Impoundment alternatives presented in this report assume that the Sea would be separated by earth dikes—structures that have water at essentially equal elevations on both sides, thus no pressure differential. It should be emphasized, however, that any attempt to control Sea elevation with declining inflow volumes would result in significant water surface elevation differences between the impoundment and the main body of the Sea. Depending upon the inflow reductions and extent to which the Sea elevation is controlled, water surface in the impoundment could be up to 30 feet lower than the rest of the Sea. This head difference could require more extensive foundation treatment, an altered design, different earth placement method, and construction of a spillway. However, since a decision on elevation control has not yet been made and effects of conservation of water in Imperial Valley are uncertain, dike construction was assumed in this report.

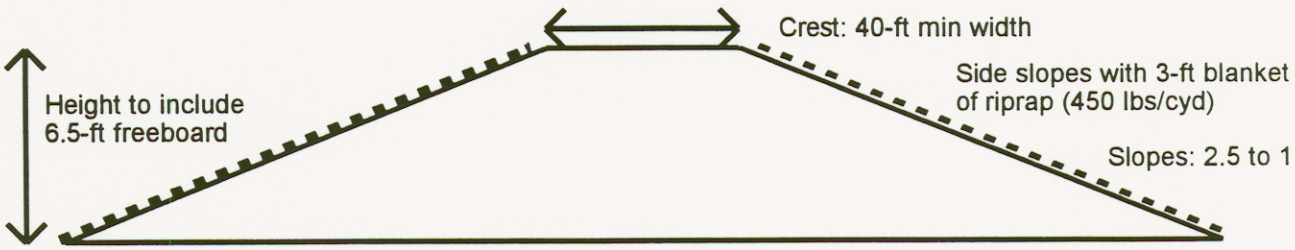
The earth dikes presented in these alternatives varied in length and in their location. In an attempt to compare the construction cost of diking alternatives, a unit cost for a typical dike was developed. The height of the dikes varied considerably among the alternatives because of the different depths of the Sea for each location. Because the cost of the dike structure changed so dramatically with a change in height versus a change in length, the cost per cubic yard of borrow material became a more credible number than the cost per mile of a dike. Reclamation's Phoenix Area Office dams branch developed a typical cost per cubic yard of borrow material for dike construction in June 1997. They arrived at this number by using costs from the *Means Building Construction Cost Data, 1996*, and applied these costs to quantities of a typical dike by using the end dump method and assuming nearby borrow areas and reasonable hauling distances. The cost per cubic yard was calculated to be $11.98. Illustration 1 is presented on the next page to show how the cost of dike construction was determined when the average height or end area of the dike was known. For each alternative, a total cost was calculated from the dike length and height/volume given in the proposal.

The estimated costs did not include allowances for items such as right-of-way acquisitions; relocations for utilities, road, and facilities; environmental clearances; bridges; and non-contract costs.

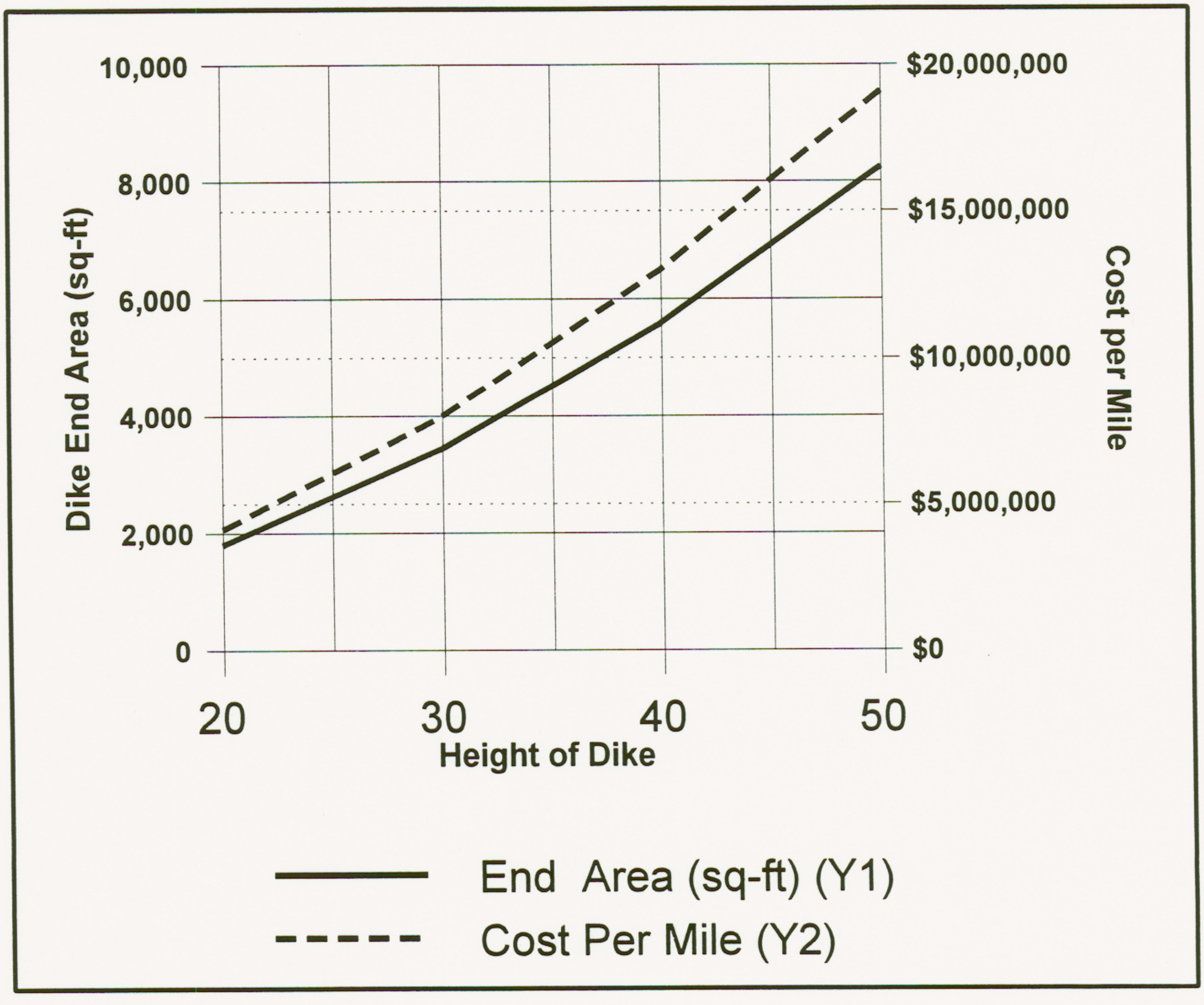
The O&M costs for the diked alternatives varied significantly. While all of the alternatives proposing dikes would require maintenance, some of the alternatives would require dredging to various degrees, which could not be pro-rated in a linear calculation. An average cost of $38,000 per mile for dike maintenance was developed by Reclamation's Phoenix Area Office dams branch in June 1997. For each alternative, we used this cost per mile for the maintenance of the dike and added an additional cost when the proposal called for dredging.

ILLUSTRATION 1.

Typical Dike Cross Section



- ❖ Dike construction assumed to be from borrowed material
- ❖ Costs include 20 mile haul route for riprap, but no costs for turbidity control
- ❖ Costs do include dust abatement measures



EVALUATION CRITERIA COMMON TO ALL IMPOUNDMENT ALTERNATIVES

Agricultural Interests

Use of the Sea as a repository of agricultural drainage would be unimpaired by any of the impoundment alternatives. Changes in inflow to the Sea, however, could result in dike design changes and higher construction cost. Higher inflow would necessitate raising the top of the dikes or protecting the top from wave action; lower inflow could require design of the dikes as dams. No agricultural lands would be involved in these alternatives unless the construction contractor elected to purchase them for borrow material.

Wildlife

The following discussion of evaporation basins and wildlife issues is relevant to all alternatives featuring basins as a mechanism to address salinity and water elevation within the Sea.

The interpretation of relationships between evaporation basins and wildlife presented here is generally derived from studies conducted in California's Central Valley where these structures have resulted in the concentration of water-born contaminants such as selenium. The Sea, because of its high salinity and selenium-metabolizing bacteria which would be assumed to remove selenium from the water column, could respond differently to contaminant concentration. A better understanding of this mechanism is required. However, for this analysis, it was assumed that contaminant concentrations within Sea water would not increase, and the processes now functioning in the volatilization of selenium would continue. Thus, it was assumed that no increase in water concentrations of selenium would occur for alternatives using Sea water in evaporation basins. These assumptions did not resolve the issue of sediment concentrations of selenium and the current problems of bioaccumulation via sediment, detritus, pileworms, and so on. However, diking and other alternatives that would reduce salinity levels within the Sea would provide some benefits to wildlife through an increased fish food supply.

For study purposes, it was assumed that the major issue affecting the region's wildlife resources is contaminants, either transported into the Sea and surrounding system by Colorado River water and concentrated through evaporation of irrigation water (selenium) or originating in farm fields (pesticides). According to the U.S. Fish and Wildlife Service, several species currently carry levels of selenium which fall within the levels of concern (*Detailed Study of Water Quality, Bottom Sediment, and Biota Associated with Irrigation Drainage in the Salton Sea Area, California, 1988-90*, James G. Setmire, Roy A. Schroeder, Jill N. Densmore, Steven L. Goodbred, Daniel J. Audet, and William R. Radke, U.S. Geological Survey Water-Resources Investigations Report 93-4014, 1993; *Biological Effects of Selenium and Other Contaminants Associated with Irrigation Drainage in the Salton Sea Area, California, 1992-94*, Jewel Bennett, U.S. Fish and Wildlife Service, Carlsbad, California, in preparation). Levels of concern for selenium (dry weight) occur in water bird eggs (.003 to .008 ppt), warm-water fish (.003 to

.006 ppt), and for dietary items (.002 to .006 ppt) used by higher trophic levels within local food chains. In order to adequately address wildlife issues, alternatives must address mechanisms that would reduce the levels of contaminants both within the Sea and those entering the system from surrounding areas.

Reduced salinity levels within the Sea would have some benefits for the fishery which, in turn, would potentially increase the food supply for several species currently feeding on various fish supported by the Sea. However, as proposed, diking did not address the issue of contaminants currently in the Sea or those that would enter the system in the future. It was assumed that water birds and fish obtain concentrations of selenium, dichlorodiphenyl dichloroethylene (DDE), and other contaminants through their food chains. The system supports a relatively constrained food chain: (1) phytoplankton> zooplankton> detritus> pileworm> forage fish> predatory fish> fish-eating bird; and (2) phytoplankton> zooplankton> detritus> pileworm> water bird. Fish-eating and other water birds that feed directly on macroinvertebrates inhabiting contaminated sediments would be at greatest risk. These include the Yuma clapper rail (endangered), brown pelican (endangered), and numerous other species of shore, wading, and diving birds.

Evaporation basins are highly saline environments. Harsh conditions limit biological diversity, but organisms that can tolerate high and fluctuating salinity and temperatures and low dissolved oxygen could exploit a situation in which there would be reduced competition and predation. Production of some food-chain organisms (some plants and several species of invertebrates) is often quite high, and primary production could be very high.

Water birds are naturally attracted to the Sea, the largest inland water body in the region. Evaporation basins located within the Sea could also be attractive to water birds. If these basins contain rich food supplies, they could receive more feeding use by water birds than surrounding waters. (It should be noted that if contaminant problems develop within evaporation basins and hazing—the practice of driving birds away from specific areas to other areas—becomes necessary, it would be generally expensive and ineffective for large bodies of water.)

The potential for attraction could be increased if evaporation basins are located near other habitat such as wildlife management areas and refuges and the mouths of tributaries.

Some alternatives would create a large evaporation basin at either the north or south end of the Sea. An enlarged (relative to existing conditions) area of fresh to brackish water would probably develop between the mouth of the inflow tributaries and the pond dike. Without mechanisms, such as wetlands, to address contaminants in the inflow water, contaminants could accumulate within this newly created fresh- to brackish-water zone and/or sediments of this area. Increased contaminant concentrations would likely adversely affect wildlife using this area.

All construction activities should avoid disturbances to bottom sediments to the greatest extent possible. Sediments contain contaminants that would likely enter the surrounding waters during construction activities. Physical disturbances would result from construction activities. If construction occurs within the bed of the Sea, sediments would likely be disturbed and the concentrations of contaminants in the surrounding waters increased.

Finally, the location of a large evaporation basin at the southern end of the Sea could adversely affect existing wildlife habitat currently managed by the U.S. Fish and Wildlife Service and/or the State of California. Because of the importance of this area within the Pacific Flyway, these impacts could require mitigation either through avoidance, reduction of effects, or replacement of values.

Disposal

The water released into the diked impoundments each year would evaporate away, leaving the salt behind. Depending on the size of the evaporation impoundment, brine in the impoundment would eventually reach a saturation point, and salts would precipitate onto the bottom of the impoundment. The alternatives did not address what would be done with the salts or how much disposal costs could be if disposal were necessary.

Water Quality

High concentrations of selenium in drain water sumps are diluted in surface drains and rivers before reaching the Sea. Further reduction in concentration occurs at the drain mouths and river deltas. This reduction is believed to be linked to selenate-respiring bacteria and perhaps other processes that remove selenium from the water column. Sediment concentrations of selenium within the Sea are low. However, selenium in bottom sediments and detritus is believed to move through the food chain and is accumulated to levels observed in resident water birds and their eggs. Selenium, boron, and DDE are major contaminants. Alternatives that reduce salinity and lower elevation may not necessarily also address the reduction of contaminant levels.

Many of the alternatives did not address the issue of lowering contaminant levels either in the Sea or before they enter the Sea, nor did they address the nutrient load entering the Sea. Nutrient load from outside sources is a problem in the Sea. Elevated nutrient levels lead to high algal populations known as blooms. When these populations can no longer be supported, they die, remove oxygen from the system, and may cause fish kills.

This area of water quality deals with the pesticides, nutrients, selenium, boron, sewage, and bacteria. The elements that are soluble and conservative would be deposited in the evaporation pond with the salt. Those substances that accumulate in the evaporation pond would not be as available in the aquatic food chain because the more saline environment of the evaporation pond would not be used by wildlife as much as the main body of the Sea. While in the Sea, the availability of substances would remain the same as before. The Sea concentration of selenium is about 1 μg/L, which approaches the detection level, and little is known about what happens to it in the Sea. However, selenium is in the sea food organisms at elevated levels, and bioconcentration has been shown to be a function of trophic level of both the Sea and freshwater environment.

The constituents that enter the food chain in the Sea would remain at approximately the same levels as at present and would continue at the current impact level on the wildlife. This includes the contaminants that adsorb to sediment in drain water since the sediment would settle before the inflows reached the intake to the evaporation pond.

An issue with the impoundment alternatives is the possibility of the inflow's short-circuiting as it flows along the channel formed between the pond berm and the shoreline. If this occurred, the water entering the evaporation pond would not carry the predicted salt load out of the Sea, and the alternative would not be as effective in reducing the Sea's salinity to the target level.

Finance Costs

Capital required for project construction would most likely come from a public source—the Federal Government, State of California, and/or local government agency. In the event that the Congress or State Legislature appropriated funds on a non-reimbursable basis, those funds would not have to be repaid, and the cost of acquiring those funds would be negligible. Reimbursable appropriations would require repayment with or without interest as determined by legislation. All other funds required for construction would presumably come from the issuance of bonds. It is difficult to anticipate the future cost of borrowed money or the cost for legal counsel, an underwriter, or other costs for bond issuance, so a specific financing cost could not be established. However, finance costs, whatever they would amount to, should be fairly consistent for all alternatives, with the only variable being the magnitude of the project construction cost.

Land and Location

Because many impoundment alternatives could be located anywhere within the Sea, there would be opportunities to accommodate land use obstacles. Specific areas that would need special consideration include the Salton Sea State Recreation Area (California), the Salton Sea National Wildlife Refuge (U.S. Fish and Wildlife Service), the Torres-Martinez Desert Cahuilla Indian land, and developed private land. Discussion with managers at the Recreation Area and Refuge revealed that, while there are issues that need to be addressed, there would be room for negotiation.

Sport Fishery

There are at least 15 species currently associated with the Sea and associated drains, but the desert pupfish is the only native species. Of these species, corvina, sargo, and tilapia have constituted the majority of sport fish.

Corvina feed on other fish, and forage fish feed on lower trophic levels. An important limiting factor for some fish in the Sea could be related to the reduced abundance of pileworms in summer and early fall (anaerobic conditions below 30 feet). An additional problem is that the Sea may be currently too saline to allow successful spawning by many fish species. Annual fish kills (tilapia and others) occur from limited oxygen, changing water temperatures, and other factors.

Alternatives that reduce salinity within the Sea would provide benefits to several species within the sport fishery. These benefits would relate directly to improved conditions for reproduction.

Two issues may be important when considering the sport fishery: (1) increasing salinity levels are adversely affecting fish reproduction; and (2) fish concentrate selenium levels and pass these levels onto higher trophic levels, including humans. Selenium levels could adversely affect the endangered desert pupfish populations. All fish within the Sea use various life stages of pileworms, which are detritus feeders, for food. It was assumed that this is the food chain pathway for selenium concentration in higher organisms, namely fish and water birds.

Economic Development

Decreased salinity and improvement in overall water quality would have a positive impact upon the sport fishery and other recreational pursuits. As those positive impacts translate to increasing visitation to the Sea, demand for services, such as food/beverage, fuel/automotive, hotel/camping/RV parks, recreational supplies, retail items, and entertainment, would encourage and support business growth in the surrounding area. Increased attractiveness of the Sea and related economic activity would increase property values in the communities surrounding the Sea.

Local land owners would not be the only beneficiaries of a salinity control project at the Sea. Benefits to the nation would include preservation of the bird diversity at the refuge, protection of habitat for endangered species, and maintenance of an environment conducive to wintering and stop-over for migratory birds using the Pacific Flyway. Recreational use would be regional in nature. Opportunities for fishing, boating and jet skiing, and camping would draw users from the large metropolitan areas of Orange County, Los Angeles, and San Diego.

An equitable way of allocating project costs to all the beneficiaries of a less salty Sea would need to be explored in more detailed future studies. While the Federal and State benefits could be difficult to quantify, a benefit/cost analysis would be performed where appropriate.

Intergovernmental Cooperation

All diked impoundment alternatives would require a Section 404 permit from the U.S. Army Corps of Engineers under provisions of the Clean Water Act. Use of an evaporation basin would require compliance with U.S. Environmental Protection Agency directives for concentration and containment of a hazardous substance—selenium—and pesticides and other contaminants which originate in agricultural runoff. Compliance with the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA) would address these issues. Excavation and transportation of borrow material will require Federal or county permits. Other permits and approvals could be required, but the NEPA/CEQA compliance process would identify these requirements and provide a mechanism for satisfying them.

It is not anticipated that the dike impoundments would present any unsurmountable barriers for obtaining the permits, approvals, licenses, authorities, permission, or warrants necessary for project construction. Such requirements would be similar for all the impoundment alternatives.

Time to Solution

In each alternative, there is a short statement indicating how many years it would take to reduce the salinity in the Sea to a certain concentration, usually ocean water salinity at about 35 ppt.

Partners

There is a high likelihood that the Federal and State governments and local agencies would have to jointly participate in construction of a project to reduce salinity of the Sea. Participation by a joint venture or commercial enterprise could be a possibility that could be pursued. Any partnership arrangements or opportunities would be similar for any of the impoundment alternatives.

Alternative 1	Diked Impoundment 50 Square Miles South End or North End

HISTORY

First formally proposed in the United States Department of the Interior and the Resources Agency of California (RAC), *Salton Sea Project, California, Federal-State Reconnaissance Report* (1969) and the final publication (1974), this alternative is one of the oldest proposals on record (it is Plan A in the 1974 report). The Aerospace Corporation mentioned its support of the alternative in the *Salinity Control Study Salton Sea Project, Report No. ATR-71(S990)-5* (1971). The most recent publication to document the alternative is the *Coachella Valley Water District Report* (undated).

The original cost given for this proposal in the 1974 report was $65 million. This cost indexed to 1996 dollars would be $207 million.

The following chart lists the numerous reports done on the 50-mi² alternative, with original costs and costs indexed to 1996 dollars.

50-mi² Impoundment (S end)
Coachella Valley Water District, undated

COST	(1992 $)	(1996 $)
Construction	$188,000,000	$209,000,000
Annual O&M	Insufficient data	

50-mi² Impoundment (S end)
Reclamation/Resources Agency, 1974

COST	(1973 $)	(1996 $)
Construction	$65,000,000	$207,000,000
Annual O&M	$416,000	$1,330,000

50-mi² Impoundment (S end)
Aerospace, 1971

COST	(1971 $)	(1996 $)
Construction	$130,000,000	$472,000,000
Annual O&M	Insufficient data	

50-mi² Impoundment (S end)
Reclamation/Resources Agency, 1969

COST	(1969 $)	(1996 $)
Construction	$110,000,000	$455,000,000
Annual O&M	$173,000	$716,000

50-mi² Impoundment (N end)
Reclamation/Resources Agency, 1969

COST	(1969 $)	(1996 $)
Construction	$183,000,000	$758,000,000
Annual O&M	$23,000	$95,000

20- and 30-mi² (S end only)
CVWD, undated

COST	
Construction	Insufficient data
Annual O&M	Insufficient data

20-mi² (N) and 30-mi² (S)
Reclamation/Resources Agency, 1969

COST	(1969 $)	(1996 $)
Construction	$168,000,000	$696,000,000
Annual O&M	$25,000	$103,000

PROPOSAL DESCRIPTION

This alternative consisted of a diked impoundment enclosing 50 mi^2 in the southeastern end of the Sea. The dike would be a partially submerged, continuous 37-mile earth structure. Typical cross-sections of the dike are shown on Illustrations 2 and 3. The 40-foot top width would permit two-way traffic and parallel parking. The near-shore dike would be 1/2- to 1 mile from shore to retain sufficient channel for the Alamo and New Rives to discharge to the Sea. This freshwater channel would also enhance marsh habitat for waterfowl along the shore.

The deepwater portion of the dike would be constructed of earth and gravel material dumped in place by trucks, using the cross-section shown in Illustration 2. Approximately 15 miles of dike would be built in this manner. Both sides of the dumped-fill dike would be protected with a 3-foot layer of riprap.

Two inlet structures would control the flow of water into the impoundment. One structure, located near the center of the deepwater portion of dike, would admit salt water from the Sea. The other structure, located on the inshore portion of dike north of Mullet Island, would admit freshwater into the impoundment, when needed, to prevent the salinity of the Sea becoming lower than desired.

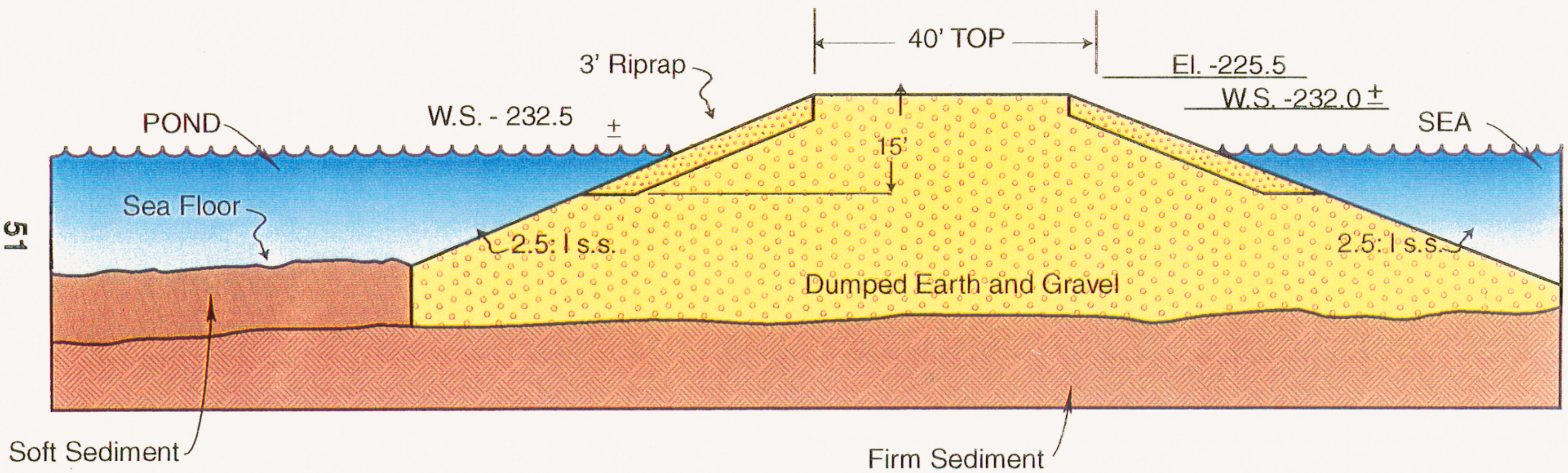
The inlet structures would consist of two or more parallel open channels 10 feet wide and 100 feet long, as shown on Illustration 4, fenced for public safety. The dike cross-section would be widened at each inlet structure to provide a foundation for the channels. Gates would control the flow of water. Both structures would include bridges over the channels for vehicular traffic.

Access to the dike would be provided by two causeways. One would be at the northeast corner of the dike, and the other would be near the southwest corner of the dike near Benson's Landing. Top width of the causeways would be 40 feet. Both causeways would have 100-foot bridges to pass discharges from the Alamo and New Rivers and to permit passage of small boats.

O&M COSTS

Operation of the dike structure included periodic adjustments of the inflow levels. Automation could reduce the operation costs but would be offset by the capital cost of automated gate controllers, power, and periodic adjustments. Maintenance of project features would consist of restoration of any wave damage to riprap and the crest of the dike, cleaning and servicing of the gates and channels of the inlet structures, and possibly adding additional embankment material in places where foundation settlement would occur. The Alamo and New Rivers discharge a significant silt load into the Sea. A continual program of maintenance dredging would be necessary to remove silt deposits that could threaten to impede flow from the rivers.

Typical Dike Section
Dumped Embankment

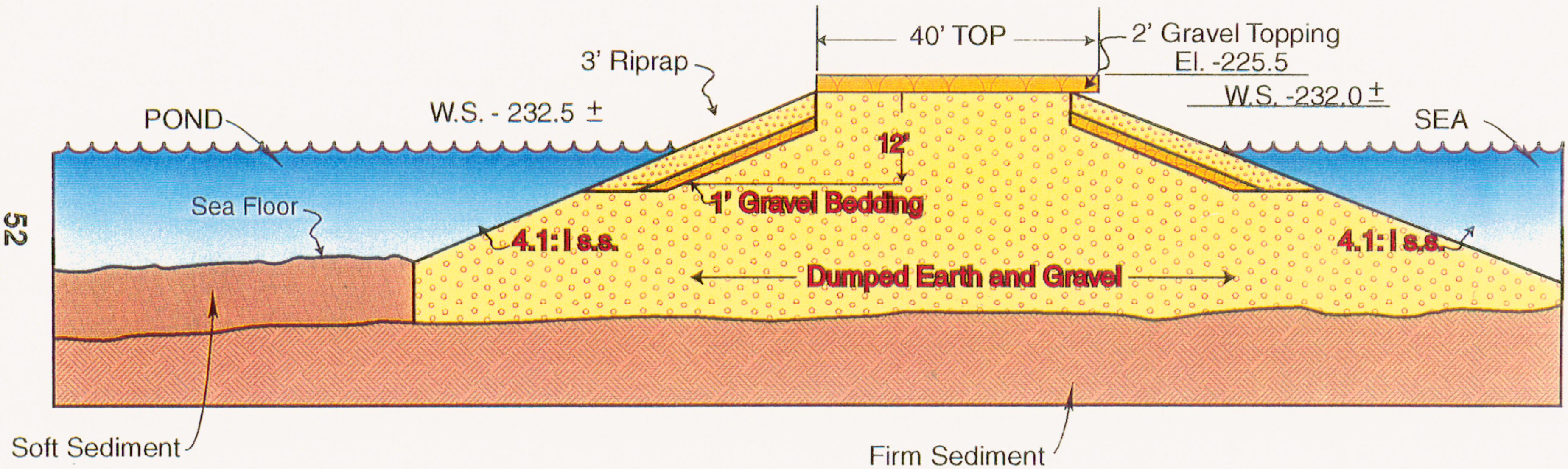


Depth of water varies from 8' to 35'

NOT TO SCALE

Alternative No. 1
Illustration No. 2

Typical Dike Section
Dumped Embankment

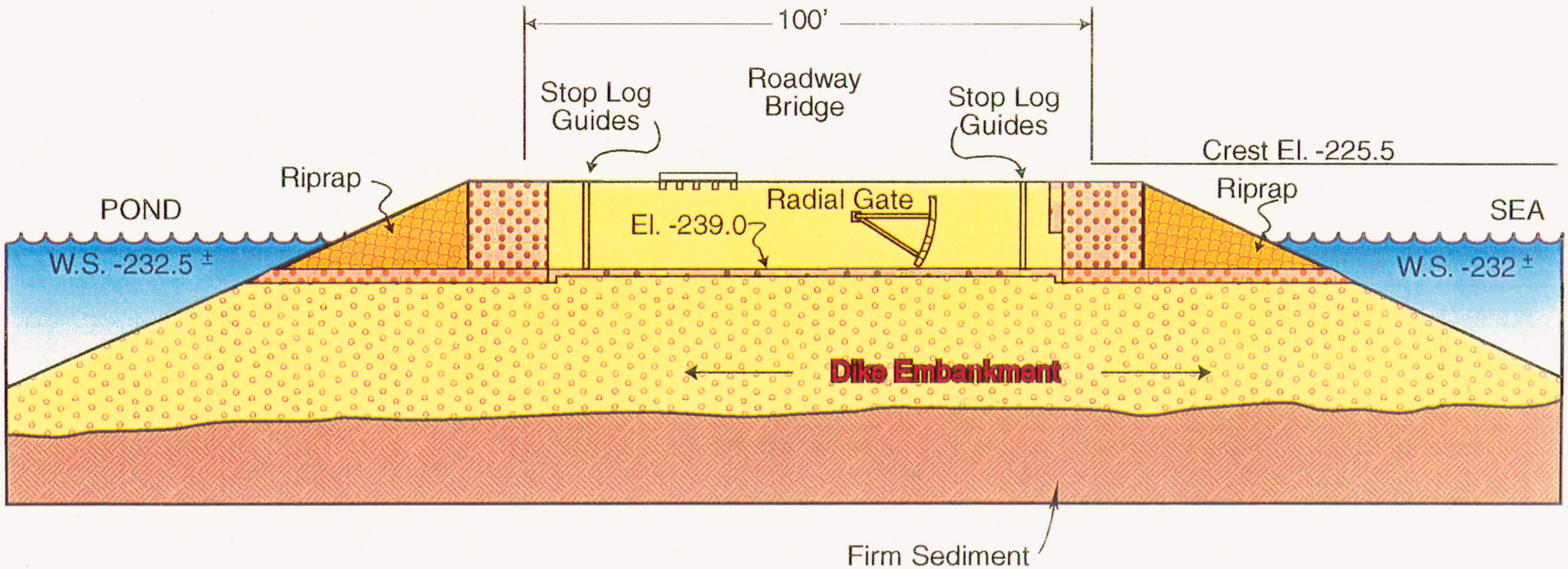


NOTE: Depth of water varies from 5' to 20' Riprap will be omitted where the dike is protected from wave exposure; gravel slope protection will be used.

NOT TO SCALE

Alternative No. 1
Illustration No. 3

Section Through Inlet Structure



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

NOT TO SCALE

Alternative No. 1
Illustration No. 4

An O&M cost of $38,000 per year per mile of dike was calculated to be $1,406,000 for the 37-mile dike. Dredging costs, for maintaining channels into the impoundment, of $320,000 from the 1974 report indexed to 1996 dollars were calculated to be $1,019,000. Total O&M costs for this alternative would be $2,425,000 per year.

CONSTRUCTION COSTS

This alternative, as proposed in the 1974 report, could not be constructed today. Dredging 10 million cubic yards (yd^3) of material from the bottom of the Sea would not likely be allowed because of environmental concerns such as turbidity, toxic particles released from sediment, and fish habitat. In addition, a value engineering study (*A Value Engineering Evaluation of Salton Sea Alternative Dike Structures*, August 1995) determined that the original design side slope of the dike should be changed from 4 to 1 to 10 to 1 because of dredged material stability. This change would increase the volume of dredged material to over 20 million yd^3.

This alternative built today would be similar to the 1974 report except all material would consist of offshore borrow. The dredged embankment material quantity listed in the 1974 report was replaced by onshore borrow and reduced to reflect the change in side slope placement, from 4 to 1 to 2.5 to 1. An adjustment was made to the height and volume of the dike used in the 1974 report when the Sea was approximately 5 feet lower in elevation. The cost for constructing the 37-mile dike, using the end dump method with a revised volume of 33.1 million yd^3 at $11.98 per yd^3, would be $396.5 million.

WILDLIFE

This, and other alternatives that would reduce salinity levels within the main body of the Sea, provide benefits to aquatic wildlife reproduction and increase the sport fish population.

The impoundment would probably be large enough to affect existing habitat managed by the U.S. Fish and Wildlife Service and/or the State of California. An area of fresh to brackish water probably would be created between the mouths of the Alamo and New Rivers and the impoundment dike. This fresh to brackish water zone could result in increased contaminant concentrations in this area.

WATER QUALITY

This alternative would reduce the salinity by about 1 ppt for each 2 years of operation at maximum inflow to the evaporation pond. The total evaporation from the Sea should not change, so the irrigation community may need to apply more efficient water conservation practices to reduce inflows to the Sea to maintain the water level at the desired elevation. If needed to control water level in the Sea, the inflow to the evaporation pond could be reduced during periods of low runoff to the Sea.

The salinity is predicted to drop from 44 ppt to 35 ppt in less than 20 years. At this time, flow would have to be managed between the two bodies of water to maintain a salinity concentration of 35 ppt.

TIME TO CONSTRUCT

It was anticipated that this project, as proposed, would take 6 years to construct. This was calculated by using productivity rates provided in the *Means Building Construction Cost Data* for hauling and placing earth material.

Alternative 2	Diked Impoundment 40 Square Mile South End

HISTORY

Like the 50-mi^2 dike, this alternative was first proposed in the Reclamation and RAC report, *Salton Sea Project, California, Federal-State Reconnaissance Report* (1969) and final publication (1974). It was identified as Plan D in that report. It was documented recently in a Coachella Valley Water District report (undated), and the latest mention of this alternative was the Reclamation and Salton Sea TAC report, *A Value Engineering Evaluation of Salton Sea Alternative Dike Structures* (August 1995).

The original cost for this proposal in the 1974 report was $58 million. This cost indexed to 1996 dollars was calculated to be $185 million. The following chart lists the numerous reports done on the 40-mi^2 alternative with original cost and cost indexed to 1996 dollars.

Reclamation/Salton Sea TAC, 1995

COST	(1994 $)	(1996 $)
Construction	$110 to $154 million	$117 to $164 million
Annual O&M	Insufficient data	

CVWD, undated

COST	(1992 $)	(1996 $)
Construction	$200 million	$223 million
Annual O&M	$ 1 million	$1.1 million

Reclamation/Resources Agency, 1974

COST	(1973 $)	(1996 $)
Construction	$58 million	$185 million
Annual O&M	$251,000	$799,000

Reclamation/Resources Agency, 1969

COST	
Construction	Insufficient data
Annual O&M	Insufficient data

PROPOSAL DESCRIPTION

This alternative would control the salinity in the same manner as the 50-mi^2 impoundment. The 27-mile dike would enclose 40 square miles, or about 11 percent, of the Sea's surface area.

The remaining features of the dike would be essentially the same as the 50-mi^2 impoundment, with the exception of the location and certain construction modifications as dictated by the location. The list of components necessary to construct a 40-mi^2 diked impoundment is essentially as described in Alternative 1, except that the length of the dike is 27 miles rather than 37 miles.

O&M COSTS

Operation of the dike structure included periodic adjustments of the inflow levels. Maintenance of project features would consist of restoration of any wave damage to riprap and the crest of the dike, cleaning and servicing of the gates and channels of the inlet structures, and possibly adding additional embankment material in places where foundation settlement would occur. The Alamo and New Rivers discharge a significant silt load into the Sea. A continual program of maintenance dredging would be necessary to remove silt deposits that threatened to impede flow from the rivers.

An O&M cost of $38,000 per year per mile of dike would be $1,026,000 for the 27-mile dike. Dredging costs of $178,000 from the 1974 report indexed to 1996 dollars were calculated to be $567,000. Total O&M costs for this alternative would be $1.593 million per year.

CONSTRUCTION COSTS

This alternative built today would be similar to the 1974 report proposal except that all material would consist of onshore borrow. The dredged embankment material quantity listed in the 1974 report was replaced by onshore borrow and reduced to reflect the change in side slope placement, from 4 to 1 to 2.5 to 1. An adjustment was made to the height and volume of the dike used in the 1974 report when the Sea was approximately 5 feet lower in elevation. The cost for constructing the 27-mile dike, using the end dump method with a revised volume of 26.5 million yd^3 at $11.98 per yd^3, would be $317.5 million.

WILDLIFE

This, and other alternatives that would reduce salinity levels within the main body of the Sea, provide benefits to aquatic wildlife reproduction and increase the sport fish population.

The impoundment would probably be large enough to affect existing habitat managed by the U.S. Fish and Wildlife Service and/or the State of California. An area of fresh to brackish water probably would be created between the mouths of the Alamo and New Rivers and the impoundment dike. This fresh to brackish water zone could result in increased contaminant concentrations in this area.

WATER QUALITY

This alternative would take 3 years to reduce the salinity 1 ppt, thus extending the time required to meet the salinity goal. The water level control should be as efficient as that of Alternative 1. The simplicity of controls and operations should also be the same. Slightly less area of the Sea would be sacrificed for salinity control as evaporation ponds.

The salinity would be predicted to drop from 44 ppt to 35 ppt in 30 years. After the 30th year, the salinity would drop below 35 ppt. At that time, flows between the two bodies of water would have to be managed in order to maintain salinity at 35 ppt.

TIME TO CONSTRUCT

It was anticipated that this project, as proposed, would take 4 1/2 years to construct. This was calculated by using productivity rates in the *Means Building Construction Cost Data* for hauling and placing earth material.

Alternative 3	Diked Impoundment 127 Square Miles North Third of the Sea

HISTORY

This proposal was presented in the *Salton Sea Management Project Summary of Salinity and Elevation Management Alternatives* by Ogden Environmental and Energy Services Company, Inc. (March 1995).

PROPOSAL DESCRIPTION

This alternative would control the salinity in the same manner as both the 50- and 40-mi^2 impoundments; however, this alternative would essentially cut the Sea into two areas. A 10-mile earthen dike would be constructed across the northern end of the Sea, enclosing approximately one-third of the Sea, or 127 mi^2. As the majority of freshwater would enter the Sea at the south end, under this scenario, the northern area of the Sea would serve as an impoundment or evaporation basin. This effectively would reduce the total volume of the Sea by one-third, allowing dilution of the remaining two-thirds of the Sea with freshwater inflow and a corresponding reduction in salinity. The elevation of the Sea would change very little because the evaporation surface area would not change appreciably. Some localized elevation control could be attained by retaining water in the southern end to stabilize seasonal fluctuations as a temporary measure. If desired, additional shallow diking could be employed to protect high value shoreline property.

O&M COSTS

O&M would consist mainly of grading the roadway and repairs to the structure due to settlement of the dike material. An average cost of $38,000 per mile was developed by Reclamation's Phoenix Area Office dams branch. Total O&M costs for the dike would be $380,000 per year.

CONSTRUCTION COSTS

The quantity of borrow material needed to construct the dike was calculated by using an average end-area multiplied by the length of the dike. The average end-area of 6,470 ft^2 had a top width of 40 feet, sideslopes of 2.5 to 1, and a height of 43.5 feet. The height was calculated from the average depth of the Sea, where the dike would be constructed, plus 6.5 feet of freeboard. The cost for constructing the 10-mile dike, using the end dump method with a volume of 12.65 million yd^3 at $11.98 per yd^3, would be $151.5 million.

WILDLIFE

This alternative would create a 127-mi^2 evaporation basin, enclosing the northern third of the Sea. The size and subsequent effects of such a structure on the overall ecological functioning of the Sea would have to be considered when evaluating this alternative.

Prevailing winds create currents which circulate nutrients, algae, and other suspended particles throughout the Sea. A dike across the northern third of the Sea could alter current movement of nutrients and particulates through the system. If such alterations occur, they could affect the current food chain system. Potential effects may be beneficial or adverse but would require detailed evaluation before such a dike were constructed.

Current reproduction or survival problems facing the aquatic resource in the Sea would be resolved in the main Sea body. Unless factors other than salinity create a limiting constraint, the sport fishery should improve significantly in the main body of the Sea, while the fishery would eventually disappear altogether in the north third of the Sea. The ecosystem of the north end would gradually convert to something that looks much like the Great Salt Lake—brine shrimp and brine flies would be the main source of food for birds which visit the area.

ELEVATION

Elevations could be controlled, to some degree, by adjusting the flow of water from the main body of the Sea to the north impoundment. Unless inflows were substantially reduced, the opportunities for managing elevations would be somewhat limited. With reduced inflows, however, regulation of discharge from the main body to the north impoundment could be used to manage both salinity concentrations and elevations in the main body. Water surface elevation in the north third of the Sea would fall in response to inflow volumes and could not be managed.

WATER QUALITY

This alternative would reduce the salinity by approximately 2 ppt per year due to the larger percentage of the Sea used as a pond and the major portion of the drainwater entering the Sea from the south end. With more limited wildlife use and less attraction for recreation in the saltier portion, these uses would decline in the north but increase in the main body of the Sea.

The salinity would drop from 44 ppt to 35 ppt in about 4 years. At that time, flow would have to be managed between the two bodies of water to maintain a salinity concentration of 35 ppt. This would be a passive system to a large degree, although some influence over salinity and elevation would be available through control of flow between the main body and the northern impoundment.

The dike across the Sea could break up the existing circulation patterns and have an effect on the current mixture conditions in the main body of the Sea. This could cause the loss of nutrients and other soluble material into the north end evaporation impoundment. If this occurs, changes to the aquatic community could result.

This alternative would not address the issues of lowering contaminant levels either in the Sea or before they enter the Sea, nor would it address the nutrient load entering the Sea.

Any alternative that concentrates contaminants in an area that allows shorebird feeding would result in bioaccumulation of those toxins, such as selenium, other heavy metals, and certain pesticides.

ECONOMICS

Impoundment of the north one-third of the Sea to serve as an evaporation pond would change the use of that section of the Sea from one of active use to one of more aesthetic enjoyment. Some shoreline and Sea surface uses at the State Recreation Area, the Torres-Martinez Desert Cahuilla land, and private property along the north and northwest shores would be foregone, adversely effecting the economy of those areas.

TIME TO CONSTRUCT

It was anticipated that this alternative, as proposed, would take 2 1/2 years to construct. This was calculated by using productivity rates provided in the *Means Building Construction Cost Data* for hauling and placing earth material.

Alternative 4 **Diked Impoundment**
47 Square Miles
In-Sea Evaporation Basins

HISTORY

This alternative was proposed in an undated publication by the Coachella Valley Water District. It was discussed and presented as a viable option by Ogden Environmental and Energy Services Company, Inc., in *Salton Sea Management Project Evaluation of Salinity and Elevation Management Alternatives* (1996).

PROPOSAL DESCRIPTION

This proposal would be similar to other in-Sea diked impoundment proposals, with a somewhat different configuration. Parallel dikes would be constructed to create two in-Sea evaporation basins totaling 47 mi^2 in the southeast end of the Sea. An additional 27 miles of road would be required. Approximately 180,000 AF of water would evaporate annually from the impoundment. This proposal would use existing engineering techniques and would require no pumps or electrical generating facilities.

O&M COSTS

O&M would consist mainly of grading the roadway and repairs to the structure due to settlement of the dike material. An average cost of $38,000 per mile was developed by Reclamation's Phoenix Area Office dams branch. O&M costs for the dike would be $1.5 million per year. Another $100,000 per year would be added for the additional 27 miles of road required in this proposal. Total O&M costs would total $1.6 million per year for this proposal.

CONSTRUCTION COSTS

The quantity of borrow material needed to construct the two diking impoundments was calculated by using an average end-area multiplied by the length of the dikes. The average end-area of 2,903 ft^2 had a top width of 40 feet, sideslopes of 2.5 to 1, and a height of 27 feet. The height was calculated from the average depth of the Sea, where the dike would be constructed, plus 6.5 feet of freeboard. The cost for constructing 40 miles of dike, using the end dump method with a volume of 22.7 million yd^3 at $11.98 per yd^3, would be $272 million.

WILDLIFE

This alternative would create two in-Sea evaporation basins totaling 47 mi^2 in the southeast end of the Sea. The size and subsequent effects of such a structure on the overall ecological functioning of the Sea would have to be considered when evaluating this alternative. Prevailing winds create currents which circulate nutrients, algae, and other suspended particles throughout the Sea. A dike across the Sea could alter current movement of nutrients and particulates through the system. If such alterations occur, they could affect the current food chain system. Potential effects may be beneficial or adverse but would require detailed evaluation before such a dike were constructed.

Current reproduction or survival problems facing the aquatic resource in the Sea would be resolved in the main Sea body. Unless factors other than salinity create a limiting constraint, the sport fishery should improve significantly in the main body of the Sea, while the fishery would eventually disappear altogether in the Sea. The ecosystem of the impoundment would gradually convert to something that looks much like the Great Salt Lake—brine shrimp and brine flies would be the main source of food for birds which visit the area.

WATER QUALITY

The salinity would drop from 44 ppt to 35 ppt in about 20 years. Since this would be a passive system, salinity could be managed somewhat but not completely controlled. Complete control would require another feature that would allow flow from the evaporation impoundments back to the main body of the Sea.

TIME TO CONSTRUCT

It was anticipated that this alternative, as proposed, would take 4 1/2 years to construct. If the two dikes were constructed simultaneously, construction time would be reduced to approximately 2 years. This was calculated by using productivity rates provided in the *Means Building Construction Cost Data* for hauling and placing earth material.

Alternative 5	**Diked Impoundment** **Phased Impoundment**

HISTORY

This concept was developed by participants in the current study early in the alternative identification process. The proposal was presented to the Authority Board in October 1994, and a version of the proposal was suggested by the Coachella Valley Water District as a practical and affordable means of maintaining the recreational and wildlife values of the Sea (Coachella, undated).

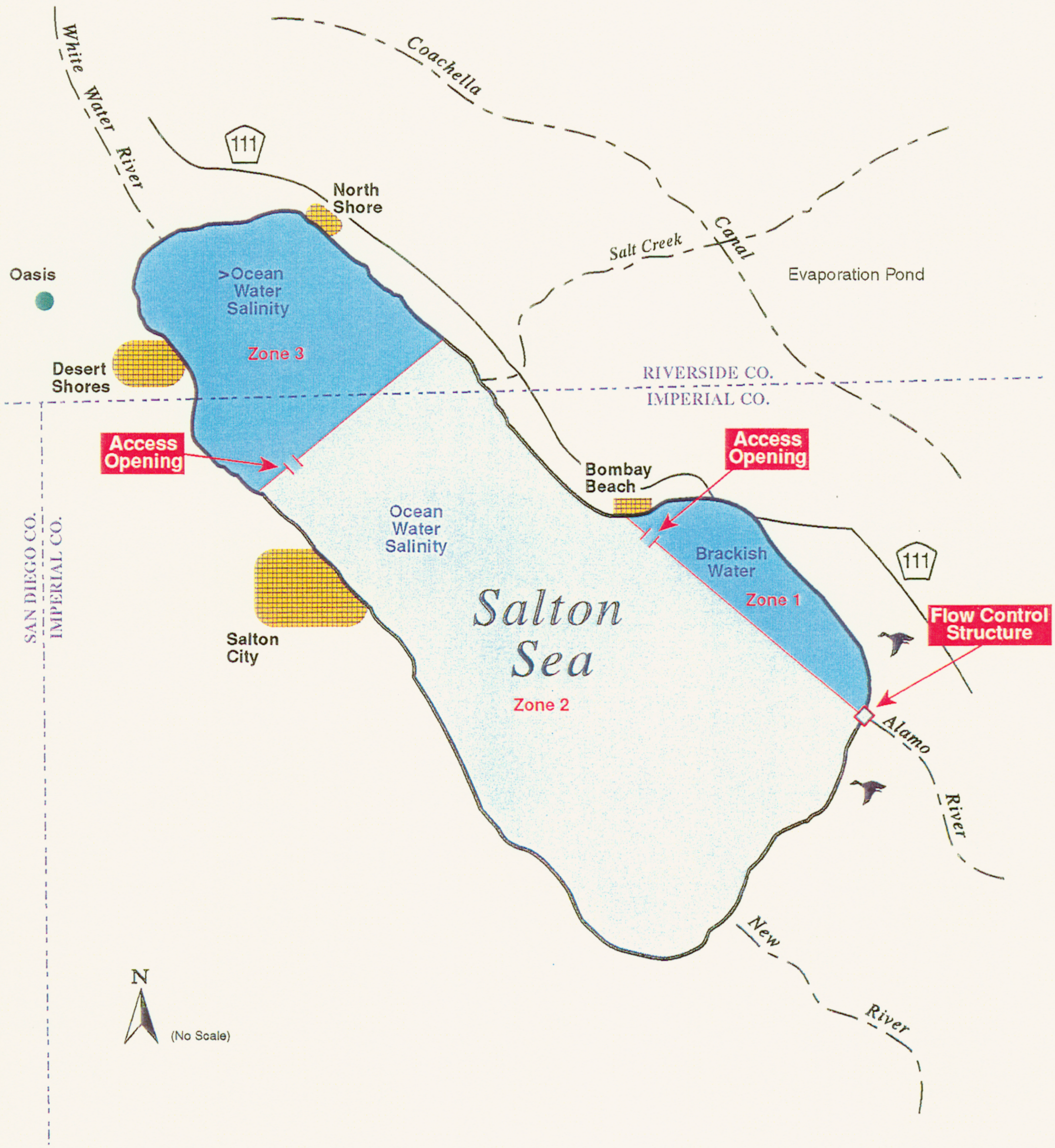
PROPOSAL DESCRIPTION

This plan would zone the Sea into several sections with different salinities. While the number and location of zones may vary, the concept would create some immediate benefits at a cost lower than the ultimate build-out, then would complete the project in later years. The project contemplated here would consist of three zones (see Illustration 5).

The first construction phase would include building a dike to create an approximate 25-mi^2 zone on the southeast shore. The Alamo River would flow into this impoundment. A low section in the dike would allow water to flow into the main body of the Sea. Salinity in this zone would quickly—perhaps within 1 year—reach the 35 ppt level and, soon thereafter, stabilize at a much lower level—perhaps as low as 6 to 10 ppt. At this salinity concentration, a unique wildlife environment would be created. Visitor amenities would provide for bird watching, fishing, boating and other water sports, picnicking, and camping.

Second and third zones would be created by the construction of additional dikes—in this proposal, one additional dike would bisect the northern third of the Sea. The second zone would reach a salinity concentration of 35 ppt in the order of 3 to 5 years after construction and could be stabilized at that level through water management techniques. The third zone would essentially become an evaporation impoundment, and salinity concentrations would continue to rise.

Construction of the first dike could present one of the better possibilities for Federal funding because construction costs would be moderate, and the proposal would specifically address the Federal interest in the wildlife refuge, migratory birds, and habitat for endangered and/or threatened species.



Alternative No. 5
Illustration No. 5

O&M COSTS

Outlet structures for each of the dikes would be adjustable to allow water surface elevation control and some degree of salinity management. An operator would have to be available to make adjustments, as appropriate. Automation could reduce the operation costs but would require capital expenditure for automated controls and power to the site. Maintenance activities would be typical for an earth dike—surface grading, weed control, painting exposed metal surfaces, inspection of all structures, replacement of riprap, and repair of any deteriorating features. Using an average cost of $38,000 per mile per year, developed by Reclamation's Phoenix Area Office dams branch, the total O&M cost for the two dikes would be about $900,000 per year.

CONSTRUCTION COST

The first dike constructed would be 10 miles long. Construction by fill from borrow would be assumed. The quantity of borrow material needed to construct the dike was calculated by using an average end-area multiplied by the length of the dike. The average cross-sectional area for the first dike was 4,146 ft^2 with a top width of 40 feet, sideslopes of 2.5 to 1, and a height of 33.5 feet. The height was calculated from the average depth of the Sea, where the dike would be constructed, plus 6.5 feet of freeboard. The cost for constructing the first dike, using the end dump method with a volume of 10.54 million yd^3 at $11.98 per yd^3, would be $126.3 million.

The second dike in this alternative would be 13 miles long. The average cross-sectional area for the second dike was 6,470 ft^2 with a height of 43.5 feet. The cost for constructing the second dike, with a volume of 12.65 million yd^3 at $11.98 per yd^3, would be $151.5 million. The total cost for constructing both dikes would be $277.8 million.

SALINITY CONTROL

Salinity in the first zone could be controlled to as low as about 6 ppt or as high as 35 ppt, depending upon the desired ecosystem to be established in that zone. This salinity level would be reached within a very short period—several years, at most. A diversion structure in the Alamo River and a gated outlet would control inflow to the zone 1 impoundment. Inflow and outflow volumes would be used to manage salinity concentrations. Constructed wetlands at the Alamo River diversion point could be used to reduce nutrients in the water flowing into zone 1 or zone 2.

Salinity in zone 2 could be controlled by adjusting flow through the second dike. While a lower salinity concentration could be achieved, it is anticipated that zone 2 would be managed for a salinity of about 35 ppt. Salinity in zone 3 would increase to levels found in natural sinks.

WILDLIFE

Since salinity in zone 1 would drop quickly after construction of the first dike and the Alamo River diversion feature, major benefits to the fishery and bird populations would be realized immediately. Any wetland development would provide additional bird habitat, especially for the endangered Yuma clapper rail.

Water quality would need to be monitored periodically. While selenium concentrations in the Sea are low because of selenate-respiring bacteria or other processes that remove selenium from the water column, it would be uncertain whether those same processes would function in the impoundments of this proposal, particularly zone 1. If selenium reaches contaminate levels, food-chain accumulations could adversely affect higher trophic levels.

ELEVATION

Water surface elevations in zones 1 and 2 could be controlled by manipulating inflow and outflow. Since there is a direct correlation between elevation control and salinity control, however, some tradeoff decisions could be necessary. The water surface elevation in zone 3 would depend upon total inflow to the Sea and the surface elevations maintained in zones 1 and 2.

WATER QUALITY

As noted earlier, selenium could become a constituent of concern. Alamo River water with a selenium level of 8 µg/L would flow into a 25-mi^2 impoundment. It is uncertain whether the same processes that now keep selenium levels low in the Sea would work to keep selenium low in zone 1. Any increase in selenium would be cause for concern.

Other water constituents that would need to be addressed include DDT metabolites and nutrients which promote algae growth. Heavy nutrient loads contribute to eutrophic conditions, including the possible growth of toxic algae that have been implicated in bird deaths at the Sea. Limnologic studies would determine if this proposal poses risks beyond current conditions.

TIME TO CONSTRUCT

Construction time for the dikes would be similar to other diking alternatives. Construction of dike 2 would take 2 1/2 years, while construction of dike 1, located in shallower water, requiring less fill, would take 2 years. Haul distance for borrow material and dike design would impact construction times. Construction times were calculated by using productivity rates provided in the *Means Building Construction Cost Data* for hauling and placing earth material.