State Water Resources Control Board
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# Analysis of Salton Sea Restoration Plans

SALTON SEA AUTHORITY

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

submitted by

**PARSONS**

in association with

Jones & Stokes

URS Greiner Woodward Clyde

John A. Pyles

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# EXECUTIVE SUMMARY

## 1.1 INTRODUCTION

Parsons was retained by the Salton Sea Authority to perform an independent technical review and critique the Phase 1 alternatives described in the Draft Salton Sea Restoration Project Environmental Impact Statement/Environmental Impact Report (EIS/EIR). Fatal flaws, as well as possible refinements, in the alternatives were to be identified. Possible Phase 2 actions/concepts were to be briefly evaluated, primarily from a cost-effectiveness point of view. In addition, other possible salinity and elevation control actions were to be identified and suggestions for further analysis were to be made.

URS Greiner Woodward Clyde, Jones & Stokes, and John A. Pyles were key members of a team assembled by Parsons to conduct the above analysis.

Generally, URS performed a review of the in-Sea dike design proposed in the Salton Sea Restoration Project January 2000 Draft Alternatives Appraisal Report and the costs of the various concepts and alternatives. Based on that review, refinements were suggested to reduce seismic risk and cost. Comments regarding construction methods for in-Sea dikes were also provided.

Jones & Stokes evaluated the Bureau's water and salt accounting model for suitability in determining if alternatives can effectively meet the salinity and elevation goals established for the restoration project. They also used the model to review the effectiveness of the Draft EIS/EIR alternatives and to assist in identifying concepts for review and evaluation.

Mr. John A. Pyles, a retired Cargill Salt employee, focused primarily on the solar salt removal (and disposal) concepts proposed in the Draft Appraisal Report and provided an in-sight into the chemical properties of

## 1.3 CONCLUSIONS AND RECOMMENDATIONS

The Salton Sea Authority and the Bureau of Reclamation with input and guidance from the Salton Sea Authority Board and Technical Advisory Committee and the Salton Sea Science Subcommittee have devoted significant time and effort to the Salton Sea Restoration Project and produced a considerable amount of information. The information gathered, the documents produced, and the public participation process has provided the foundation for completion of appraisal level studies and initiation of more detailed evaluations that can lead to selection of a preferred project for the Final EIS/EIR.

Our more significant conclusions and recommendations, based on a review and analysis of available data, are listed below. These conclusions and recommendations are discussed in the body of the report. Other less significant conclusions and recommendations are contained in the report itself.

### 1.3.1 Conclusions

- The water and salinity accounting model and the assumptions used in the model provide a suitable tool for evaluating the effectiveness of proposed alternatives for meeting salinity and elevation goals established for the Salton Sea.
- Each of the Phase 1 Draft EIS/EIR alternatives can meet the elevation and salinity goals within 40 years of implementation.
- If the inflows to the Sea are ultimately reduced to 0.8 million acre-feet per year (MAF/yr.) additional replacement inflows and/or displacement facilities will be required to meet the current salinity and elevation goals.
- The south pond would remove essentially the same surface area from the Salton Sea as the displacement dike for about one-half the estimated cost (about $195 million versus $450 million).
- The in-Sea north and south ponds and the displacement dike (as currently designed for the proposed operation) are very vulnerable to damage or failure due to a major seismic event.
- If the north and south in-Sea ponds (and the displacement dike) are constructed as proposed, they should be operated with water on both sides of the dike to reduce the vulnerability to seismic events. To reduce consequences of possible breaching, water on the pond side should be slightly lower than the Sea.
- A displacement dike can be designed and constructed to be dry on one side. A conceptual design is provided in this report.

- Low in-Sea dikes are considerably less costly than tall in-Sea dikes and less vulnerable to earthquakes. For example, a 17-foot high dike would cost about one-third as much per linear foot as a 35-foot high dike.
- Onshore dikes would cost considerably less per linear foot than in-Sea dikes, assuming the same height and good foundation conditions.
- A series of solar evaporation ponds are more effective for evaporating Salton Sea water and removing salt than a single deep pond.
- The single deep ponds, if constructed, should be operated as the first solar evaporation pond in a series with separate salt disposal ponds and/or an EES to increase the life expectancy and efficiency of the ponds.
- Enhanced Evaporation Systems (EES) accelerate evaporation, but are not currently used by the salt industry to make salt because the annual operation, maintenance and replacement costs are much higher than for solar evaporation ponds.
- Use of Colorado River flood flows (if they are available) and Central Arizona Salinity Interceptor (CASI) water (if it becomes available) are much more cost-effective than other methods of obtaining replacement inflows or reducing the amount of inflow needed to stabilize the elevation of the Sea.
- Exporting Sea water to the Pacific Ocean or the Gulf of California is an effective but prohibitively expensive way to remove salt from the Sea.
- Importing Pacific Ocean or Gulf of California water to the Sea is not an effective way to reduce or control the Sea's salinity or water elevation. The salt content of the Pacific Ocean and/or the Gulf of California water is too high.
- Higher salinity and lower elevation goals would reduce the size and cost of the actions or concepts needed to achieve and maintain salinity and elevation goals.

### 1.3.2 Recommendations

- An evaluation of alternative(s) using a series of solar evaporation (onshore and/or in-Sea) ponds with onshore salt disposal and bittern disposal ponds should be made.
    - Because of construction cost, priority in evaluation should be given to onshore solar evaporation ponds, followed by shallow in-Sea and then deep in-Sea ponds.
    - Consideration should be given to potential displacement benefits from in-Sea ponds and to using deeper ponds to dispose of bittern while using the surface of the ponds to evaporate Sea water.

  - If insufficient land is available and/or solar evaporation ponds cannot be constructed for a reasonable cost, consideration should be given to using an EES in conjunction with solar evaporation ponds.

- Borings should be performed along the alignment of all in-Sea dikes selected for detailed analysis to determine foundation material properties and to verify and refine costing assumptions.
- A preliminary earthquake response evaluation should be performed on the proposed in-Sea dike designs to analyze and predict potential deformation modes.
- Soil percolation data should be obtained for those sites where onshore ponds may be constructed. Leakage will affect the amount of pond area needed to achieve a certain rate of salt removal.
- A series of small solar evaporation test ponds should be constructed and operated at the Salton Sea to obtain data for preliminary sizing and development of the solar evaporation pond concepts.
  - The evaporation rate of Salton Sea water is needed so that the size of the evaporation ponds can be refined.
  - The volume of salt produced and its density are needed so that the size of salt disposal facilities can be refined.
  - The characteristics of the bittern are needed to determine if it will dry out and if it can be disposed of in the bottom of deep evaporation ponds without interfering with the evaporation rate.
- An evaluation of the cost of dredging the Sea's bottom and depositing the dredged material at the shore for creation of shallow ponds and/or displacement of Sea surface area should be made.
- The feasibility and cost-effectiveness of fallowing should be evaluated for maintaining Sea inflows instead of, or until CASI water is available.
- EES should be pilot tested to obtain better annual cost data and confirm area requirements and evaporation rates. An EES demonstration plant should be constructed and operated for at least a year to refine pilot plant data for final design if the EES is part of the project alternative.
- A review of the Sea's elevation and salinity goals should also take place before completion of the Final EIS/EIR. A salinity range of 35 to 40 ppt and an elevation range of –230 to –235 feet MSL was previously established; however, a target elevation of –230 feet was recently established. If the inflow to the Sea decreases, a lower target elevation would require smaller quantities of replacement inflows and/or smaller displacement facilities.

SECTION

2

# REVIEW OF WATER AND SALT ACCOUNTING MODEL

The basic design and sizing of the alternatives were based on results from the water and salt accounting model. This section provides a brief review of the major assumptions for the model used by the Bureau of Reclamation to formulate and evaluate the proposed Sea alternatives for a range of assumed future inflow conditions.

The assumptions used to develop the model were generally found to be reasonable. The model can be used to assist in development of Salton Sea Restoration alternatives and predict their effectiveness in meeting target salinities and elevations.

It should be noted that additional information from test ponds would allow the model to be refined. However, uncertainty relating to the future reduction in Sea inflows does not warrant construction and operation of test ponds only for purposes of refining the model.

## 2.1 SALT AND WATER ACCOUNTING MODEL

The area-volume-elevation data for the Salton Sea and for the evaporation ponds or displacement dike areas were obtained from Geographical Information System (GIS) database maps. The Salton Sea accounting model contains the north and south evaporation ponds and the displacement dike area geometry data. Any modifications to these geometry data must be obtained from the GIS database. The process of selecting alternative pond locations and determining the necessary geometry data must be accomplished outside of the model and imported to simulate other pond configurations. Finding other combinations of pond dike alignments to cover the same area but with shallower depths (i.e., to reduce dike construction costs) must be evaluated from the GIS database.

The water and salt accounting model contains several "triggers" that are used to reduce the import of water and the export of salt once the target elevation and/or salinity is reached. The elevation trigger of –232 feet mean sea level (MSL) has been used for most of the alternatives with reduced inflows. The salinity target of 37.5 ppt is often not quite satisfied. The actual inflow and export each year is calculated in the model for each alternative, but these results were not reported in the Draft EIS/EIR. Many of the potential imports and export volumes described for each alternative are not fully required after about 2040 or 2050 when the target elevation and salinity are achieved.

The results shown in the Draft EIS/EIR generally indicate the correct "response-time" required to achieve the elevation and salinity targets. Each of the alternatives has been designed to generally achieve the elevation and salinity targets for the full range of potential future inflows. The Draft EIS/EIR results also include the range of possible future conditions resulting from the uncertainty and variation in the inflows and evaporation rates that have been historically observed. This has been analyzed by the Bureau with a spreadsheet enhancement program called @RISK. This uncertainty analysis produced a range of likely future elevations and salinities that were shown in the Draft EIS/EIR.

Generally the results from the water and salt accounting model for each alternative have been found to be reliable. The following sections describe some of the most important assumptions and results from the accounting model.

### SALTON SEA GEOMETRY

The Bureau of Reclamation conducted an extensive survey of the Salton Sea geometry (i.e., bathymetry) in 1995. This database has been summarized as GIS elevation-contour maps with 5-foot contours and as elevation-area-volume tables for use in alternative development and evaluation. Because of the direct relationship between surface area and the evaporative loss of water from the Sea, as well as the effect of Sea volume on salinity, these basic geometry data provide one of the most important pieces of information for developing and evaluating Salton Sea restoration alternatives.

Table 2–1 provides a summary of this Salton Sea geometry data between elevation –245 feet and elevation –220 feet, which is the top of several of the near-shore levees protecting agricultural and other developed properties near the Salton Sea shore. The Salton Sea geometry data expressed as surface area (acres) and cumulative volume (acre-feet) is available for 1-foot increments between elevation –278 feet and –220 feet.

### Table 2–1 – Summary of Salton Sea Geometry Data

| | | | Assumed Evaporation (feet/year) | Current Assumed Salton Sea Salinity (ppt) | Target Assumed Salton Sea Salinity (ppt) |
|---|---|---|---|---|---|
| | | | 5.8 | 44 | 37.5 |
| **Salton Sea Elevation (feet msl)** | **Salton Sea Capacity (TAF)** | **Salton Sea Area (acres)** | **Evaporation and Inflow (TAF)** | **Salton Sea Salt Content million tons)** | **Salton Sea Salt Content (million tons)** |
| -220 | 9,319 | 250,082 | 1450 | 558 | 475 |
| -221 | 9,070 | 247,699 | 1437 | 543 | 463 |
| -222 | 8,823 | 245,351 | 1423 | 528 | 450 |
| -223 | 8,579 | 243,037 | 1410 | 513 | 438 |
| -224 | 8,337 | 240,756 | 1396 | 499 | 425 |
| -225 | 8,097 | 238,502 | 1383 | 485 | 413 |
| -226 | 7,860 | 236,290 | 1370 | 470 | 401 |
| -227 | 7,625 | 234,113 | 1358 | 456 | 389 |
| -228 | 7,392 | 231,973 | 1345 | 442 | 377 |
| -229 | 7,161 | 229,868 | 1333 | 429 | 365 |
| -230 | 6,932 | 227,798 | 1321 | 415 | 354 |
| -231 | 6,705 | 225,750 | 1309 | 401 | 342 |
| -232 | 6,481 | 223,734 | 1298 | 388 | 331 |
| -233 | 6,258 | 221,752 | 1286 | 374 | 319 |
| -234 | 6,037 | 219,640 | 1274 | 361 | 308 |
| -235 | 5,819 | 217,196 | 1260 | 348 | 297 |
| -236 | 5,603 | 214,646 | 1245 | 335 | 286 |
| -237 | 5,389 | 211,809 | 1228 | 323 | 275 |
| -238 | 5,179 | 208,485 | 1209 | 310 | 264 |
| -239 | 4,972 | 205,426 | 1191 | 298 | 254 |
| -240 | 4,768 | 202,360 | 1174 | 285 | 243 |
| -241 | 4,568 | 198,993 | 1154 | 273 | 233 |
| -242 | 4,370 | 195,554 | 1134 | 262 | 223 |
| -243 | 4,177 | 191,887 | 1113 | 250 | 213 |
| -244 | 3,987 | 187,726 | 1089 | 239 | 203 |

The current elevation of the Salton Sea is about –227 feet (with some seasonal variations) and the surface area of the Sea at elevation -227 feet is 234,113 acres. The volume of the Sea at this elevation is therefore 7,625,000 acre-feet. With an assumed evaporation rate of 5.8 feet per year a net inflow (from all sources) of 1,358,000 acre-feet per year [or 1,358 thousand acre-foot per year (TAFY)] is required to maintain the current elevation.

The surface area and volume for other target elevations can be compared with the current Sea area and volume. For example, a target elevation of –232 feet (five feet below the current elevation) corresponds to a surface area of 223,734 acres and a volume of 6,481,000 acre-feet. This target elevation represents a reduction of 10,379 acres from the current surface area, and a reduction of 1,144,000 acre-feet from the current Sea volume. The inflow necessary to maintain this elevation would be 1,298 TAF per year (60 TAFY less than the inflow needed to maintain the current elevation). Other target elevations can be evaluated and compared with existing conditions in a similar way.

## 2.2 SALINITY AND SALT CONTENT OF THE SALTON SEA

As generally described in the Draft EIS/EIR, adding salt to the Salton Sea increases the salt concentration and thereby increases the density of the Sea water. Salinity is measured in units of milligrams per liter (mg/l) salt (i.e., weight of salt per unit volume of water) and as milligrams per kilogram (mg/kg) or parts per million (ppm) (weight of salt per unit weight of water). At low concentrations, these two units are almost equivalent, since a liter of water weighs 1000 grams (at a temperature of 4 degrees C). As salt is added to water, the salt dissolves in the water, increasing the weight but not changing the volume. The water density increases by the weight of salt added. The salinity in weight units (ppt) therefore diverges from the weight per volume units (g/l) as more salt is added. The relationship is:

**Salt per water weight (g/1000 g) = Salt per volume (g/l) / [1000 + salt (g/l)]**

For example, the current Sea salinity is about 44 g/l (44,000 mg/l), so the salt content in ppt is 42 (i.e., 44/1044). If the salinity increases to 100 g/l, the equivalent ppt value will be about 91 (i.e., 100/1100). Because the Salton Sea salt balance is integrated with the water volume budget, all calculations in the salt model and most used in this report will be given in salt weight per volume units of g/l.

If the salinity of the Sea is assumed to be currently about 44 g/l, then the salt content of the current volume of the Sea can be calculated as 456 million tons from the following formula:

**Salt (tons) = 1.36 * volume (ac-ft) * salinity (g/l)**

An acre-foot of Salton Sea water, with a salinity of 44 g/l contains about 60 tons of salt. By way of comparison, an acre-foot of ocean water with a salinity of 35 g/l contains about 48 tons of salt. For the current inflow of about 1,358 TAF per year, with an average assumed salinity of 2.8 g/l, the inflowing salt load is about 5.1 million tons per year (i.e. 3.8 tons per acre-foot). The inflowing salt will be mixed throughout the Sea, increasing the salinity of the Sea by about 0.5 g/l per year if the inflow and Salton Sea volume remain about the same as current values (i.e., No Action Alternative).

For perspective, a standard railroad car holds about 100 tons. The salt entering the Salton Sea in a year would require about 51,000 railroad cars. This would be equivalent to a very long train of 140 cars each day. This is a lot of salt.

If Sea water with an assumed current salinity of 44 g/l was removed to balance (prevent the salinity from increasing) the inflowing salt load of 5.1 million tons per year, a removal (export) volume of about 87,000 acre feet per year would be required. Additional water and salt must be removed initially (about 100,000 acre-feet per year) to reduce the volume and salt content of the Sea to achieve the lower salinity goal of 35 to 40 g/l.

## 2.3 EVAPORATION AND INFLOWS

Evaporation from the Sea and inflows to the Sea are directly linked. Evaporation has been estimated from evaporation pan measurements and from heat-transfer studies [United States Geological Survey (USGS) 1960s], as well as by comparison with the measured and estimated inflows. The best current estimate of Salton Sea evaporation is about 70 inches (5.8 feet) per year. This estimate of evaporation rate is slightly (i.e., 5 percent) less than freshwater evaporation, because evaporation rate decreases as salinity increases.

The total inflows to the Sea have been back calculated from the long-term USGS surface elevation records, using the elevation-area data shown in Table 2–1. The estimated inflows have averaged about 1,360 TAF, with a range of between 1,100 and 1,500 TAF per year. If the evaporation rate had actually been 5 percent more than estimated, the back-calculated inflows will also have been about 5 percent greater than estimated with the assumed 70 inches of evaporation. If the actual evaporation had been 5 percent less, then the inflows would have been 5 percent less.

The future expected total inflows to the Salton Sea (relative to the historical inflows) will have a dramatic effect on the alternatives and their ability to meet the target elevation and salinity goals. Whatever the actual evaporation rate has been, it is likely to remain the same. Therefore, the future change in the inflow to the Sea is the major uncertainty in the water balance for the Salton Sea. The Draft EIS/EIR evaluated three possible future inflow sequences:

- Inflows similar to recent historical values, with an average of 1.36 MAF per year.
- Inflows decreasing by an average of 10 TAF per year until a new long-term average of 1.06 MAF per year is reached in the year 2030.
- Inflows decreasing by an average of 10 TAF per year until a new long-term average of 0.8 MAF per year is reached in the year 2055.

Because today's Sea volume at –227 feet is considerably higher than the target volume at elevation –232 feet, it will take several years for the declining inflows to reduce the Sea volume through evaporation. The volume at the target elevation of –232 feet is 1,144 TAF less than the current volume of 7,625 TAF. The Sea elevation and volume will decline more rapidly if water is removed (i.e., exported) from the Sea for one of the salt removal alternatives in the Draft EIS/EIR.

The Sea inflows may decline more rapidly than assumed in the Draft EIS/EIR. For example, the water transfer to San Diego is expected to increase by 20 TAF per year during the next 10 years. If all of this water is obtained by conservation of tail water, the Sea inflow could be reduced at the same rate that the water transfer is increased. That is unlikely because of bank storage, but if it occurred, the Sea inflow may decrease by 20 TAF per year over the next 10 years. The selected restoration alternative must be designed to allow for adaptive management of Sea salinity and Sea elevation under this worst-case inflow scenario. Because the current Sea elevation is higher than the target elevation, there will be adequate time to observe and measure the actual decline in Sea inflows and the corresponding decrease in the Sea elevation. Refinements in the use of replacement inflows and/or the sizing of additional displacement facilities can be made as the future inflows become more certain.

## 2.4 SALT DENSITY AND VOLUME RELATIONSHIPS

As NaCl crystallizes in a salt pond, the density of the salt deposit will depend on the brine chemistry and impurities in the crystal lattice. Pure salt (NaCl) has a density of about 2,300 g/l (i.e., 2.3 times water) or about 3,130 tons per acre-foot. But generally the crystallized salt has a relatively high porosity (i.e., voids) and water content, so the density of the salt bed is expected to be between 1250 and 1500 tons per acre-foot. This allows an estimate of the volume of salt disposal ponds that will be required to hold 5.1 million tons of salt per year (current inflow to Salton Sea). Assuming the lowest density of 1250 tons per acre-feet, a volume of more than 4,000 acre-feet will be needed to depose of the salt load entering the Sea each year.

An additional volume for salt deposition must be provided to remove the salt contained in the water that must be removed to lower the Sea to the elevation target and lower the salt remaining in the Sea to the salinity goal (See Table 2–1). For example, if the target elevation of -232 feet is to be achieved with the current Sea salinity (44 g/l), then 68 million tons of salt must be removed as the volume is reduced by 1,144 TAF. This will require a salt disposal volume of about 55,000 acre-feet (about 5 percent of the water volume). This salt disposal volume has not been simulated in the accounting model, but has been included in the general assumption about the 30-year life of the ponds.

## 2.5 EFFECTIVENESS OF ALTERNATIVES FOR ACHIEVING THE TARGET ELEVATION AND SALINITY

The water and salinity management strategy for each of the alternatives is similar. Each alternative removes an average of 150 TAFY to 200 TAFY during the first 25 years of operation. This is sufficient to remove about 250 million tons (an average of 10 million tons per year) of salt from the Sea. This lowers the salinity of the Sea to the target salinity of 37.5 g/l within 40 years. The timing is different for each alternative and for each of the future assumed inflow scenarios. The alternatives can each be operated under adaptive management principles to remove less water and salt if the elevation drops below the target. This flexibility will not correct the rising elevation that was simulated for Alternative 1 with current inflows. The simulated elevation rises to elevation –227 feet after the ponds are taken out of operation in year 2040, because the export of 150 TAFY is not enough to compensate for the reduced evaporation from the pond area.

Generally, each of the alternatives will need additional replacement inflow and/or displacement facilities (dikes) after the year 2040 for the 0.8 MAFY Scenario.

For the reduced future inflow scenarios, each of the alternatives uses potential flows available from Colorado River flood flows and from the CASI project to supplement the agricultural drainage inflows. The flood flows are only available in some years (i.e., about 20 percent of the years). Some flexibility in the Sea's elevation range is needed to allow flood flows to surcharge the Sea elevation in a sequence of wet years when they are available.

The salt removal export volumes of 150 TAFY to 200 TAFY can be reduced in the future, after the target salinity and elevation are reached, by operating the salt export facilities at less than full capacity. The general assumptions used in the water and salt accounting model are confirmed to be a reliable basis for the Draft EIS/EIR alternative evaluations.

# SECTION 3

# ANALYSIS OF ALTERNATIVE COMPONENTS AND CONCEPTS

Each of the Phase 1 alternatives described in the Draft EIS/EIR has the potential, if modifications and/or additions are made, to meet the salinity and elevation objectives established for the Salton Sea Restoration Project until at least the year 2030. However, a more efficient and cost effective way of meeting the salinity, and perhaps the elevation, goal(s) may be achievable. To the extent practical, the components of the selected project should have useful lives of more than 30 years. Some of the components appear to have much shorter lives (10 to 30 years) whereas others have much longer lives.

The water and salt management actions are linked. The Phase 1 alternatives performance can be evaluated by considering their components. The components of the alternatives are described and evaluated herein to determine what, if anything, could be done to increase their useful lives, their functionality, and their effectiveness. These components were grouped into those that:

- Remove and dispose of salt.
- Only remove salt.
- Only dispose of salt and/or concentrated brine.
- Control the elevation of the Sea.

Additional concepts, some that were previously analyzed by the Bureau of Reclamation and others, were also identified by Parsons and added to each group.

## 3.1 SALT REMOVAL AND DISPOSAL

Removing and disposing of 5- to 10-million tons of salt per year at the Salton Sea is a very large task. The United States (U.S.) is the largest producer of salt in the world. It produces 20 to 25 million tons of dry salt per year. The solar salt component of that is 5- to 6-million tons per year. The largest solar salt facility in the world produces 7-million tons per year. Attempts to commercially produce large quantities of salt at the Salton Sea would add significantly to the total salt produced in the U.S. and would greatly affect current producers of salt, especially those on the West Coast. Past contacts with salt producers generated little interest in making salt at the Salton Sea because of the low quality of salt that would be produced and the high transportation cost of moving salt to the market. Thus, for purposes of this report, it is assumed that any salt removed from the Salton Sea must be disposed of in a landfill or in some other manner rather than used for commercial purposes.

### *CHEMICAL PROPERTIES OF SALTON SEA AND ITS EFFECTS ON SALT REMOVAL*

Table 3–1 depicts the average concentrations of the major ions in Salton Sea water in milligrams per liter (mg/l) as compared to Ocean seawater. The seawater concentrations were ratioed up by total dissolved solids (TDS) to match the Salton Sea water TDS.

**Table 3–1 – Average Concentrations (mg/l) of Major Ions in Salton Sea water and Ocean Seawater**

| Chemical | Salton Sea Water[1] | Ocean Seawater[2] |
|---|---|---|
| Ca | 1,006 | 512 |
| Mg | 1,384 | 1,629 |
| Na | 12,356 | 13,418 |
| $HCO_3$ | 246 | – |
| $SO_4$ | 11,236 | 3,388 |
| Cl | 16,332 | 24,280 |

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[1] "Draft Salton Sea Restoration Project EIS/EIR" Jan 2000, table 3.1-3, pg. 3-13.

[2] Bolz, R. and Tuve, G., "Handbook of Tables for Applied Engineering Science" *The Chemical Rubber Co. 1970*, pg. 537.

Upon evaporation, these ions would crystallize to the major salts shown in Table 3–2 below:

**Table 3–2 – Major Crystallized Salts in Salton Sea and Ocean Seawater**

| Chemical | Salton Sea Percent (%) | Seawater Percent (%)[3] |
|---|---|---|
| NaCl | 64 | 78 |
| $MgCl_2$ | 0 | 11 |
| $MgSO_4$ | 16 | 5 |
| $CaSO_4$ | 8 | 4 |
| $NaSO_4$ | 12 | 0 |
| $NaHCO_3$ | <1 | 0 |
| $K_2SO_4$ | 0 | 2 |

The brines and resultant salts are different, although NaCl dominates both brines. Thus evaporation characteristics should be similar to seawater brines, except at high concentrations. The first salt to form will be $CaSO_4$ (gypsum), followed by NaCl, then the remaining salts.

The main effect of the differences shown above will appear toward the end of NaCl deposition. In seawater brines, the phase chemistry is not temperature dependent until somewhat after NaCl deposition. The phase chemistry of Salton Sea brines would be expected to become temperature dependent sooner. The type of salts formed after NaCl would depend on the ambient temperature at the time and would vary from summer to winter. The salts formed are typically complex, hydrated multiple salts. Since the highly concentrated brine (bittern) would probably not contain $MgCl_2$, it may be efflorescent meaning the dried solids would give up water of crystallization slowly and form a powdery substance on the surface as the salt dries. As a consequence, the bittern may dry all the way, or it could crust over and trap liquid below the crust. If the salts are hygroscopic, they will pull moisture from the air and will not evaporate to dryness. Generally, the Salton Sea climate may be dry enough to approach evaporation to dryness; however, the Sea and agricultural effects add significant humidity to the air. A small test pond is needed to help determine the composition of the highly concentrated brine (bittern) and its characteristics.

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[3] Kaufman, D., "Sodium Chloride – The Production and Properties of Salt and Brine", *Reinhold Publishing 1960*, pg. 368.

Some of the minor constituents in the brine could alter NaCl crystal growth, and could be occluded in the crystals. These two possibilities only affect the salt density and would impact the salt quality if it were to be produced for commercial purposes.

### *SALT INDUSTRY APPROACH*

The salt industry uses a series of solar evaporation ponds to make salt for two reasons. First, it is desirable to extract a single salt (e.g. NaCl) from brine containing multiple salts that crystallize at different brine concentrations per the phase chemistry. A series of ponds assists greatly in controlling what salt crystallizes where. Second, about 90 percent of the water introduced into the ponds must evaporate to get to the NaCl crystallization stage. As brines become more concentrated, their evaporation rate slows markedly. In a single pond system, as new brine is pumped in and evaporation takes place, the salt brine concentration will build up, the average salinity will increase over time, and the evaporation rate will slow down. Evaporation stops at a salinity of somewhere over 450 parts per thousand (ppt) even in a hot, dry climate. The bottom line is that a single pond is very inefficient in terms of making solid phase salt when compared to a series of ponds with the same total surface area.

A well-designed solar evaporation facility contains a feature that allows high-density liquors (bittern) containing magnesium salts to be removed after the NaCl salt is crystallized. As stated above, these brines may not evaporate to dryness. They form complex salts whose composition changes with the ambient temperature. In the salt production business, these brines are typically discharged back to the Ocean or stored in waste ponds.

### *APPROACH AT SALTON SEA*

At this point, no commercial use has been determined to be viable for the Salton Sea dry salt or bittern. Thus the approach to reduce the salinity of the Sea should focus on the most efficient and cost-effective way(s) of removing and disposing of salt from the Sea.

## 3.1.1 Deep Ponds

Alternative 1, as described in the Draft EIS/EIR proposes to use "single" deep ponds for evaporation and disposal of water from Salton Sea and disposal of the salt that remains. No commercial solar salt facility or any related mineral extraction process using solar evaporation, anywhere in the world is known to use a single deep pond to evaporate water and make salt. Solar facilities normally use a series of ponds and have a method to bleed off final liquids from the system because they are more efficient.

The north and south concentrator ponds described in the Draft EIS/EIR in Alternative 1 were intended to remove salt and dispose of salt from the Sea through evaporation in deep ponds for about 30 years. They would also remove approximately 33 square miles of surface area from the Sea and thus assist in maintaining the Sea's elevation. If the ponds were operated at an elevation of –227 feet, the evaporation rate would initially be about 120,000 AF per year (AFY), but would be reduced to about 105,000 AFY within about eight years due to increased salinity in the ponds. If the ponds were used beyond that point, the evaporation rate would drop to about 94,000 AFY at the end of an additional five years, when solid NaCl would begin to form. The ponds could operate for a total of about 13 years by simply concentrating Sea water to the point where solid phase salt begins to crystallize. Thereafter, the evaporation rate drops further at an accelerating rate as solid phase salt crystallizes and sinks to the sides and bottom of the ponds. The salt deposited on the sides would cause the surface area of the ponds to shrink and eventually the evaporation rate would fall to nothing. Their effectiveness over 30 years, as described in the Draft EIS/EIR, is questionable.

The Bureau of Reclamation envisioned that the ponds would be dewatered after they were no longer useful as evaporation ponds. The dikes would be strengthened so they could continue to function as a displacement device (see discussion in Subsection 3.4.1) and the ponds might be converted to a final disposal site for salt and brine removed by an Enhanced Evaporation System (EES) or some other salt removal system.

### DIKE DESIGN AND CONSTRUCTION

The deep ponds are designed to be separated from the Sea by earthen dikes. The south pond will entail construction of dikes totaling 13 miles whereas 11-mile long dikes will enclose the north pond. The dikes are currently designed to have a crest width of 30 feet at elevation of –220 feet. The dikes would be a maximum of about 35 feet high and are currently designed with side slopes at inclinations of 3½:1 (horizontal:vertical). It is estimated that approximately 21,000,000 cubic yards ($yd^3$) of material will be required to construct the dikes.

The dikes would be constructed by first removing about 5 feet of sludge and soft material from the bottom of the Sea along the dike's alignment. The dike would then be constructed by end dumping borrow material into the Sea. The current design calls for operating the ponds with their water elevation close to elevation –227 feet by pumping Sea water into the ponds where it would evaporate.

A previous investigation[4] found the thickness of the soft seafloor sediments to range from 1 to 15 feet thick. A report from the State Mineralogist[5] described the dry playa in 1893 as having 6 inches of black mud covering a 7-inch-thick crust of chlorides of sodium and magnesium. The next 22 feet was a black ooze containing over 50 percent water, and consisted "largely of chlorides and carbonates of sodium and magnesium, the soda salts predominating, besides fine sand, iron oxide, and a small amount of organic matter." This is possibly bittern that has been left from previous inundation and drying out of the Sea. It will be important to adequately characterize the strength of the foundation materials along the proposed dike alignments. If materials of similar strength and depths are encountered, substantially more excavation may be required than what is currently estimated.

The Bureau of Reclamation assumed that the dikes would be constructed by end tipping material from the crest of constructed parts of the dikes. The material would be hauled in large dump trucks that would travel along the crest of the dike. However, this construction process would result in side slopes at the angle of repose of the earthen materials. The angle of repose is the steepest inclination a material can be piled; for a silty sand it is typically about 2:1 in water. This inclination would create an embankment with slopes that are at incipient failure. The side slopes would need to be constructed flatter to promote more stable embankments, both statically and during an earthquake (discussed further below). To place materials flatter than the angle of repose would require a different or additional construction procedure that may add cost to the construction. Material could be added above and beyond the end-tipped slope by either barge or conveyor placement. Barge placement would require a barge loading station near shore and towing the barge to the dike toe where the material would be placed. Alternatively, material could be placed above and beyond the end-tipped slope using a conveyor system with a gantry at the end to distribute material. A similar system is shown in Figure 3–1. The conveyor system could also be used to place all the material in the dike, and may reduce the required crest width of the dike.

We estimate that the requirement to place additional material beyond the angle of repose of the dike material may increase the cost of the dike as currently designed by about 20 to 30 percent. However, if a conveyor system is used to place the material, the crest width of the dike could be

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[4] United States Department of the Interior and The Resources Agency of California, 1974. "Feasibility Report, Salton Sea Project," dated April 1974.

[5] Redway, J.W., 1893. "Salton Lake," Geog. Journal, v.2, pp. 170-171.

reduced from 30 to 20 feet and the required dike quantities could be reduced by 15 to 20 percent.

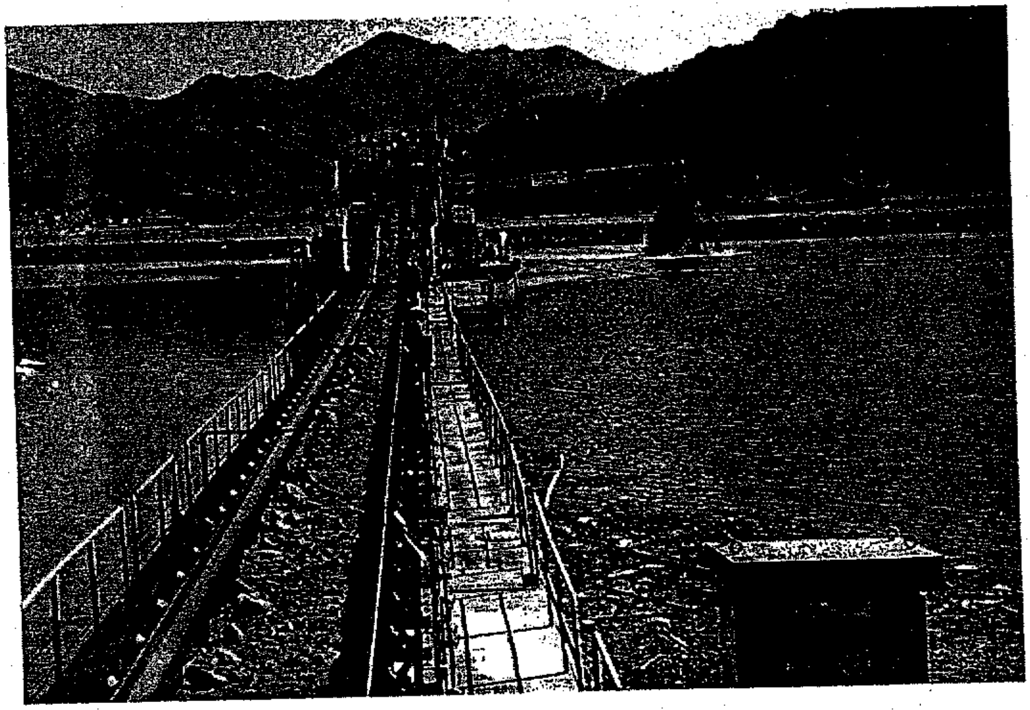

**Figure 3–1 – Gantry Conveyor System**

Consideration should also be given to minimizing the heights of the dikes to minimize the cost of the ponds. The seismic vulnerability would also be reduced with the lower height dikes because the internal shear stresses and magnitude of possible seismic slumping will be less. Figure 3–2 shows the conceptual relationship between seismic vulnerability and dike height.

The quantity of material needed to construct a 17-foot-high dike would be 70 to 75 percent less than for a 35-foot-high dike (assuming both have crest widths of 30 feet and side slopes at 3½:1). Since, the cost for constructing the dikes is driven primarily by the amount of borrow material placed, the linear cost for a 35-foot-high dike would be about three times the linear cost for a 17-foot-high dike. Figure 3–3 presents a hypothetical example for optimizing the height of the south pond dikes. This figure presents the estimated dike volume for enclosing equal areas of the Sea for use as an evaporation pond at various average water depths along the dike alignments. This example indicates than an optimum dike height might be about 20 feet (5 feet of foundation excavation plus 8 feet of water plus 7 feet of freeboard). However, it does not consider effects on stream inflows, near-shore habitats, etc. Dike construction cost needs to be balanced with such effects. Similar optimization studies should be completed using actual dike configurations and seafloor bathymetry.

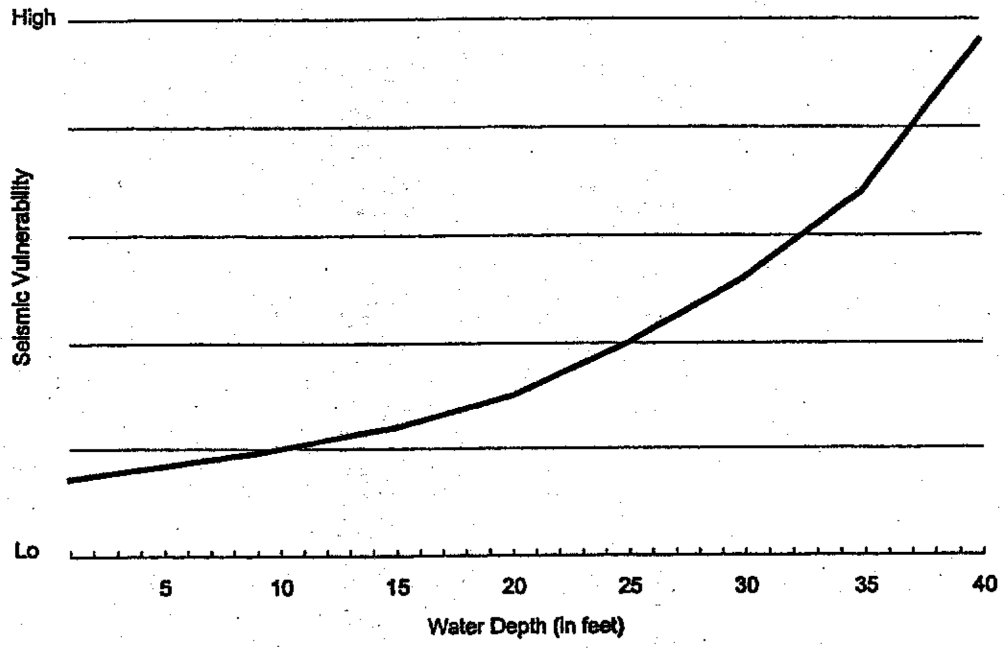

**Figure 3–2 – Dike Seismic Vulnerability versus Water Depth**

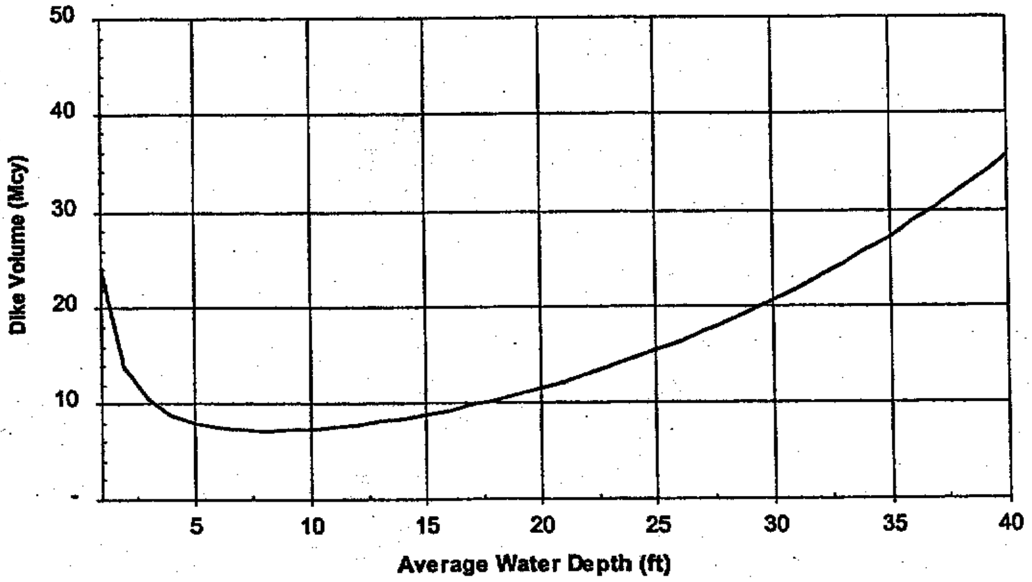

**Figure 3–3 – Dike Volume versus Average Water Depth**

Similarly, dikes constructed onshore will cost substantially less than dikes in the Sea. Dikes constructed onshore could be built with side slopes of 2:1 and the quantity of material would be reduced by 35 percent from an in-Sea dike. The dike constructed onshore could also be constructed of compacted fills such that its seismic vulnerability would be very low, provided the foundation soils are not liquefiable.

### SEISMIC VULNERABILITY

The primary seismic hazards potentially impacting the dike are fault rupture, liquefaction, and strong ground shaking. These hazards and their possible consequences are discussed below.

The Sea is within the Salton Trough, a northerly extension of the Gulf of California Rift Zone, and is considered one of the most seismically active areas in the world. The seismic exposure is great in the area, and design of any facilities for the Sea restoration will need to consider the likely effects of earthquakes. The major fault systems in the area are the San Andreas, San Jacinto, and Elsinore fault zones. These faults are characterized by right-lateral movement and are considered "active," as they have produced ground rupture within the last 11,000 years. Several short, discontinuous, fault segments have been identified in the southern part of the Sea.

Linear features (e.g., dikes, pipelines, roadways) that cannot avoid crossing an active fault are usually designed to accommodate the anticipated displacement (if small) or to be repaired quickly (if the anticipated displacement is large). The dike system may not be breached by fault displacement alone if its movement is less than the crest width of the dike. However, it may create a weak area that could be breached immediately after the earthquake by internal erosion if the water levels are substantially different between the pond and the Sea. A probabilistic fault displacement analysis (PFDA) should be performed during the design of the dikes to evaluate the probable fault displacements. The PFDA evaluates the probability of an earthquake occurring on a fault segment, whether it will be large enough to generate surface rupture, and the probability of the displacements exceeding a specific value. Further evaluations of the possible consequences of a breach by fault movement should then be made in light of the probable fault displacements. However, we anticipate that the probable fault displacements will be considerably less than the dike crest width.

Seismically induced soil liquefaction is a phenomenon in which loose to medium-dense, saturated, granular materials undergo particle rearrangement, develop high-pore water pressure, and lose shear strength due to cyclic ground vibrations induced by earthquakes. The rearrangement and strength loss is followed by a reduction in bulk volume of the liquefied soils. Consequences of liquefaction include sand boils, loss of bearing capacity below foundations, and settlements in level ground; and slumping and instabilities in areas of sloping ground. All of these have been observed following earthquakes in Imperial County in the last 25 years, including liquefaction that was documented at San Felipe Creek and the Wildlife Refuge at the south end of the Sea[6,7,8].

It is desirable to use granular soils (sand) to construct the dikes as they can be built steeper than fine grained soils and will be more trafficable during construction. The dikes will need to be constructed by dumping soils through the Sea water. This process will not allow for compaction of the dike soils and will result in a loose saturated granular soil that will have a high potential for liquefaction. The Draft EIS/EIR evaluated only the consequences of liquefaction of the foundation soils and did not evaluate the consequences of liquefaction of the dike itself. Ground improvement/vibratory densification could be undertaken after the soils have been placed to mitigate their liquefaction potential. However, that would probably add at least $100 to $150 million to the cost of the two dikes and would be difficult to perform along the side slopes of the dikes.

It is desirable to construct the dikes with 3½:1 side slopes so that if liquefaction were to occur (and there is a high potential for this to occur), the dikes would "slump" rather than have slope instabilities. Dikes with 3½:1 slopes should slump rather than have catastrophic slope failures if the dike soils liquefy. The dikes may slump 20 percent of their height (7 feet for 35-foot dike). Figure 3-4 shows a typical slump failure. However, little is known about the Sea bottom conditions along the dike alignments, and additional slumping/settlement could occur if the foundation soils were to liquefy.

Even if the soils were not to liquefy, permanent deformations of the dikes could occur, due to strong ground shaking that is anticipated during an earthquake. However, this would most likely only control the design of the onshore dikes that can be compacted so they are not potentially liquefiable. Deformations associated with liquefaction would most likely control the design of the in-Sea dikes.

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[6] Youd, T.L., and Wieczorek, G.F., 1982 "Liquefaction and Secondary Ground Failure in the Imperial Valley, California Earthquake of Oct. 15, 1979," The Imperial Valley Earthquake October 15, 1979, U.S. Geological Survey, Professional Paper 1254, pp. 223-246.

[7] Youd, T.L., and Wieczorek, G.F., 1984 "Liquefaction During 1981 and Previous Earthquakes Near Westmoreland, California," Open File Report 84-680, U.S. Geological Survey, Menlo Park, California.

[8] Holzer, T.L., Youd, T.L., and Hanks, T.C., 1989. "Dynamics of Liquefaction During the 1987 Superstition Hills, California Earthquake," Science, Vol. 244, pp. 56-59.

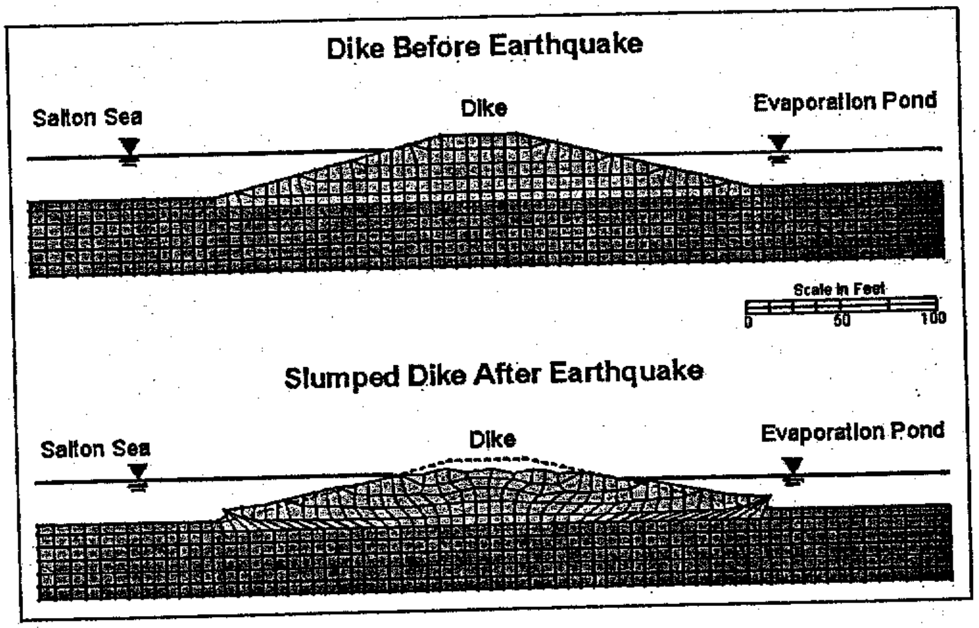

**Figure 3-4 – Typical Slump Failure**

We recommend that seismic response analyses be performed to evaluate the effects of liquefaction and ground shaking on the dikes. This will require investigation of the dike and foundation materials and their response to anticipated ground shaking. We recommend that explorations be performed to evaluate the probable foundation materials and characteristics of the proposed borrow materials for dike construction. Material properties can be developed for the response analyses by using samples and data obtained from the explorations. Computerized simulations of the response of the dikes using the developed material properties and anticipated earthquake ground motions can be used to evaluate the required dike geometry.

The Bureau of Reclamation has evaluated the probable ground motions that could be experienced for 30-year and 100-year return periods. These ground motions were then used to evaluate the probability of failure of the dikes during: (1) the 8-year construction period; (2) during 27 years of operation; and (3) during the next 65 years after the operation is closed. The Bureau estimated the probability of failure at 20 to 50 percent during the 27-year operational period. Their evaluations of probable dike failure are probably appropriate for the given return periods. However, current building codes typically require designs that result in only minor damage for a 72-year return period (50 percent probability of exceedance in 50 years) earthquake and that also prevent a catastrophic failure for a 475-year (10 percent probability of exceedance in 50 years) return period earthquake. Therefore, the ultimate design may need to consider much higher acceleration levels than those cited by the Bureau for the lower return levels.

Given the seismic exposure at the Sea, it would be very expensive to construct a diking system with a low probability of failure. Therefore, the system should be designed and operated such that the consequences of a failure are minimized. Consideration should be given to always operating the ponds with their water level slightly lower than the Sea level. This would not only eliminate the need for pumping into the ponds but would also mitigate the consequences of a possible breach during a seismic event. The less-saline Sea water would flow into the pond until the water levels equilibrate. The dike breach could then be repaired quickly and the operation restored.

The consequences of failure if the ponds are operated above the Sea's elevation (as proposed in Alternative 1) are likely to be much greater, including possible return of large quantities of concentrated saline water to the Sea.

Consideration should also be given to using the ponds as a final disposal area for bittern. These fluids will be denser than Sea water and can possibly be layered in the bottom of the ponds, allowing Sea water to continue to evaporate in the ponds. These materials would also help buttress the dikes and reduce the dikes' potential for slumping. We do not recommend that the pond areas be allowed to completely dry out. This would create large hydraulic heads on the dikes that would require an extensive pumping system to control seepage through the dikes. A dike breach could also cause a flood into the ponds; access to the area would need to be restricted or the dike strengthened. The dikes could be strengthened by placing additional soil beyond and along the side slope of the dike. However, large quantities of additional fill would be required and there would be a risk to workers if an earthquake would occur during the strengthening process.

### *MODIFICATIONS IN RESPONSE TO SEISMIC ISSUES*

Because of concerns over seismic stability, the deep north and south in-Sea ponds were evaluated for use as the first concentration (solar evaporation) pond in a series of concentration ponds and as initial concentration ponds in conjunction with disposal of bittern. To reduce the risk from seismic events, this analysis assumed that the ponds would be operated at or slightly below the level of the Sea. For purposes of the analysis, it was assumed that the ponds would initially be operated at –227 feet and that the operating level would be lowered by 0.5 feet per year until reaching a level of –232.5 feet. That would allow water to flow into the ponds by gravity and would reduce the consequences of a potential breach of the dikes if a major seismic event occurred.

If the ponds were operated at an initial elevation of –227 feet and at lower levels as described above, the evaporation rate would initially be about 120,000 AFY but would be reduced to about 88,000 AFY within about eight years. If the ponds were used beyond that point, the evaporation rate would drop to about 80,000 AFY at the end of an additional two years, when NaCl would begin to form. The ponds could operate for a total of about 10 years instead of 13 years by simply concentrating Sea water to the point where solid phase salt begins to crystallize. Thereafter, salt deposited on the sides would cause the surface area of the ponds to shrink and eventually the evaporation rate would fall to nothing.

### MODIFICATIONS TO EXTEND POND LIFE

If the north and south deep ponds are used as the initial concentration ponds their efficiency can be increased substantially and their life can be increased well beyond 30 years. For example, these ponds are capable of evaporating about 120,000 AFY every year if the Sea water is concentrated to 130 ppt in the ponds initially and then concentrated further in subsequent ponds. This can be done with the two ponds in either series or parallel. Assuming zero leakage, a series of additional onshore and/or in-Sea ponds with a surface area of about 6 square miles would be required to complete the evaporation process to obtain about 8-million tons of salt per year. A system can be designed to remove a larger or greater amount of water and salt. Additional ponds would be needed for salt and bittern disposal.

It should also be noted that bittern could be placed back into the bottom of the north and south concentration ponds for disposal without significantly affecting the evaporation rate if a method can be found to layer the bittern without mixing. The bittern would tend to stay on the bottom because of its higher density. A surface layer of about 5 feet may be necessary for efficient Sea water evaporation. After many years, the ponds would fill up with bittern and the ponds would no longer be useable as concentration ponds.

### CONCLUSIONS

The deep in-Sea ponds as currently described in the Draft EIS/EIR are likely to be damaged and may be breached in a major seismic event. However, they can be operated in a manner that would reduce the consequences of failure. Onshore ponds south of Salton City, or elsewhere, can be designed to resist seismic loads, most likely at a lower cost than in-Sea ponds. However, onshore ponds would not displace surface area in the Sea to assist in maintaining the elevation of the Sea. Lower in-Sea dikes (for example, 17-foot high instead of 35-foot high) can be used to reduce seismic risk and potentially the overall cost, but may not be as effective in maintaining the elevation of the Sea.

The north and south in-Sea ponds should be also evaluated further for operation at an elevation slightly lower than the elevation of the Sea. These ponds can potentially be used as concentration and/or bittern disposal ponds in series with onshore concentration ponds and/or an EES. Other in-Sea ponds with lower dikes (about 10-feet maximum water depth) near Bombay Beach and the Salton Sea Base Site should also be evaluated for use either as concentration (solar evaporation) ponds or as concentration ponds and bittern disposal ponds.

### 3.1.2 Exporting Salton Sea Water to Gulf of California and Pacific Ocean

The Bureau of Reclamation evaluated the cost of exporting 250,000 AFY of Salton Sea water to the Gulf of California and to the Pacific Ocean. The conceptual designs and cost estimates were reviewed and found to be reasonable. The present value[9] of these concepts for 30 years at interest rates of 5 percent ranges from $1.35 to $1.73 billion. If the facilities were downsized for a 150,000 AFY concept, the present value would still be in excess of $ 1 billion.

#### *3.1.2.1 Gulf Of California*

The Bureau evaluated two concepts. The first involves pumping water to Golfo de Santa Clara through about 140 miles of large diameter pipeline with two pumping stations. The Bureau estimated the construction cost for this concept at $1.15 billion. The present value of the annual operation, maintenance, and replacement (OM&R) ($1.25 million) and energy ($15 million) for 30 years is $199 million.

The second involves pumping to San Felipe through about 178 miles of large diameter pipeline with three pumping stations. The Bureau estimated the construction cost for this concept at $1.5 billion. The present value of the annual OM&R ($1.7 million) and energy ($17.3 million) for 30 years is $225 million; thus the total present value of this concept is $1.73 billion.

#### *3.1.2.2 Pacific Ocean*

The Bureau evaluated pumping Salton Sea water to the Pacific Ocean at Camp Pendleton north of Oceanside in more detail after discarding other alternatives due to cost. This concept involves pumping water through about 83 miles of large diameter pipeline and 28 miles of tunnel with 5

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[9] All present value calculations herein are based on a 30-year life at 5 percent interest.

pumping stations. Three power plants would be constructed to recover energy. The Bureau estimated the construction cost for this concept to be $1.14 billion. The present value of the annual OM&R ($3.03 million) and energy ($15.4 million) for 30 years is $233 million; thus the total present value of this concept is $1.37 billion.

***CONCLUSIONS***

The concept of exporting Salton Sea water to the Gulf of California or the Pacific Ocean was evaluated by the Bureau of Reclamation and was not included in the actions in the Draft EIS/EIR alternatives. This concept for removing and disposing of salt from the Salton Sea is very costly and has many political and environmental issues, that would take many years to resolve (some may not be resolvable). These issues include, but are not limited to, permits for discharging Salton Sea water to Mexican waters or the Pacific Ocean, and introduction of species living in the Salton Sea to other waters. In addition, the acquisition of right-of-way for the long large-diameter pipelines can be controversial, especially if or when environmentally sensitive or urban areas are involved. We concur with Reclamation's decision to not include this concept as one of the actions in the Draft EIS/EIR alternatives. The concept of exporting and importing water from the gulf or the ocean is discussed in Section 4.5.3.

### 3.1.2.3 Pipeline to Palen Dry Lakebed

The Bureau of Reclamation evaluated the cost of exporting Salton Sea water to Palen Dry Lake. Palen Dry Lake is about 650 feet above the Salton Sea. Nearly 50 miles of large diameter pipeline, four pumping stations, and three power plants (to generate power) were needed to lift the water over the mountains and down to Palen Dry Lake. A dam would be used to create a lake to store the water. Their analysis assumed that 250,000 AFY of Sea water would be pumped to Palen Dry Lake where it would evaporate.

The Bureau estimated the construction cost for the conveyance facilities, the power plants and the dam at $800 million. The present value of the annual OM&R ($3.25 million) and energy ($19 million) for 30 years is $309 million; thus the total present value of this concept for 30 years is $1.11 billion.

***CONCLUSIONS***

A series of solar evaporation ponds would be more effective for evaporating water at Palen Dry Lake and may be more cost effective. The long pipelines, pumping stations, and the energy costs to pump Sea water to Palen Dry Lake makes this concept more costly than a concept that evaporates water near the Sea and then disposes of the brine or dry salt and bittern near the Sea or at the Palen Dry Lakebed (see Section 3.3.2). At least partial evaporation of water removed from the Sea should take place near the Sea when practical to reduce facility size and energy costs if disposal must take place away from the Sea.

## 3.2 SALT REMOVAL ONLY

The concepts discussed below address only salt removal from the Salton Sea. These concepts would need to be combined with one or more of the salt disposal concepts described in Section 3.3 to be effective.

### 3.2.1 Shallow Solar Evaporation Ponds (New Concept, Not In Draft EIS/EIR)

The proposed Salton Sea Restoration Project would be one of the largest projects in the world dedicated to making or removing salt. The salt industry uses shallow solar evaporation ponds to make salt because they are the most efficient for producing dry NaCl.

An efficient solar salt facility would operate a series of perhaps ten ponds, each succeeding pond operating at a higher salinity. The ponds would be much shallower than the in-Sea ponds in Alternative 1 described in the Draft EIS/EIR. There must be a place to store the highly concentrated brines (bittern) after the salt is removed, and a plan must be developed to store or dispose of the resultant salt. Following is a basic design.

#### *ASSUMPTIONS*

The assumptions are as follows:

- Assume a small seepage factor of 400 gallons/acre/day (the soils are tight).
- Average evaporation rate of Sea water from the Sea itself of 5.78 feet per year.
- Average rainfall of 2.5 inches per year.
- Concentrated brines transferred to crystallizer ponds at 309 ppt.

Given the above assumptions, a 5-million-ton per year facility would require about 27,300 acres or 42.7 square miles (28.6 square miles for concentrator ponds, 8.4 square miles for crystallizer ponds, and 5.7 square miles for bittern disposal ponds). A 10-million-ton facility would require about 95.4 square miles.

The above acreage does not include area required for the dikes. Steeper terrain would also increase the area required because common dikes between ponds would become impractical. In addition, the seepage factor affects the amount of evaporative area required. For example, if the seepage factor is zero, the total area required would be 38.3 and 76.6 square miles, respectively, for a 5-million-ton and 10-million-ton per year facility. It should be noted that the seepage factor for in-Sea ponds with water on both sides of the dike (with little or no differential head across the dike) would be zero.

From a salt making or removal perspective, the best place to build the ponds would normally not be in the Sea because of higher construction cost. This may impact the goal of stabilizing the elevation of the Sea. Maintaining the Sea's elevation and other factors will determine the overall best location to build the ponds. The size of the ponds in this example is approximate and can be modified to fit the topography near the Salton Sea and other priorities.

Key points that must be kept in mind when siting the shallow ponds include:

- Soil conditions, especially impermeability.
- Slope of land (2 feet per mile or less is desirable).
- Size of area where ponds can be located (several square miles needed for efficient operation).
- Distance to salt and bittern disposal site(s).

#### CONCLUSIONS

Shallow solar evaporation ponds should be further evaluated as a means of removing salt from the Salton Sea. A brief review of topography maps and a tour around the Sea indicate that compromises would have to be made to develop a shallow solar evaporation pond alternative. For example, the land with the flattest slope is located in and along the shore of the Sea south of Bombay Beach and in the USFWS Refuge area. Agricultural lands south of Niland also have a relatively flat slope. A cost-effective solution may involve using some of the above land for shallow ponds and other in-Sea and/or onshore lands for deep ponds and/or an ESS.

### 3.2.1.1 Deep Ponds

The use of deep ponds for salt removal and disposal was previously discussed in Subsection 3.1.1. Generally, a series of shallow ponds should be used to remove salt because they cost less to construct. However, if land with flat slopes is not available, somewhat deeper ponds can be used effectively. Also, in this particular project, the use of deep in-Sea ponds provides the additional benefit of displacing evaporative surface area in the Sea and the potential benefit of providing a site for disposal of bittern. Thus the overall benefits need to be weighed against the seismic risks and overall costs when evaluating where and how to build the evaporation ponds.

### CONCLUSION

Deep ponds should be considered for solar evaporation ponds when they can provide other benefits (such as displacement of Sea surface area and bittern disposal) or when land is not available for providing shallow solar evaporation ponds.

## 3.2.2.2 Enhanced Evaporation Systems (EES)

Mr. John Pyles contacted other salt experts from around the world. There are no known salt facilities using any kind of EES. Some forms of EES have been tested, but are not currently used in the salt industry, because of cost. Salt is a relatively cheap commodity in a very competitive market. No one wants to add a penny to the cost of production. This equipment would be expensive to operate from an energy perspective and annual operation, maintenance, and replacement costs are significantly greater than solar evaporation ponds.

EES are successfully used to evaporate water in the mining industry in specific instances where it is undesirable or impractical to use solar evaporation ponds. EES may be cost-effective at the Salton Sea, because of the limited availability of relatively flat land

Evaporation takes place by heat and mass transfer. Spraying water into the air or dropping water after it passes through nozzles from a 50- to 70-feet in the air increases the surface area, and thus potentially the mass transfer rate. That may result in less land area being used to concentrate the salt. However, the area required for crystallizing the salt and disposing of the dry salt and bittern would remain unchanged. If an EES is used to evaporate water, it is critical that the fine droplets be recaptured and do not leave the system. It must be warm enough (may not work in the winter) to allow water to evaporate as it falls to toward the ground. Wind must be available to transport the water vapor away (may not work if the wind is not blowing strongly enough), and the humidity must be low. A spray system would work best with dilute brine where the evaporation discount factor is favorable, but not so well with a more concentrated brine.

An EES has the potential to produce relatively dry salt. It would have to be sized to operate over a wide range of conditions to do so. The efficiency of such an operation is questionable. Thus a standalone EES is not recommended. However, the concept of using an EES with one or more shallow concentration ponds and a crystallizing pond would control possible drifting of salt deposits and improve operational efficiencies (see discussion below).

Little experience with large-scale use of an EES (none with salt brine) exists to predict the operation, maintenance, and replacement (OM&R) costs with much certainty. Pilot tests should be performed with the various EES under consideration to establish preliminary design parameters and to obtain refined annual operation and energy costs. A larger scale demonstration plant should then be designed and constructed and operated for at least a year before implementing an EES to remove salt from the Salton Sea. With proper maintenance and replacement of system components, the life expectancy of an EES is only dependent on the ability to dispose of the salt and bittern produced.

### OTHER ENHANCED EVAPORATION CONCEPTS

The only evaporation enhancement used currently in the salt industry is the mixing of certain dyes in the brine where the brines are either not colored or not deeply colored. Another evaporation enhancement under discussion, but not yet tested by the salt industry involves softball sized floating balls. The balls would continuously expose a thin film of brine to the air for evaporation. These concepts can be pilot tested to determine the extent, if any, of evaporation enhancement that may be achieved with Salton Sea water.

### CONCLUSIONS

EES are not currently used in the salt-making industry. They have the potential to use less land to evaporate Salton Sea water than solar evaporation ponds. However, the overall cost may be greater than solar evaporation ponds because of the higher annual operation and maintenance and energy costs. Pilot testing of EES should be performed at the Salton Sea to obtain refined annual operation, maintenance, and replacement and energy costs as well as area requirements and evaporation rate information at various salinities. This information will allow ESS to be evaluated as an alternative to or, in conjunction with, solar evaporation ponds. If a full scale ESS is to be implemented, a demonstration scale EES project should be constructed and operated for at least a year to determine the optimum way to use an EES at the Salton Sea.

### 3.2.2 EES With Ponds

Alternative 5 in the Draft EIS/EIR includes an EES constructed adjacent to the north concentration pond. An alternative where an EES is located within a shallow pond south of Salton City is a variation that may be more cost-effective. The intent of both of these concepts is to reduce the land area needed to evaporate water. These systems are not known to exist in the salt industry. However, an EES system located at or near concentration and/or disposal ponds has the potential to increase efficiency and may be more cost effective than a standalone EES. The comments about cost in Subsection 3.2.2 also apply to this concept.

If the EES is located within a pond, it may have to relocated periodically as salt accumulates. Access to the equipment for maintenance, relocation, etc. will be difficult unless the bittern is removed beneath and around the EES. Pilot studies should be performed to determine effectiveness and to refine design parameters.

#### CONCLUSIONS

An EES with shallow solar evaporation ponds is likely to be more cost-effective than an EES without shallow solar evaporation ponds. This concept should be tested over a range of water salinity to obtain data for how to best use this technology. Because of the large volume of salt to be removed from the Salton Sea and the relatively small amount of flat land, an EES may be cost-effective for removal of salt in conjunction with shallow and/or deep ponds.

## 3.3 SALT AND BRINE DISPOSAL

The quantities of dry salt to be removed from the Salton Sea under the restoration project are huge. As-deposited NaCl bulk densities range from 1,250- to 1,600-tons per acre-foot depending on weather and other factors in any one year. This translates to an average of 712 AF per million tons of solid phase salt deposited when the middle of the range is used. Conducting evaporation pond tests at the Salton Sea can refine this number.

The salt crystallizer pond(s) needed for the shallow ponds (or an EES) would cover 5,385 and 10,770 acres, respectively, for a 5- and 10-million ton facility. The production area would need to be relatively flat. The acreage needed does not have to be contiguous. Different pond areas can be connected by ditch or pipeline. Several concentrator and/or crystallizer facilities can be built with the acreage totaling the numbers shown above.

The dikes for the concentrators would be relatively low, containing only about 3 feet of brine. The dike for the crystallizer, however, would be high to contain many years of production. Each year's production will add about 10 inches of salt deposition. Therefore, depending on the surface area, a dike height of 30 feet could store at least 30 years of salt production plus brine depth and freeboard.

It is anticipated that the concentrated brines left after the NaCl making or removal phase would not evaporate to dryness. Tests should be conducted to determine the volume of bittern produced and its characteristics (whether it stays in a liquid form or dries out). In the solar salt industry, this heavy brine is called "bittern." A plan needs to be developed for long-term storage of bittern. Liquid bittern production from a 5-million ton facility would be about 1,300-million gallons per year. If the bittern is put into a separate pond, much of it will evaporate to a solid, but perhaps one-third could remain as a liquid forever.

### 3.3.1 Deep Ponds

The north and south in-Sea ponds are not recommended to be used for disposal of dry salt because of seismic stability concerns. Failure of the dikes may result in a significant portion of the salt being dissolved back into the Salton Sea. This is consistent with experience at the Great Salt Lake where an infusion of less saline water caused previously precipitated salt to be dissolved back into the Lake. It would be very expensive to construct dikes capable of withstanding a large magnitude earthquake. Consideration should be given to siting dry salt disposal ponds onshore in lieu of in the Sea because the construction cost is likely to be significantly less. With onshore salt disposal ponds, there would be little or no risk of the salt being dissolved back into the Sea in the event of a major seismic event.

Calculations were made to determine the life expectancy of the north and south deep in-Sea ponds only to illustrate their potential life expectancy for storing dry salt and to provide a sense of the size of ponds that would be needed at an alternate location. The surface area of the north and south ponds in the Draft EIS/EIR is 33 square miles. Using information supplied by the Bureau of Reclamation for pond volume and picking elevation –227 for maximum crystallized salt fill (leaves 4 feet of dike height for wave action and residual brine), the total volume of the two ponds for solid phase salts is 335,684 AF. Dividing this by 712 AF per million tons gives a capacity of 471 million tons. At 5-million tons per year, the life of the ponds would be 94 years, and at 10-million tons per year the life is 47 years. Independently, the north pond would have a life of 27 and 13.5 years at the above removal rates whereas the south pond would have a life of 66 and 33 years.

If the north and south ponds were used only as a final disposal site for bittern, the life would be significantly greater because the volume of bittern is expected to be less than dry salt. It is not possible to make a reasonable estimate unless evaporation tests with Salton Sea water are performed. The ponds could also be used as concentration ponds as described in Subsection 3.1.1 and 3.2.1.

#### CONCLUSIONS

Evaporation tests with Salton Sea water should be conducted to establish parameters for sizing salt and/or bittern disposal facilities. The in-Sea ponds should not be used for disposal of solid phase salt because breaching of the dike due to a significant seismic event may result in return of the salt to the Sea.

### 3.3.2 Drying Beds (New Concept; Not in Draft EIS/EIR)

The salt removed through evaporation becomes dry after the bittern is removed. In theory, the salt could be used to create a berm if highly concentrated brine is placed in shallow ponds and the salt is allowed to dry after the bittern is removed. When the shallow pond is nearly full of salt more storage area could be created by pushing the salt into a berm around the outside of the pond to increase the height of the dike. However, when the concentrated brine comes in contact with the salt berm, it would find a path through the berm and escape (leak) unless an impervious clay core or some other means of stopping the leakage was used.

The cost associated with constructing a deeper pond would be less than constructing berms piecemeal if it was practical to use dry salt to create a berm for storing salt brine. In addition, the annual costs involved in maintaining the berms would be greater than the costs of maintaining deeper ponds. Based on experience in the salt industry, it costs about $1 per ton to produce salt using shallow ponds and at least $2 to $6 per ton to move dry salt. Installation of a clay core or some other impervious system would result in additional cost.

#### CONCLUSIONS

This concept does not warrant further evaluation.

### 3.3.3 Palen Dry Lakebed

The Bureau of Reclamation evaluated the use of Palen Dry Lake for disposal of concentrated Salton Sea water (brine). Their analysis assumed that 250,000 AFY of Sea water would be pumped 6 miles to an

EES where approximately 90 percent of the water would be evaporated. The remaining concentrated water (brine) would be pumped to Palen Dry Lake. Nearly 60 miles of pipeline and seven pumping stations were required.

The Bureau estimated the construction cost for the complete system to be $595 million. The present value of the annual OM&R ($15.6 million) and energy ($17 million) for 30 years is $480 million; thus the total present value of this concept is $1.08 billion.

#### CONCLUSIONS

Revised designs and cost estimates for a 150,000 AFY should be prepared by using a series of concentration ponds and/or an EES near the Sea to determine the most cost-effective way of implementing this concept. However, the long pipelines and pumping stations and the energy costs to pump the brine to Palen Dry Lake are likely to make this concept more costly than an alternative that disposes of the brine or dry salt and bittern closer to the Sea.

## 3.4 ELEVATION CONTROL MEASURES

### 3.4.1 Displacement Dikes

Displacement dikes are planned to be constructed as early as 2015 for all of the alternatives, if the inflows to the Sea decrease to 1.06 MAFY or less. The purpose of the displacement dikes is to eliminate additional surface area from the Sea to reduce the evaporative losses, and maintain Sea elevations near target goals. Essentially, they would reduce the inflows needed to maintain a given Sea elevation. The displacement dikes, as currently planned, would reduce the surface area of the Sea by 13,500 acres.

The dikes would separate the Sea from areas that are currently within the Sea and would be constructed similar to the deep in-Sea ponds (See Section 3.1.1). The dikes are also designed for a maximum height of 35 feet and a crest width of 30 feet at elevation –220 feet, with side slopes of 3½:1. Approximately 14,500,000 $yd^3$ of borrow material will be required to construct the dikes.

As currently proposed, it is planned to let the area enclosed by the dikes dry up. The dikes would then be reinforced by buttressing the dike on the dry side with additional borrow materials. Materials would be placed to increase the crest width to 40 feet and flatten the side slope to an inclination of 4:1. The estimated cost of the displacement dike is $460 million. Another $76 million would be required to place the buttressing berm.

Many of the considerations previously discussed regarding the deep in-Sea ponds are also applicable for the displacement dikes. Specifically:

- It will be important to investigate the depth of soft materials beneath the dike alignments.
- The dikes will need to be constructed with a final side slope of about 3 ½:1, which is flatter than the angle of repose.
- The heights of the dikes should be minimized.
- Allowing the area within the dikes to dry out will create a large hydraulic head across the dike; jeopardizing the stability of the dike.
- The proposed strengthening of the dike would be difficult and risky to construct and may require substantially more material than currently planned. The cost for the strengthening is not currently included in the summarized costs.
- Consideration should be given to using the area within the diked-off area as solar evaporation ponds and final disposal ponds for bittern. This will also help to buttress and stabilize the dikes.

The major consequences of dike failure, under the current design, would be flooding of the area behind the dikes with a subsequent lowering of the Sea' s elevation. Significant funds (possibly many millions of dollars) and possibly several years of time would then be required to repair the dikes and to dry out the area or pump the water back into the Sea.

As an alternative to the displacement dikes, consideration should be given to reclaiming part of the Sea with dredged materials. This would eliminate concerns about the large differential head across the dikes and the consequences of a potential dike failure. The reclamation could be positioned along existing contours such that when the Sea level drops, the top of the reclamation fills would be exposed, reducing the Sea's surface area. This is shown schematically in Figure 3–5 (above the Sea floor) of 30 feet. A 17-mile barrier would cost approximately $835 million.

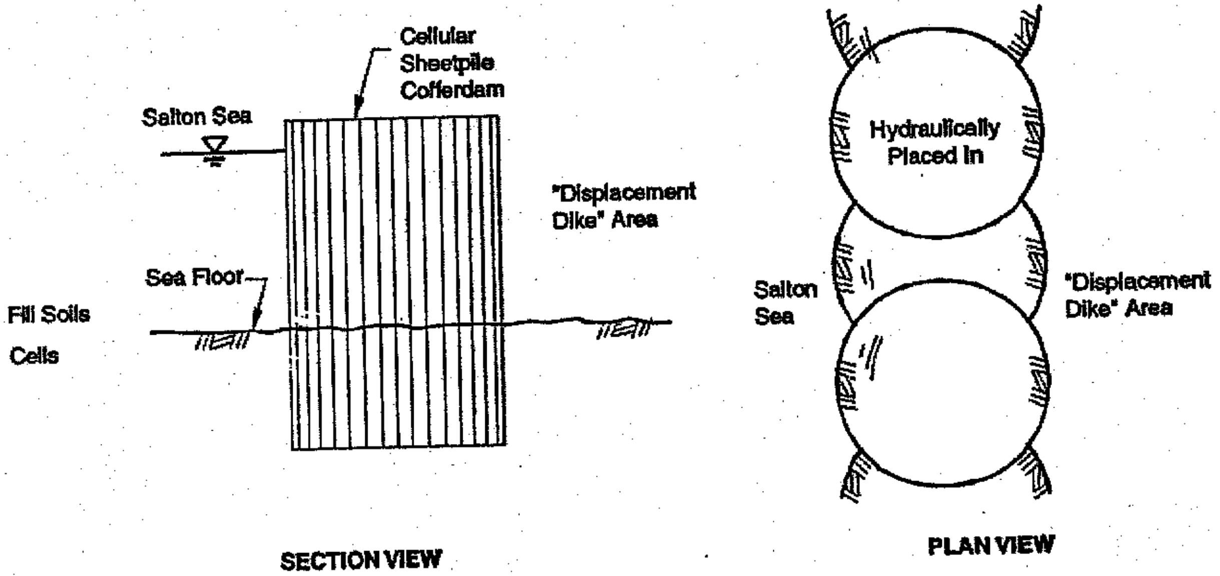

Figure 3–6 – Cellular Sheet Pile Coffer Dam

*CONCLUSIONS*

The displacement dikes as currently planned are expensive and subject to seismic damage or failure because of the high differential head across the dikes and because the foundation under the dikes may liquefy. Alternative ways of removing surface area from the Sea with a lower risk of dike damage or failure due to earthquakes should be evaluated. Specifically, the possible use of lower dikes, constructed to create evaporation ponds and to displace surface area, should be evaluated.

In addition, dredging material from the Sea and filling shallow areas near the shore should be evaluated as a means of removing surface area from the Sea. The reclaimed area could potentially be used for recreational uses but also should receive serious consideration for siting of evaporation ponds.

### 3.4.2 Replacement Inflows

Several replacement inflow sources to the Sea were previously identified to replace or supplement future agricultural drainage inflow reductions from 1.363 to 0.8 MAFY and to replace water withdrawals/exports of up to 150,000 AFY needed to remove salt from the Sea. For example, a total Sea inflow of about 1.3 MAFY is required to balance evaporation, without any in-Sea evaporation ponds or displacement dikes, if the Sea is at an elevation of –232 feet.

### 3.4.2.1 Colorado River Flood Flows

Colorado River flood flows are defined as water releases available from the Colorado River above and beyond scheduled water user needs and obligated releases to Mexico. Normally, the Bureau makes flood flow releases in September through December to make room for anticipated runoff. The variability and predictability of future Colorado River runoff depends on weather patterns. Flood flows are dependent on runoff and water user needs and are thus uncertain.

The Bureau of Reclamation developed a model to predict future Colorado River flood flow releases based on historical Colorado River runoff and future anticipated scheduled deliveries to Colorado River users and obligated releases to Mexico. Based on that model, some flood flows would be available in nearly 20 percent of the years between 2010 and 2040. Flood flow water releases are likely to be less in 2040 than in 2010 and will continue to decrease after 2040, because the Upper State users will require more water. Average annual releases ranged from 1.1-million AFY in the near future to 300,000 AFY in later years. The probability of flood flow releases ranged from 20 percent in the near future to 15 percent in the further out years.

Flood flow releases of up to 1,250 cubic feet per second can be delivered (during the months of September to December) through the existing Coachella and/or All-American Canals and the dumped into the Alamo River for delivery to the Salton Sea. This is equivalent to about 300,000 AFY. About $10 million of improvements to the Alamo River would be required.

#### CONCLUSIONS

Up to 300,000 AFY of Colorado River flood flow releases can be delivered to the Salton Sea when available. These flood flow releases were assumed to have a salinity of 800 mg/l by the Bureau of Reclamation. Introduction of flood flows into the Salton Sea can assist in stabilizing the elevation of the Salton Sea. In addition, because the salinity is relatively low, slightly less salt would have to be removed to maintain salinity goals. Flood flows of 300,000 AF contain only 0.325 million tons of salt.

Efforts should be made to ensure that up to 300,000 AFY of Colorado River flood flow releases would be made available for the Salton Sea in years when flood flows are available. In addition, provisions should be made to optimize the use of these flows when they are available. That may include construction of improvements to permit delivery of larger quantities of flood flow releases or storage of peak flood flow releases for later delivery or increasing the proposed operating range of the Sea.

### 3.4.2.2 Central Arizona Salinity Interceptor Water

Central Arizona Salinity Interceptor (CASI) is a proposed treatment plant and pipeline that Tucson and Phoenix are considering building to reduce the salinity of Colorado River water before delivery to their domestic customers. About 300,000 AFY of brine with a salinity of about 4,500 mg/l would be discharged from the proposed treatment plant to the Gulf of California. Since this brine would be considerably less saline than Salton Sea water it could be delivered to the Salton Sea, instead of the Gulf of California, to help reduce the salinity of the Salton Sea and to stabilize its elevation.

About 2 miles of large diameter pipeline, 39 miles of open channel, and some channel modifications to the Alamo River would be required to deliver the water to the Salton Sea. Four power plants would be constructed to recover energy along the canal. The Bureau of Reclamation estimated the construction cost for this concept at $83 million. The present value of the annual OM&R ($0.7 million) and energy (–$2.3 million) for 30 years is –$29 million (power sales more than offset other annual costs); thus the total present value of this concept is $54 million.

#### CONCLUSIONS

CASI is a potentially a very cost-effective way of obtaining replacement water for the Salton Sea. It has the potential to be a firm supply of inflow water. However, at this point, there is no certainty that CASI will be implemented. A commitment to use the brine for the Salt Sea Restoration Project might ensure completion of the CASI project because discharging the brine to the Gulf of California may not be feasible. Discussions with the cities of Phoenix and Tucson should take place regarding the timing of the CASI project and the mutual benefits that may be achieved if the CASI project is implemented.

### 3.4.2.3 Reclaimed Wastewater

Another source of replacement water is reclaimed wastewater. The closest source with a significant quantity of water is the Point Loma Wastewater Treatment Plant in San Diego. The salinity is 1,750 mg/l which makes it suitable for reducing the salinity and assisting in stabilizing the elevation of the Salton Sea.

About 86 miles of large diameter pipeline and 21.5 miles of tunnel and four pumping stations would be required to pump the water from the wastewater treatment plant to the Salton Sea. Three power plants would be constructed to recover energy. Additional treatment would be required to remove nutrients from the wastewater to prevent excessive algal growths and resultant problems from occurring in the Salton Sea.

The Bureau of Reclamation estimated the construction cost for this concept at $1.3 billion. The net present value of the annual OM&R ($41.6 million) and energy ($6.6 million) for 30 years is $690 million; thus the total present value of this concept is $1.99 billion.

#### *CONCLUSIONS*

This concept is not a cost-effective way to reduce Salton Sea salinity. The acquisition of right-of-way for long large-diameter pipelines between San Diego and the Salton Sea would also be challenging, but not impossible task, which might increase the concept's cost. No further evaluation of this concept is warranted or necessary at this time. If CASI water does not become available in the future, this concept should be reconsidered.

### 3.4.3 Fallowing (New Concept; Not In Draft EIS/EIR)

The Parsons Team has identified fallowing as a concept to maintain inflows when water is transferred to San Diego or some other entity. This concept should be evaluated in more detail prior to contracting for or constructing improvements to deliver replacement or supplemental water to the Sea. Fallowing has the potential to reduce the costs associated with stabilizing the Sea's elevation and reducing and maintaining salinity levels.

Currently, the Imperial Irrigation District (IID) and the Coachella Valley Water District (CVWD) deliver about 3 MAFY of water to Imperial County and Riverside County farmlands. Different crops consume different rates of water. An average of more than 3 AF per acre is consumed by Imperial County farmlands. However, a greater quantity of water is applied in order to:

- Convey the water to the crop plants.
- Flush dissolved salts past the root zone.

Thus some water runs off (tail water) and is collected via drainage ditches and other water is collected in tiles (tile water) below the plants. This collected water currently flows through a series of drainage ditches and streams (rivers) to the Salton Sea. More than 90 percent of the 1.363 MAFY flowing into the Sea is agricultural drainage water delivered by the IID and the CVWD to farmlands in Imperial County and Riverside County. Most of the remaining inflows originate from Mexico.

Table 3–3 shows a hypothetical example comparing how water is used now on a 100-acre parcel of land, after applying conservation, and when 25 percent of the land is fallowed. In Table 3–3, we assumed a base case (now) with ¾ (450 AF) of the water applied to the land soaking into the ground and ¼ (150 AF) of the water applied flowing into the Sea as tail water. Of the 450 AF soaking into the land, we assumed the plants consumed 400 AF and 50 AF flows into the Sea as tile water. The actual amount of water applied and consumed will vary with type of crop, soil, and other factors. The column headed "Conservation" assumes all of the tail water is recycled onto the land and water saved (150 AF) is available for transfer. As a result, only the tile water flows into the Sea. The quantity flowing into the Sea is reduced from 200 AF to 50 AF and salinity of the inflow is very high. For "Fallowing," we make the same 150 AF available for transfer by removing ¼ of the land from production. The remaining farms function as in the "Now" case. Inflow to the sea is reduced from 200 AF to 150 AF and the quality of the inflow is unchanged. Many different scenarios can be analyzed. The actual amount of water going to the Sea could be more or less than the 150 AF in Table 3–3.

**Table 3–3 – Conservation versus Fallowing**

| No. | Items | Now | Conservation | Fallowing |
|---|---|---|---|---|
| | Acres Farmed | 100 | 100 | 75 |
| | | Acre Feet of Water | | |
| 1 | Water Budget | 600 | 600 | 600 |
| 2 | Water Applied | 600 | 450 | 450 |
| 3 | Water Consumed | 400 | 400 | 300 |
| 4 | Tail Water | 150 | 0 | 112.5 |
| 5 | Tile Water | 50 | 50 | 37.5 |
| 4 + 5 | To Sea | 200 | 50 | 150 |
| 1 - 2 | San Diego/MWD | 0 | 150 | 150 |

Based on the example, if 100,000 AF were transferred, approximately 16,670 acres (26 square miles) of land would have to be fallowed. The net reduction on Sea inflows would be 25,000 AF for every 100,000 AF transferred based on the above hypothetical example. The actual amount of land fallowed, the amount of water available for transfer, and the reduction in Sea inflows would depend on the type of crops grown and the type of land fallowed.

The drainage salt load entering the Sea is assumed to be equal to the salt load of the applied Colorado River water. Therefore, both conservation and fallowing would reduce the salt load entering the Sea. Because inflows would be lower with conservation than with fallowing, the salinity of the inflows with conservation would be higher. The potential use of fallowing as a source of water for the Sea should be analyzed further to determine the likely institutional and environmental barriers and tradeoffs.

Some of the fallowed land could be used for shallow concentration ponds, final disposal sites for dry salt and/or bittern, or converted to hunting preserves.

### *CONCLUSIONS*

Fallowing should be evaluated further as a means of maintaining or supplementing future Salton Sea inflows. The legal and water rights issues associated with using water obtained by fallowing to supplement the Sea inflows need to be carefully considered. Fallowing may be a cost-effective way of obtaining water for the Sea until CASI water becomes available or if CASI water does not become available. Fallowing can provide a more reliable supply than future Colorado River flood flows.

# SECTION 4

# ANALYSIS OF AND SUGGESTED REFINEMENTS TO PHASE 1 ALTERNATIVES

The Phase 1 Alternatives were developed to reduce the elevation and control the salinity of the Salton Sea. The salinity of the Salton Sea is increasing each year, because of the inflowing salt load, which is about 5.1-million tons per year. The elevation of the Sea has also been slowly rising because inflows to the Sea slightly exceed evaporation from the Sea's surface. The increased elevation has flooded commercial development and agricultural lands near the Sea. The increasing salinity will eventually cause fish in the Sea to stop reproducing and may affect birds and wildlife that reside at or visit the Sea.

The Salton Sea Science Subcommittee involved with monitoring the Sea established salinity goals of 35 to 40 parts per thousand (ppt) and elevation goals of –230 to –235 feet. The task of trying to reduce and control the Sea's salinity and stabilize its elevation is very complex, but is further complicated by uncertainties relating to future Sea inflows and the variability and salinity of that inflow. The current inflow to the Sea averages about 1.36 million acre-foot per year (MAFY) and consists primarily of runoff from irrigated agricultural lands. In the future that inflow is assumed to decline by 10 thousand acre-foot per year (TAFY) to as low as 0.8 MAFY by the year 2055.

The Phase 1 Alternatives described in detail in the Draft EIS/EIR and the January 2000 Draft Alternatives Appraisal Report were developed in response to the above goals and the anticipated reduction in inflows to the Sea.

Each of the alternatives includes an in-Sea displacement dike and/or one or more in-Sea concentration ponds (that also act as displacement facilities) to reduce the inflows needed to balance Sea evaporation. Each of the alternatives also includes an evaporation system [ponds and/or an Enhanced Evaporation System (EES)] that allows water to be removed from the Sea and evaporated away, thus leaving salts behind. In addition, the alternatives include a general disposal strategy for the salt and concentrated brine (bittern).

The following discussion provides a brief understanding of the chemical properties of Salton Sea water and some of the key issues involved in attempting to remove and dispose of salt from the Sea and to control the Sea's elevation. This background information also sets the scene for a limited cost-effective analysis and leads to suggesting certain refinements or changes to the alternatives to make them more effective in meeting the elevation and salinity goals and/or more cost-effective.

## 4.1 CHEMICAL PROPERTIES OF SALTON SEA WATER AND ITS EFFECT ON SALT REMOVAL

The chemical properties of Salton Sea water are similar to Ocean water. Thus removing salt from Sea water can be accomplished in a manner similar to that used to make commercial salt from Ocean water. Because there is no apparent market for salt from the Salton Sea, the process can be simplified because it is not necessary to obtain pure salt. Additional information is needed to predict with more certainty the evaporation rate for the Sea water, the brine concentration point at which salt begins to crystallize, the density of solid phase (dry) salt produced, and whether the concentrated brine will evaporate to dryness. Test ponds should be operated at the Salton Sea to obtain evaporation rate, salt density information, and concentrated brine characteristics. Soil percolation data is also needed for designing the onshore evaporation ponds.

Mr. John A. Pyles, a retired Cargill Salt employee with more than 20 years of salt making experience, was retained by Parsons to analyze the chemical properties of Salton Sea water and to develop a hypothetical design for removing salt with shallow solar evaporation ponds. Mr. Pyles also reviewed the "single" deep concentration (solar evaporation) pond and salt disposal (crystallizer) concept (Alternative 1) described in the Draft EIS/EIR and other salt removal (EES) and disposal concepts. Mr. Pyles performed his work without the benefit of test ponds, evaporation rate, and soil percolation information. After test ponds are operated at the Salton Sea and evaporation rate and soil percolation data is obtained, the size of various salt removal and disposal facilities can be refined.

More detail about removal and disposal of salt from the Salton Sea and the chemical properties of Salton Sea water is contained in Sections 3.1, 3.2, and 3.3.

## 4.2 EFFECTS OF DISPLACEMENT DIKES AND IN-SEA EVAPORATION PONDS

Displacement dikes can be used to reduce the surface area and volume of the Sea. A displacement dike removes surface area from the Sea thus reducing evaporation and reduces the volume of the Sea, but it does not remove any salt from the Sea.

Evaporation ponds formed by dikes in the Sea will trap a portion of the Sea volume with its associated salt load, and reduce the surface area and volume of the main Sea. The north and south in-Sea ponds, as proposed in Alternative 1, would convert a portion of Sea into a salt removal and disposal facility and would reduce the quantity of inflow water needed to maintain a given Sea elevation.

Table 4–1 shows the surface areas of the Sea, the north and south ponds, and the area removed from the Sea by the displacement dike for several water surface elevations.

**Table 4–1 – Surface Areas**

| Elevation (Feet) | Main Sea (Acres) | South Pond (Acres) | North Pond (Acres) | Displacement Area (Acres) |
|---|---|---|---|---|
| –227 feet | 234,113 | 14,383 | 6,524 | 15,386 |
| –232 feet | 223,734 | 12,689 | 5,053 | 11,587 |
| –237 feet | 211,809 | 9,834 | 3,473 | 8,917 |

Table 4–2 shows the relationship between the existing Sea inflow required to maintain a given elevation, and the reduced inflow needed to maintain the Sea's elevation if it is lowered from –227 feet. Lowering the elevation of the Sea from the current elevation of –227 feet to the target elevation of –232 feet will reduce the inflow required to maintain the Sea's elevation by 60 TAFY. This is more than 4 percent of the current inflow of 1,358 TAFY that balances the evaporation at the current elevation of –227 feet. Reducing the elevation by another five feet to –237 feet would reduce the necessary inflow by 130 TAFY (about 10 percent of current inflow). The pond and displacement dike effectiveness at reducing the necessary inflow is proportional to the area.

**Table 4–2 – Existing Sea**

| Elevation (Feet) | Main Sea (Acres) | Evaporation Loss/Inflow Required (TAFY) | Reduced Inflow (TAFY) |
|---|---|---|---|
| –227 | 234,113 | 1,358 | – |
| –232 | 223,734 | 1,298 | 60 |
| –237 | 211,809 | 1,228 | 130 |

Table 4–3 shows the reduced area of the Sea assuming the north and south pond and the displacement dike are constructed, and the evaporation loss from the Sea assuming 5.8 feet per year, and the inflow required to maintain the Sea at a given elevation (which is the same as the corresponding reduction in inflow necessary to stabilize the Sea at the same elevations). The ponds and displacement dikes contribution for reducing the inflow needed to maintain the Sea's elevation decreases from 211 TAFY to 128 TAFY, as the elevation of the Sea falls but the reduced evaporation due to the lower elevation (from Table 4–2) increases from 0 to 130 TAFY. This results in a net increase from 211 to 268 TAFY

**Table 4–3 – Modified Sea**

| Elev. (Feet) | Main Sea (Acres) | Evaporation Loss or Inflow Required (TAFY) | | Reduced Inflow Required (TAFY) | | |
|---|---|---|---|---|---|---|
| | | Existing Sea | Modified Sea | Disp. Effect | Elev. Decr. | Total |
| –227 | 197,820 | 1,358 | 1,147 | 211 | 0 | 211 |
| –232 | 194,725 | 1,298 | 1,129 | 169 | 60 | 229 |
| –237 | 189,585 | 1,228 | 1,100 | 128 | 130 | 268 |

The evaporation value of the north and south ponds and the potential evaporation value of the displacement dike area, if used for evaporating Sea water, is shown in Table 4–4. The values represent the initial evaporation rate. These rates would decrease over time if the ponds are operated as single ponds rather than as the first pond in a series of ponds or the initial pond before water is transferred to an EES for further evaporation.

**Table 4-4 – Evaporation from Sea and Ponds for 5.8 foot/year Evaporation Rate**

| Elevation (Feet) | Main Sea (TAFY) | South Pond (TAFY) | North Pond (TAFY) | Displacement Area (TAFY) |
|---|---|---|---|---|
| –227 | 1,358 | 83 | 38 | 89 |
| –232 | 1,298 | 74 | 29 | 67 |
| –237 | 1,228 | 57 | 20 | 52 |

Evaporation ponds formed by dikes in the Sea are included in some Phase 1 alternatives. These ponds trap a portion of the Sea volume with its associated salt load and reduce the surface area and volume of the main Sea. The ponds essentially use a portion of the Sea's surface area and volume to evaporate Sea water and concentrate the salt content of that water.

Displacement dikes are used in all of the reduced inflow alternatives to reduce the surface area (and volume) of the Sea. If the area behind the displacement dike were dry, evaporation from the Sea would be reduced thereby assisting in meeting elevation goals. If these displacement dike areas are also used to remove or assist in salt removal, they will still reduce the amount of inflow needed to maintain a certain Sea elevation.

The specific role of the north and south ponds and the displacement dike areas is discussed in Sections 4.5 and 4.6.

## 4.3 SEISMICITY

The proposed construction methods, proposed function(s), and operation of the in-Sea dikes (for the evaporation ponds and displacement purposes) creates an unsatisfactory risk from a seismic perspective. These risks can be mitigated if the pond and displacement dikes are designed and constructed so they will withstand the large seismic forces expected to occur at the Salton Sea over the life of the dikes. As an alternative, the dikes can be operated with a small differential head (water depth on one side of the dike is approximately the same as on the other side) to reduce the potential for damage from a seismic event. The differential head should not exceed one to two feet.

Constructing dikes in the Sea with a lower probability of failure is costly. Vibratory densification could be employed after the dike fill is placed or cofferdams could be used to separate the Sea from the displacement areas.

Section 3.1.1 contains additional information on the type of failure that is likely and the potential consequences of such a failure. Section 3.1.1 also provides a suggested operational change that would reduce the potential for breach of the dikes and the consequences of dike damage. A comparison of the evaporative capacity and useful life of operating the ponds as concentration and disposal ponds at an elevation of –227 with a maximum differential head of about 5 feet and at a smaller differential head (maximum of 0.5 feet) is also contained in Section 3.1.1. Allowing gravity inflow to the ponds will reduce the hydrostatic loading and lessen the consequence of seismic damage or failure. If the ponds are operated in the manner described above, the risks of failure and the resultant consequences should be acceptable.

## 4.4 ENHANCED EVAPORATION SYSTEMS (EES)

Use of an EES at the Salton Sea for removal of salt shows considerable promise, primarily because the amount of area required is considerably less than for solar evaporation ponds. In addition, an ESS can be constructed in phases more readily than a solar evaporation pond system. It can be expanded or modified to react to changing conditions because the land requirements are less and the system can be installed more readily on land with somewhat steeper (greater than 2 to 3 feet per mile) slopes. However, the evaporation rates, and thus the construction costs, and annual operation, maintenance, and replacement and energy costs assumed for the EES are based on vendor claims for evaporating water with much different characteristics than Salton Sea water. The commercial salt industry has not used an EES to make salt, because solar evaporation ponds are less costly.

Extensive testing needs to be performed at the Salton Sea to develop realistic area requirements and operating costs before planning to implement a large scale EES. The area requirements for an EES could increase or decrease significantly. Prior to full-scale testing of EES facilities, the potential availability of land for solar evaporation ponds should be fully evaluated. The construction and annual costs could also be much different than those assumed.

## 4.5 EVALUATION OF PHASE 1 ALTERNATIVES

Table 4–5 and Figure 4-1 provide an overview of the Draft EIS/EIR alternatives and the actions associated with each alternative. Sections 4.5.1 through 4.5.2 provides more detail about the salt removal and disposal facilities and elevation control facilities that are to be constructed up through the year 2030 for each alternative. For purposes of the net present value analysis, some adjustments were made to Alternatives 1 and 5 to ensure that all five alternatives would function effectively though the year 2030.

## Table 4-5 – Summary of Salton Sea Restoration Project Alternative Actions[1]

| Inflow (MAFY) | Phase 1 (Before 2030) | | | Phase 2 (2030 and beyond) | |
|---|---|---|---|---|---|
| | 2003 | 2008 | 2015 | 2030 | 2060 |
| **Alternative 1** | | | | | |
| 1.36 | Fish Harvesting<br>Improve Rec. Facilities<br>Shoreline Cleanup<br>Wildlife Disease Control<br>North Wetland Habitat | 2 Ponds at 98 kaf/yr. Pupfish Pond | Accelerated Export – 150 KAF/yr.[2] | – | – |
| 1.06 | Same as above | Same as above | Same as above, plus Displacement Dike | Import Central Arizona Salinity Interceptor (CASI) Water (up to 304.8 KAF/yr., as required) | – |
| 0.80 | Same as above | Same as above | Same as above | Same as above, plus Import Flood Flows | – |
| **Alternatives 2 and 3** | | | | | |
| 1.36 | Fish Harvesting<br>Improve Rec. Facilities<br>Shoreline Cleanup<br>Wildlife Disease Control<br>North Wetland Habitat | 150 KAF/yr. EES (shower- line technology) | – | – | – |
| 1.06 | Same as above | Same as above | Displacement Dike<br>Import Flood Flows | Import CASI Water (up to 304.8 KAF/yr., as required) | – |
| 0.80 | Same as above | Same as above | Same as above | Same as above | Additional Displacement or Inflow |
| **Alternative 4** | | | | | |
| 1.36 | Fish Harvesting<br>Improve Rec. Facilities<br>Shoreline Cleanup<br>Wildlife Disease Control<br>North Wetland Habitat | 100 KAF/yr. EES<br>1 Evaporation Pond (S) at 68 KAF/yr.<br>Pupfish Pond | – | Increase EES Capacity to 150 KAF/yr. | – |
| 1.06 | Same as above | Same as above | Displacement Dike<br>Import Flood Flows | Same as above, plus Import CASI Water (up to 304.8 KAF/yr., as required)<br>Reduce EES at 100 KAF/yr. | – |
| 0.80 | Same as above | Same as above | Same as above | Same as above | – |
| **Alternative 5** | | | | | |
| 1.36 | Fish Harvesting<br>Improve Rec. Facilities<br>Shoreline Cleanup<br>Wildlife Disease Control<br>North Wetland Habitat | 100 KAF/yr. EES in Sea Evaporation Pond (N) | – | Export – 150 KAF/yr. | – |
| 1.06 | Same as above | Same as above | Displacement Dike<br>Import Flood Flows | Import CASI Water (up to 304.8 KAF/yr., as required) | – |
| 0.80 | Same as above | Same as above | Same as above | Same as above | Additional Displacement or Inflow |

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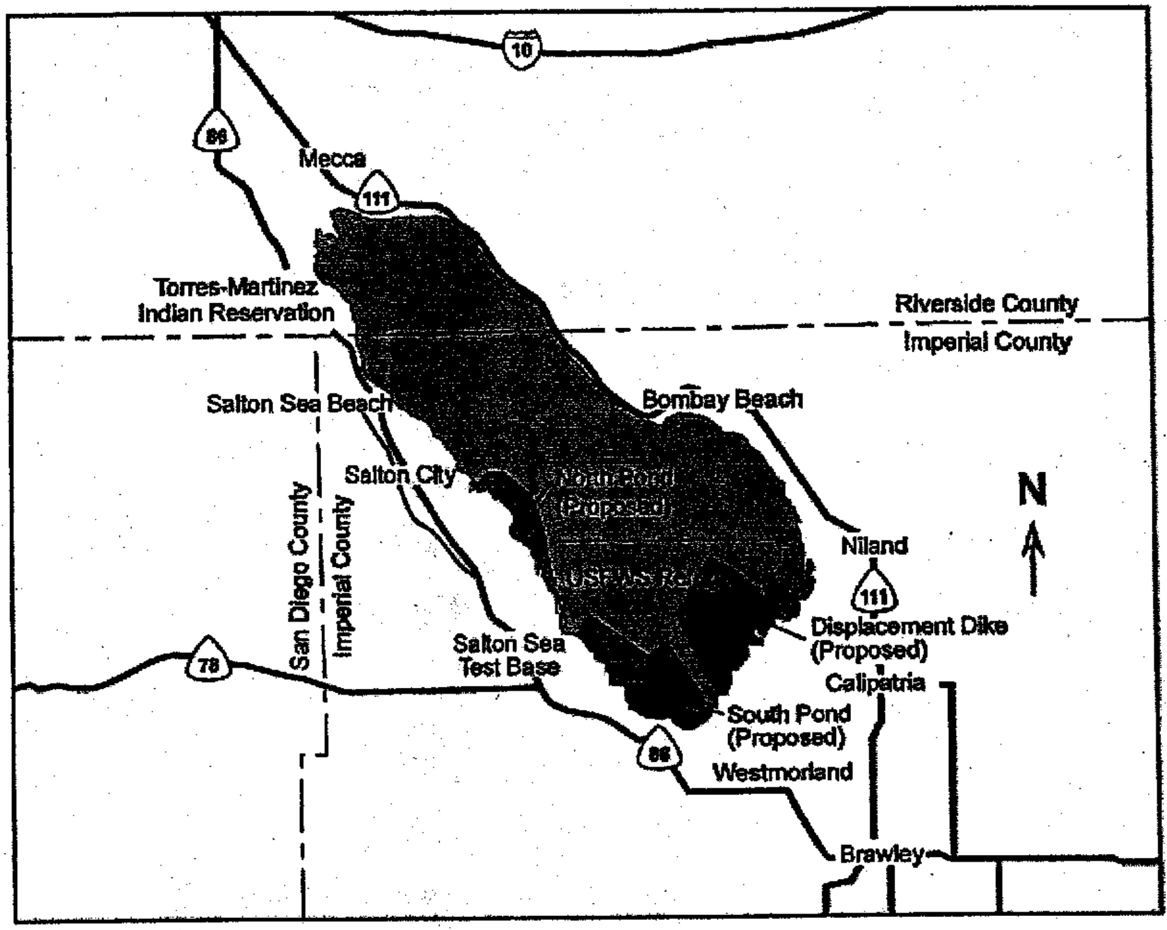
[1] Draft EIS/EIR Salton Sea Restoration Project, January 2000

[2] Accelerated export implemented as a Phase 2 action.



Projects/202188 Salton Sea/SSO

Figure 4–1 – Salton Sea Overview

## 4.5.1 Description of Alternatives

### *4.5.1.1 Alternative 1 – Two In-Sea Concentration Ponds*

This alternative consists of two in-Sea deep concentration ponds (referred to as the north and south ponds) and a displacement dike. The ponds would be placed in service in 2008 and the displacement dike would be placed in service in 2015 for the reduced inflow scenarios. An EES or some other export (salt removal) system would also be needed in 2015. Sea water would be pumped into the concentration ponds where it would evaporate and form salt. The salt would remain in the ponds. The ponds were assumed to operate at an elevation of –227 feet and were expected to have a 30-year life. Initially, the evaporation rate from the ponds would be about 120 TAFY. The Bureau of Reclamation projected that the evaporation rate would decrease to about 98 TAFY after about seven years and remain constant for the reminder of the 30-year operative period.

Our analysis indicates that the evaporation rate would decrease to about 105 TAFY after about eight years and continue to decrease to about 94 TAFY after about 13 years when the salinity in the ponds reached 309 ppt. At that point, the evaporation rate would continue to decrease, as the evaporation surface area became smaller due to salt deposits on the sides of the ponds. The rate of further reduction cannot be readily quantified. The difference in the anticipated evaporation rates between the Bureau's and our analysis is not believed to be significant up to the year 2030, but it would become significant beyond that if the ponds were to continue to be operated as described under this alternative. If constructed, we recommend using and operating the north and south ponds much differently to extend their useful life and to reduce seismic risk (see Section 4.3).

Alternative 1 is assumed to require a 150 TAFY export facility around the year 2015. That is a reasonable assumption. Therefore, for purposes of the net present value comparison, we added costs for the EES from Alternative 6.

#### 4.5.1.2 Alternative 2 – Shower-Line EES near Bombay Beach

This alternative consists of a 150 TAFY shower-line EES near Bombay Beach and a displacement dike. The EES would be placed in service in 2008 and the displacement dike would be placed in service in 2015 for the reduced inflow scenarios. Sea water would be pumped into the EES where it would evaporate and form salt. The concentrated brine would be pumped to nearby onshore ponds for final evaporation and disposal. Pilot tests, as described in Sections 3.2.2 and 3.2.3, are needed to confirm and/or determine the area requirements and operating costs in order to refine this alternative if it is implemented.

#### 4.5.1.3 Alternative 3 – Shower-Line EES at Salton Sea Test Base

This alternative is similar to Alternative 2, except that the EES is constructed at the Salton Sea Test Base. The concentrated brine would be pumped to nearby onshore ponds for final evaporation and disposal. Pilot tests, as described in Sections 3.2.2 and 3.2.3 are needed to confirm/determine the area requirements and operating costs in order to refine this alternative if it is implemented.

### 4.5.1.4 Alternative 4 – South Concentration Pond and Shower-Line EES at Salton Sea Test Base

This alternative uses the south concentration pond to evaporate 68 TAFY of Sea water and a shower-line EES with a capacity of 100 TAFY at the Salton Sea Test Base and a displacement dike. The concentrated brine would be pumped to nearby onshore ponds for final evaporation and disposal. The concentration pond and the EES would be placed in service in 2008 and the displacement dike would be placed in service in 2015 for the reduced inflow scenarios.

The evaporation rates for this pond would initially be about 80 TAFY and would decrease as described under Alternative 1 to about 68 TAFY after about 13 years. Thereafter it would continue to decrease as salt forms on the sides of the ponds.

The EES would be expanded to a capacity of 150 TAFY in 2030 under the 1.363 MAFY inflow scenario to compensate for removal of the pond from operation. Pilot tests, as described in Sections 3.2.2 and 3.2.3, are needed to confirm and determine the area requirements and operating costs in order to refine this alternative if it is implemented.

### 4.5.1.5 Alternative 5 – Ground-based EES in In-Sea Pond

This alternative uses the north concentration pond and a ground-based 150 TAFY EES on the dike of the north pond and a displacement dike.

The concentration pond and the EES would be placed in service in 2008 and the displacement dike would be placed in service in 2015 for the reduced inflow scenarios. Sea water would be pumped into the EES where it would be sprayed into the air. Most of the water would be evaporated in the air as it falls toward the surface of the ponds. The concentrated brine would be captured in the pond where final evaporation and crystallization of salt would occur.

The volume of the north concentration pond is adequate to handle only 15 to 20 years of salt disposal. Thus, the costs of a dike at the Salton Sea Test Base was added for salt disposal purposes in the net present value analysis. Pilot tests, as described in Sections 3.2.2 and 3.2.3 are needed to confirm/determine the area requirements and operating costs in order to refine this alternative if it is implemented.

### 4.5.2 Effectiveness in Meeting Salinity and Elevation Goals

Each of the Phase 1 alternatives was previously analyzed in the January 2000 Draft Appraisal Report and the Draft EIS/EIR for effectiveness in meeting the salinity and elevation goals established by the Salton Sea Science Subcommittee (Refer to Figures 4–2, 4–3, and 4–4.). Parsons performed an independent analysis using the water and salt accounting model developed by the Bureau of Reclamation and compared the results with the analysis presented in these Figures. Each of the alternatives can achieve the basic salinity and elevation goals within 40 years. None of the alternatives begin operation until 2008; thus there is a continued increase in salinity until 2010.

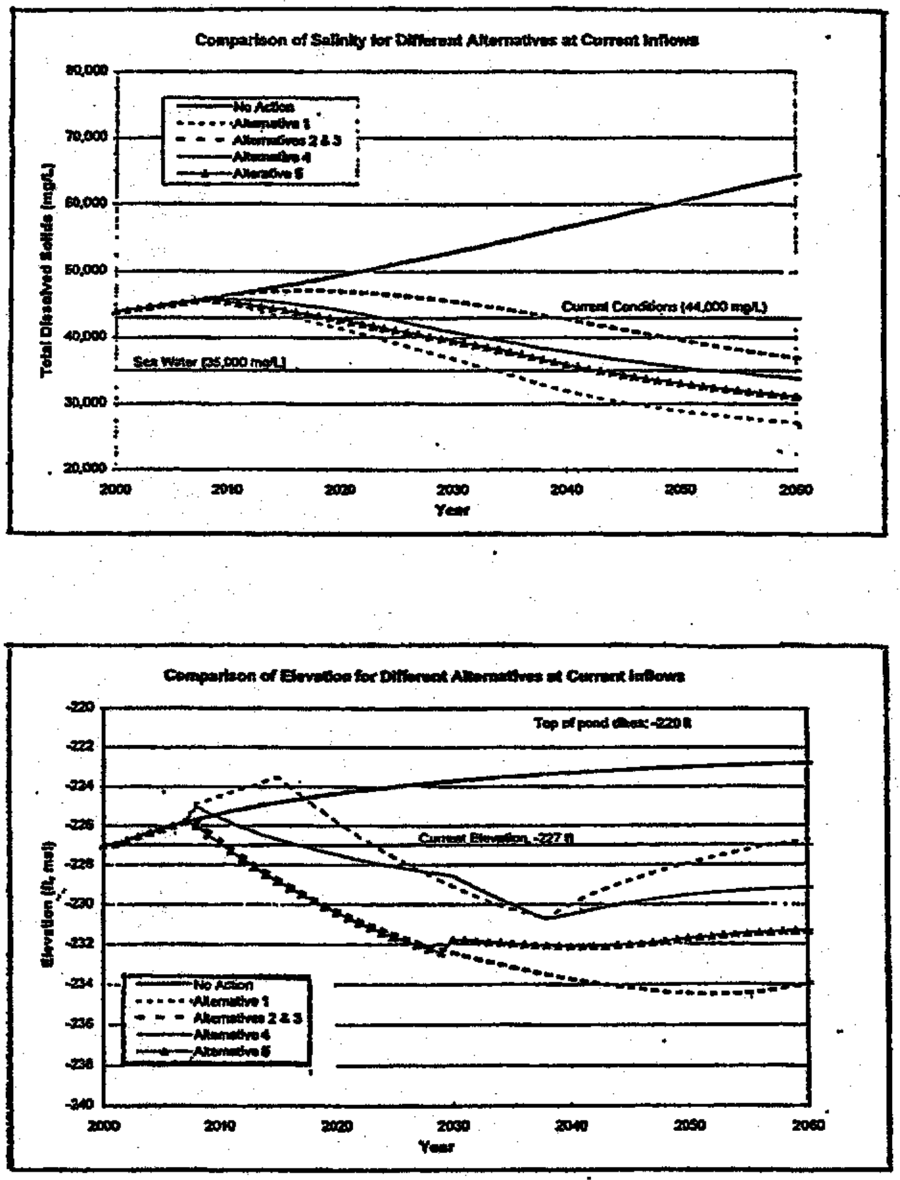
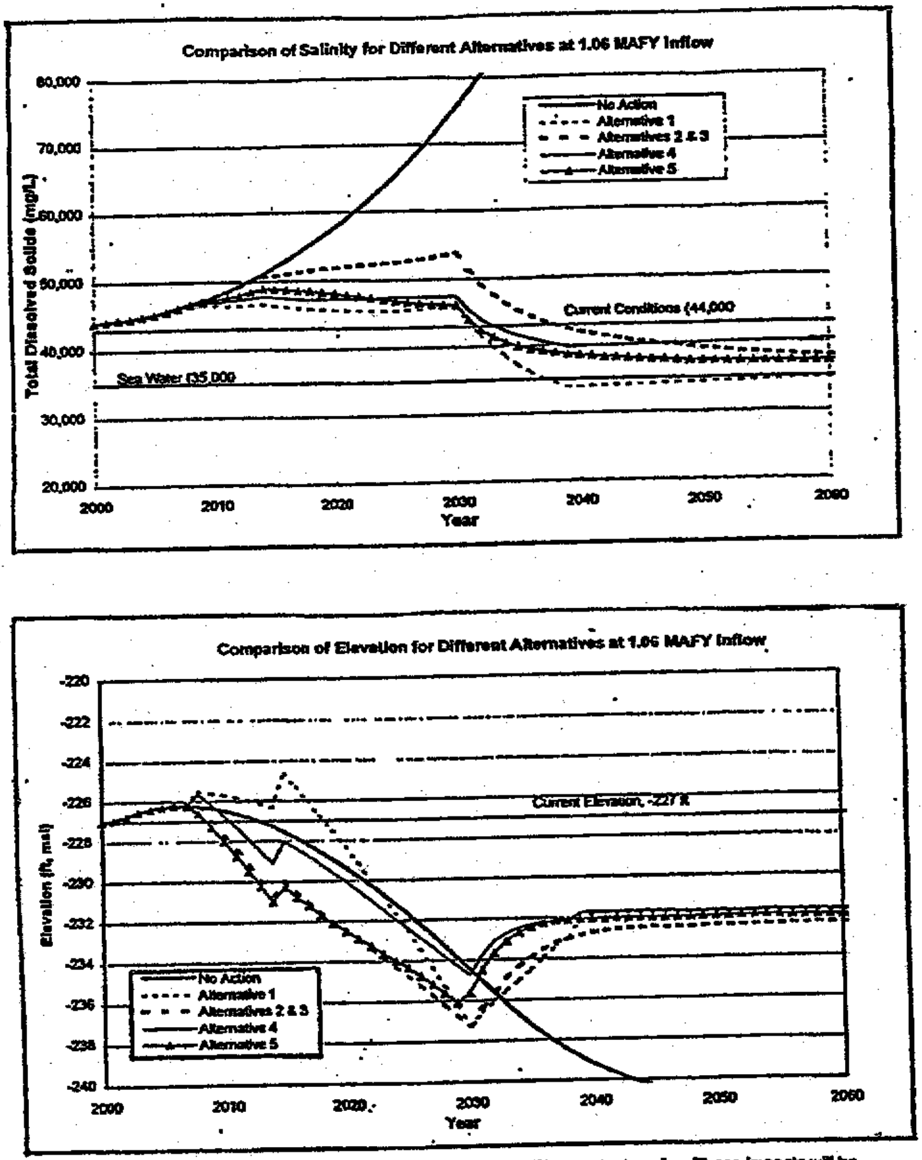


**Figure 4–2 – Projected Changes in Salinity and Elevation over Time at Current Flows**



* This model does not specifically simulate the impact of the IID/San Diego water transfer. Those impacts will be evaluated in a separate EIS/EIR and may demonstrate more or less severe salinity/elevation impacts than shown here.

**Figure 4–3 – Projected Changes in Salinity and Elevation Over Time with Inflow Reduced to 1.06 MAFY***

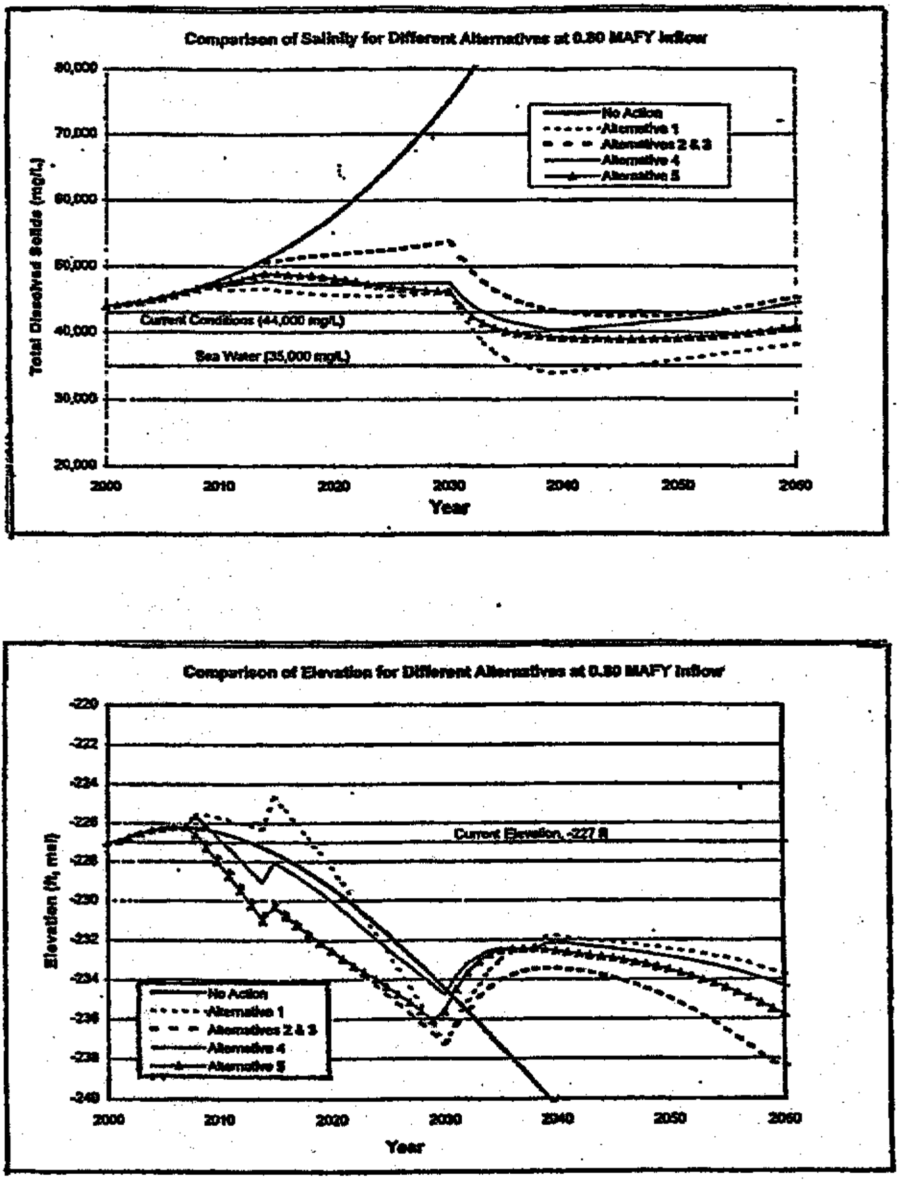


**Figure 4–4 – Projected Changes in Salinity and Elevation Over Time with Inflow Reduced to 0.80 MAFY**

The water and salinity management strategy for each of the alternatives is similar. Each alternative removes an average of 150 TAFY to 200 TAFY of water from the Sea thorough a combination of concentration ponds and water exports to an evaporation and salt removal facility during the first 25 years of operation. About 250-million tons of salt is removed from the Sea during the first 25 years of operation. About 50 percent of the salt removal lowers the salinity of the Sea, whereas the remainder removes salt contained in the annual Sea inflows. The salt removal facilities remove water and salt which lowers the salinity in the Sea. The export of Sea water, together with decreased inflows, also lowers the Sea's elevation. The timing is different for each alternative and for each sequence of future assumed inflows. The alternatives can each be operated under adaptive management principles to remove less water and salt if the Sea's elevation drops below the target. The alternatives are sized and designed to allow salt removal rates to be varied to meet salinity objectives; however, the competing elevation objective will be not be achievable after about 2050 under the 0.8 MAFY inflow scenario unless additional supplemental inflows and/or displacement facilities are provided. It should be noted that revised target goals (higher salinity and lower elevation) would potentially allow the alternatives to function without additional inflows and/or displacement facilities.

For assumed reduced future inflows, each of the alternatives, uses the potential flows available from Colorado River flood flows and from the CASI project to supplement the agricultural drainage inflows. The salt removal volumes are reduced in the future after target salinity and elevation is reached, by operating the salt export facilities at less than full capacity. The flood flows are only available in some years (i.e., about 20 percent). Some flexibility in the elevation range is needed to allow flood flows to surcharge the Sea elevation in a sequence of years when they are available.

#### CONCLUSION

Each of the alternatives can meet the elevation and salinity goals within 40 years of implementation. Additional inflows and/or displacement facilities will be needed in the future if the inflows decrease to 0.8 MAFY.

### 4.5.3 Cost Effectiveness

A net present value comparison of the alternatives was performed and is shown in Figure 4–5. The construction and annual costs used in the net present value comparison are shown in Table 4–6. These costs were adjusted from those generated by the Bureau of Reclamation to reflect additions and changes made to achieve a minimum 30-year life for each of the alternatives. All costs are based on appraisal level estimates.

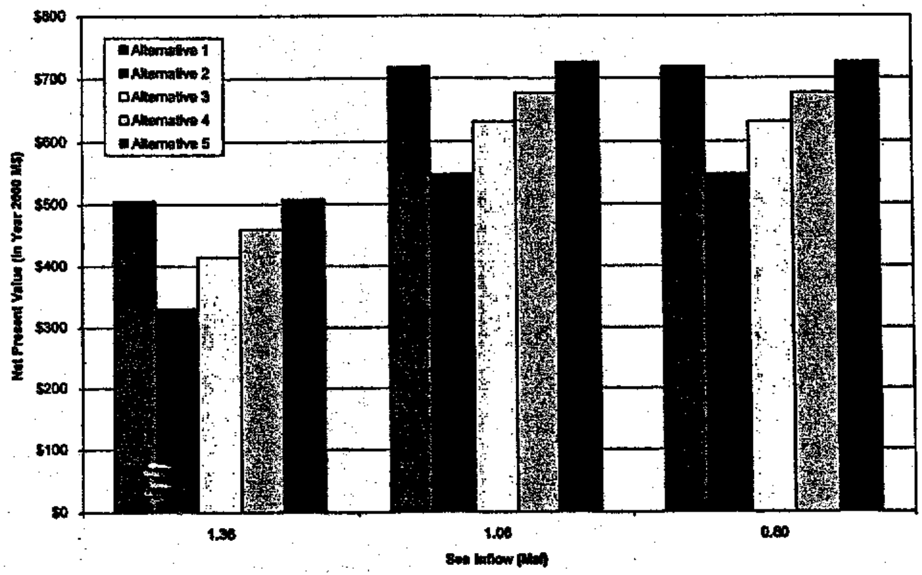


**Figure 4–5 – Net Present Value of Phase 1 Alternatives through Year 2030**[3]

## Table 4–6 – Salton Sea Restoration Project Phase 1 Alternative Costs April 24, 2000

| | 2003 | | | 2006 | | | 2015 | | | TOTAL | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total Sea Inflow (ac-ft/yr) | Const. Cost Estimate ($M) | O,M&R ($M/yr) | Cost Energy ($M/yr) | Const. Cost Estimate ($M) | O,M&R ($M/yr) | Cost Energy ($M/yr) | Const. Cost Estimate ($M) | O,M&R ($M/yr) | Cost Energy ($M/yr) | Const. Cost Estimate ($M) | O,M&R ($M/yr) | Cost Energy ($M/yr) |
| **Alt 1** | | | | 2 Concentration Ponds | | | | | | | | |
| 1.36 | 25 | 2.1 | 0.0 | 424 | 1.2 | 0.1 | 182 | 3.9 | 15.0 | 631 | 7.2 | 15.1 |
| 1.06 | 25 | 2.1 | 0.0 | 424 | 1.2 | 0.1 | 632 | 5.3 | 15.0 | 1081 | 8.6 | 15.1 |
| 0.80 | 25 | 2.1 | 0.0 | 424 | 1.2 | 0.1 | 632 | 5.3 | 15.0 | 1081 | 8.6 | 15.1 |
| **Alt 2** | | | | Borrego Beach | | | | | | | | |
| 1.36 | 25 | 2.1 | 0.0 | 286 | 8.7 | 3.0 | 0.0 | 0.0 | 0.0 | 311 | 10.7 | 3.0 |
| 1.06 | 25 | 2.1 | 0.0 | 286 | 8.7 | 3.0 | 460 | 1.4 | 0.0 | 771 | 12.1 | 3.0 |
| 0.80 | 25 | 2.1 | 0.0 | 286 | 8.7 | 3.0 | 460 | 1.4 | 0.0 | 771 | 12.1 | 3.0 |
| **Alt 3** | | | | Test Base EES | | | | | | | | |
| 1.36 | 25 | 2.1 | 0.0 | 409 | 9.1 | 3.0 | 0.0 | 0.0 | 0.0 | 434 | 11.2 | 3.0 |
| 1.06 | 25 | 2.1 | 0.0 | 409 | 9.1 | 3.0 | 460 | 1.4 | 0.0 | 894 | 12.6 | 3.0 |
| 0.80 | 25 | 2.1 | 0.0 | 409 | 9.1 | 3.0 | 460 | 1.4 | 0.0 | 894 | 12.6 | 3.0 |
| **Alt 4** | | | | EES & 1 Concentration Pond | | | | | | | | |
| 1.36 | 25 | 2.1 | 0.0 | 523 | 6.7 | 2.1 | 0.0 | 0.0 | 0.0 | 548 | 8.8 | 2.1 |
| 1.06 | 25 | 2.1 | 0.0 | 523 | 6.7 | 2.1 | 460 | 1.4 | 0.0 | 1008 | 10.2 | 2.1 |
| 0.80 | 25 | 2.1 | 0.0 | 523 | 6.7 | 2.1 | 460 | 1.4 | 0.0 | 1008 | 10.2 | 2.1 |
| **Alt 5** | | | | EES in In Sea Pond | | | | | | | | |
| 1.36 | 25 | 2.1 | 0.0 | 349 | 6.0 | 16.4 | 84 | 0.4 | 1.5 | 458 | 8.5 | 17.9 |
| 1.06 | 25 | 2.1 | 0.0 | 349 | 6.0 | 16.4 | 544 | 1.8 | 2.9 | 918 | 9.9 | 19.3 |
| 0.80 | 25 | 2.1 | 0.0 | 349 | 6.0 | 16.4 | 544 | 1.8 | 2.9 | 918 | 9.9 | 19.3 |

In general, the net present value comparison shows that the present value of the higher annual costs tends to offset lower construction costs. If a longer time frame was examined, the net present value of the high-annual cost alternatives would increase faster than the lower annual cost

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[3] The net present value is based on a 30-year life and a 5-percent interest rate and assumes that the facilities are operated at capacity after they are placed into service.

alternatives. Refined construction and annual costs should be obtained, especially for the annual cost intensive components, to perform a more rigorous net present value analysis. Some of those costs can be refined only after conducting pilot studies. Additional geological information may also allow development of better construction cost estimates.

An increase or decrease in the annual salt removal needed would increase or reduce the net present value significantly for the high-annual cost alternatives (those with an EES), but would not affect the net present value of the low annual cost alternatives as much. This also reinforces the need to refine the annual costs for the alternatives.

The salinities of the source waters that could be used to replace Sea inflows or reduce the inflows needed to maintain the Sea's elevation was also reviewed. The salinities of those source waters vary from about 800 mg/l to 35,000 mg/l (See Figure 4-6). The salinity of the Sea would increase unless the salt load in the Sea's inflow sources is removed. It is not cost-effective to reduce the salinity of the source waters below that shown in Figure 4-6, thus it is assumed that salt will be removed from the Sea by evaporation or export of Sea water. That reduces the net amount of water delivered to the Sea from a given source (See Figure 4-7). In essence, that means that more water must be delivered to the Sea to achieve a net delivery. Figure 4-8 shows the total deliveries for a net delivery of 100 TAFY. It should be noted that nearly 1.5 MAFY of ocean water would need to be delivered to the Sea and nearly 1.4 MAFY would have to be exported or evaporated to achieve a net delivery of 100 TAFY.

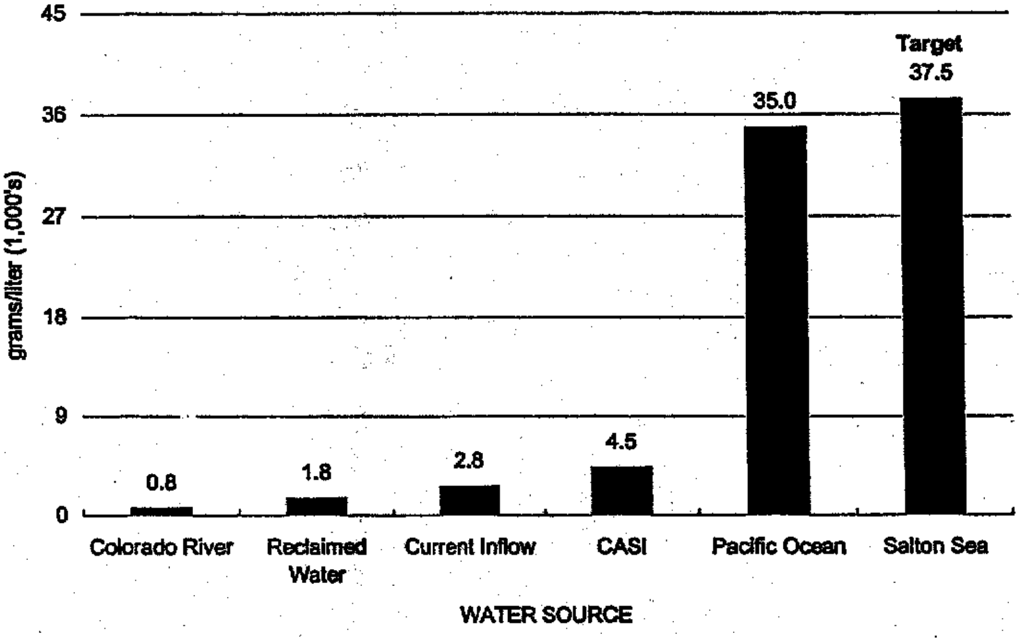

**Figure 4–6 – Salinity of Source Waters**

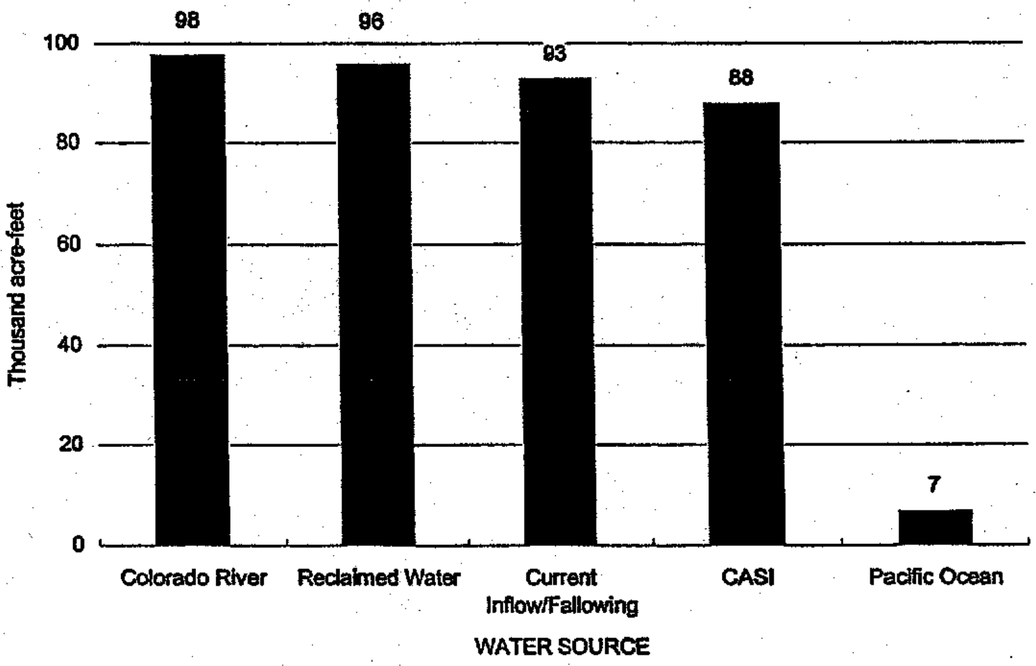

**Figure 4–7 – Net Inflows from 100 TAF of Imported Water**

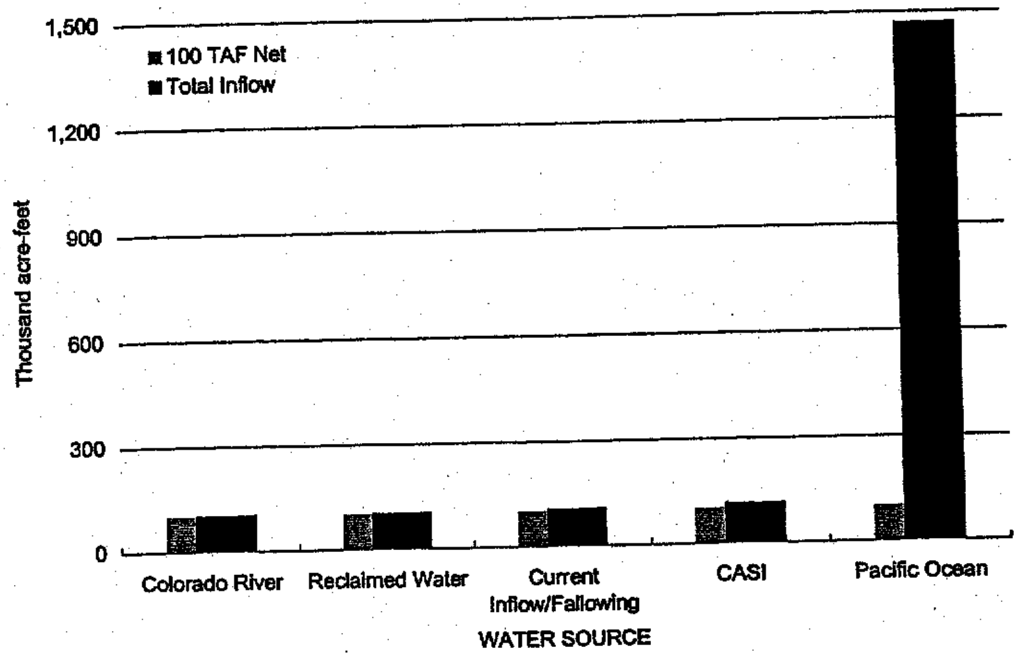

Figure 4–8 – Inflow Required to Replace 100 TAF of Evaporation

A brief cost comparison of the concepts that could be used to replace Sea inflows or reduce the inflows needed to maintain the Sea's elevation was also performed. The construction cost for each concept was divided by the average annual water deliveries or reductions in inflow to determine the capital cost per acre-foot. The results are displayed in Table 4–7.

**Table 4–7 – Concepts with Cost Comparisons**

| Concept | Average Annual Delivery (TAF) | Construction Cost ($ X $10^6$) | Capital Cost ($/AF) |
|---|---|---|---|
| Flood Flows | 60 | 10 | 170 |
| North Pond | 29 | 200 | 6,900 |
| South Pond | 74 | 195 | 2,630 |
| Displacement Dike | 67 | 450 | 6,720 |
| Fallowing | Needs Analysis | Needs Analysis | Needs Analysis |
| CASI | 304 | 84 | 270 |
| Reclaimed Water | 250 | 1,300 | 5,200 |
| Gulf/Ocean | 250 | 2,800 | 11,200 |

Table 4–8 shows similar results using only the annual operating cost for each concept. In Table 4–8, the estimated annual cost was divided by the average annual deliveries or reductions in inflows. This analysis neglects the cost of money and depreciation but does allow some conclusions to be drawn.

**Table 4–8 – Annual Operating Costs for Each Concept**

| Concept | Average Annual Delivery (TAF) | Annual Operating Cost ($ X $10^6$) | Annual Costs ($/AF) |
|---|---|---|---|
| Flood Flows | 60 | 0 | 0 |
| North Pond* | 29 | 0.6 | 21 |
| South Pond* | 74 | 0.5 | 7 |
| Displacement Dike [a] | 67 | 1.4 | 21 |
| Fallowing | Needs Analysis | Needs Analysis | Needs Analysis |
| CASI | 304 | – 1.6 | –5 |
| Reclaimed Water | 250 | 48.2 | 193 |
| Gulf/Ocean | 250 | 41.0 | 164 |
| [a] Assumes Operation at –232 feet | | | |

A comparison of the effectiveness of the concepts (shown in Table 4–9) was also made to arrive at the adjusted cost per acre-foot shown in Table 4–10. An incremental cost for operating (and perhaps enlarging) salt removal facilities should be added to each concept except the Ocean water concept. Essentially the only way to deal with the huge salt load from the ocean is to pump in larger quantities of Ocean water and pump out large quantities of Sea water (i.e. about 250 TAFY of Ocean water and 233 TAFY of Sea water).

No attempt to compare the cost of constructing and operating the salt removal and disposal facilities was made. Refinements to the salt removal and disposal concepts as well as some other evaluations should be performed prior to performing those comparisons. It should be noted that the final alternatives need to be considered as whole because some concepts i.e., in-Sea ponds, perform more than one function Table 4–9.

### Table 4-9 – Effectiveness of the Concepts

| Concept | Salt Content (mg/l) | Salt Imported (lbs. X $10^3$/AF) | Effectiveness (%) [a] |
|---|---|---|---|
| Flood Flows | 800 | 2 | 98 |
| North Pond | None | 0 | 100 |
| South Pond | None | 0 | 100 |
| Displacement Dike | None | 0 | 100 |
| Fallowing | 2800 | 7.5 | 93 |
| CASI | 4500 | 12 | 88 |
| Reclaimed Water | 1750 | 4.7 | 96 |
| Gulf/Ocean | 35,000 | 95 | 7 |
| [a] If Salton Sea is at target salinity of 37.5 g/l | | | |

### Table 4–10 – Adjusted Cost per Acre Foot[4]

| Concept | Average Net Annual Delivery (AF ) | Capital Cost ($ /AF ) | Annual Costs ($/AF ) |
|---|---|---|---|
| Flood Flows | 58,800 | 170 | 0 |
| North Pond | 29,000 | 6,900 [a] | 21 [a] |
| South Pond | 74,000 | 2,630 [a] | 7 [a] |
| Displacement Dike | 69,000 | 6,720 [b] | 21 [b] |
| Fallowing | Needs Analysis | Needs Analysis | Needs Analysis |
| CASI | 264,000 | 310 | –6 |
| Reclaimed Water | 239,300 | 5,430 | 200 |
| Gulf/Ocean | 17,000 | 164,700 | 2,410 |
| [a] Portion of the costs for these facilities should be allocated to salt removal and possibly bittern disposal.<br>[b] If this facility is used as a concentration pond, a portion of its cost should be allocated to salt removal and possibly bittern disposal. | | | |

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[4] If Salton Sea is at target salinity of 37.5 g/l.

### CONCLUSIONS

Pumping water to/from the Ocean/Gulf is ineffective in meeting elevation or salinity goals at the Salton Sea. Use of Colorado River flood flows and CASI water are cost-effective ways of replacing Sea inflows; however, Colorado River flood flows may not be available in the future as demand for potable water increases and the CASI project is a planning concept. Efforts need to be made to firm up these supplies as replacements for Sea inflows.

From a displacement facility perspective, the south pond appears to be significantly more cost-effective than either the displacement dike or the north pond. It also has about the same surface area as the displacement dike area and would thus be more effective as a concentration (solar evaporation) pond if only one major in-Sea evaporation pond is constructed. However, shallow in-Sea ponds may be even more cost-effective, especially if locations can be identified that will allow them to serve as both displacement and evaporation ponds.

## 4.6 SUGGESTED REFINEMENTS TO PHASE 1 EIS/EIR ALTERNATIVES

The Parsons Team identified the following refinements to the Phase 1 alternatives described in the Draft EIS/EIR. The refinements are broken into two categories, those relating to water and salt management of the Sea and those related to increasing the effectiveness of the Phase 1 EIS/EIR Salton Sea Restoration Project Alternatives.

A more detailed analysis of the refinements should be performed prior to implementation of the project. Significant capital and annual operation, maintenance, replacement, and energy cost savings appear to be possible.

### 4.6.1 Management of the Salton Sea

Salinity and elevation goals were established for the Salton Sea. Modification of those goals may result in reduced construction and annual operation, maintenance, and replacement costs and annual energy costs without adversely affecting the Salton Sea.

### *4.6.1.1 Expand Sea's Operational Range*

The goal for the Sea's future water surface elevation was established at –230 to –235 feet based on scientific data and a desire to maintain and promote recreational and economic uses near the Sea. The Sea's elevation will decrease from the current elevation of –227 feet because water must be exported to remove salt and inflows to the Sea will decrease as a result of water transfers to San Diego or others and implementation of the California 4.4 Plan.

Implementation of the Salton Sea Restoration alternatives would allow the Salton Sea to be managed like a storage reservoir as inflows to the Sea decrease. The Sea's elevation normally fluctuates about 1 foot every year due to inflow variations and evaporation. The water surface elevation of the Sea can be allowed to drift downward toward –235 feet during periods when Colorado River flood flow releases are not available and rise upward towards –230 feet during periods when they are available. Up to 300 TAFY of Colorado River flood floods can be delivered to the Salton Sea annually when it is available (about 20 percent of the years). At a sea elevation of –232 feet (300 TAFY) would increase the elevation of the Sea by 1.3 feet.

Flood flows are often cyclical (wet years can be bunched together followed by dry periods) and may not coincide with elevation management of the Sea. The proposed five-foot operational range (–230 to –235) provides a maximum of 1.1 MAF acre-feet of storage (about 3 to 4 years of flood flows) and provides operational flexibility to accept Colorado River flood flows to maintain the Sea's future elevation. If the operational range is increased from five to seven feet (–228 to –235), an additional 460 TAF (less than two years of flood flows) of storage volume would be available in the Salton Sea to accommodate additional Colorado River flood flow releases. Operating above –228 feet is not advisable because flood damage tends to occur and wave action could cause the levees protecting the properties near the Sea to be overtopped or breached. Flood damage could then occur. In addition, a large tropical rainstorm could cause a relatively rapid increase in elevation (a nine-inch increase occurred during flooding in September 1976) and potential flooding of properties near the Sea.

Alternatively, an additional 640 TAF (more than two years of flood flows) of storage volume would be available if the range was established at – 230 to –238 feet. In-Sea evaporation ponds and/or displacement dikes would reduce the total volume of the Sea and the operational storage slightly. Once the target elevation of –230 feet is achieved through the water and salt management actions, several additional years would be required to lower the Sea further.

Operating over a seven- to eight-foot range rather than a five-foot range may allow greater quantities of inexpensive, relatively high quality Colorado River water to be delivered to the Sea to stabilize the Sea's water surface elevation. However, it would have some impact on recreational opportunities and commercial operations near the Sea. The operating range should be re-evaluated and considered along with the overall costs and benefits of the restoration project.

### 4.6.1.2 Lower Elevation Goal for Sea by Five Feet

A lower elevation goal would reduce the amount of inflows needed to stabilize the Sea's elevation. For example, maintaining the Sea at an average of –237 feet rather than –232 feet would reduce the annual quantity of water evaporated from the Sea by about 70 TAFY. Thus, this would reduce the total net inflows needed to stabilize the Sea's water surface elevation from 1.30 MAFY (for elevation –232 feet) to 1.23 MAFY if no in-Sea evaporation ponds or displacement dikes are constructed.

It has been estimated that 660,000 visitors visited the Sea in 1961–1962[5] when the Sea was at an elevation of about –235 feet. Recently, when the Sea has been at an elevation of about –227 feet, the visitor usage has been in the 200,000 to 275,000 range. Lowering the Sea to –238 feet may provide increased recreational opportunities (i.e., camping) although it may create economic hardships for some existing businesses near the Sea. An assessment of the benefits and costs of operating the Sea at a lower level in the future should be made if:

- Inflows to the Sea are significantly reduced.
- Displacement dikes or in-Sea ponds are not constructed.
- Replacement inflows are inadequate to stabilize the Sea between –230 and –235 feet.

The cost of improvements (dredging of channels, relocation or modification of facilities to provide continued Sea access) should be estimated. As an alternative, the property near the Sea could be purchased from the private owners and used for construction of salt removal and disposal facilities and public purposes.

It should be noted that lowering the Sea's elevation would reduce the volume of the Sea and cause the salinity of the Sea to increase. There is an important linkage between the elevation target and the salinity target for the Sea. For example, at elevation –230 feet, the salt content of the Sea would be 354 million tons if the salinity was reduced to 37.5 g/l. The salt content would be 348 million tons at an elevation of –235 feet with a salinity of 44 g/l. If the elevation of the Sea were lowered from –230 feet to –235 feet, the salinity would increase from the target of 37.5 g/l to about 44 g/l unless additional salt was removed from the Sea. Thus the effects of water elevation and salinity must both be considered when establishing elevation and salinity goals and in development of a management plan for the Sea.

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[5] January 2000 Salton Sea Restoration Project Draft EIS/EIR (page 3-137)

### 4.6.1.3 *Increase Salinity Goal*

The goal for the Sea's future salinity was established at 35 to 40 ppt, which is based on preliminary scientific data. Recent scientific evidence indicates that the wildlife using the Sea is very healthy and that the Sea's fishery is very productive at current salinity levels of 44 ppt. The fish in the Sea have adapted to the higher salinity and may continue to adapt for some period of time.

Consideration should be given to maintaining the Sea at a salinity of 40 ppt to perhaps as high as 45 ppt rather than 35 to 40 ppt over the near future. After experience is gained at those salinities, it may be desirable to allow the salinity to increase slightly. A higher salinity goal would reduce the amount of salt that must be removed from the Sea. If the salinity goal was increased from 37.5 g/l to 42.5 g/l, the salt content of the Sea at the target elevation of –232 feet would be increased from 330-million tons to about 375-million tons. This would reduce the salt removal management necessary to achieve the target salinity by 45-million tons. This is equivalent to 9 years of current Sea inflow. This higher salinity target will also reduce the volume of Sea water that must be removed to maintain the Sea's salinity from 100 TAFY to 88 TAFY based on an inflow of 5.1 million tons. This would reduce the size of the salt management facilities by about 12 percent.

The size of the facilities to remove water and salt from the Sea are driven by the need to remove salt entering the Sea as well as the need to remove salt already in the Sea. Thus there may be some opportunity to reduce their sizes if the target salinity is increased.

## 4.6.2 Refinements to Phase 1 Alternatives

### 4.6.2.1 *Modify Operation and Function of North and South Ponds (Alternative 1)*

The north and south deep ponds should not be used for final disposal of crystallized salt because a major seismic event could cause their dikes to be breached. A breach would cause the salt in the ponds to be dissolved and returned to the main body of the Sea.

These ponds should be used as concentration (solar evaporation) ponds with a small differential head across the dikes as described in Section 3.1 and possibly as bittern disposal ponds. Sea water can then be delivered to these ponds by gravity rather than pumping. Thus Alternative 1 should include, at the minimum, onshore crystallization ponds and appropriate pumping facilities and conveyance pipelines between the ponds. Additional onshore concentration ponds or an EES should be incorporated (if necessary) to achieve the desired evaporation rates and salt removal rates. Figure 4–9 shows conceptually how this system

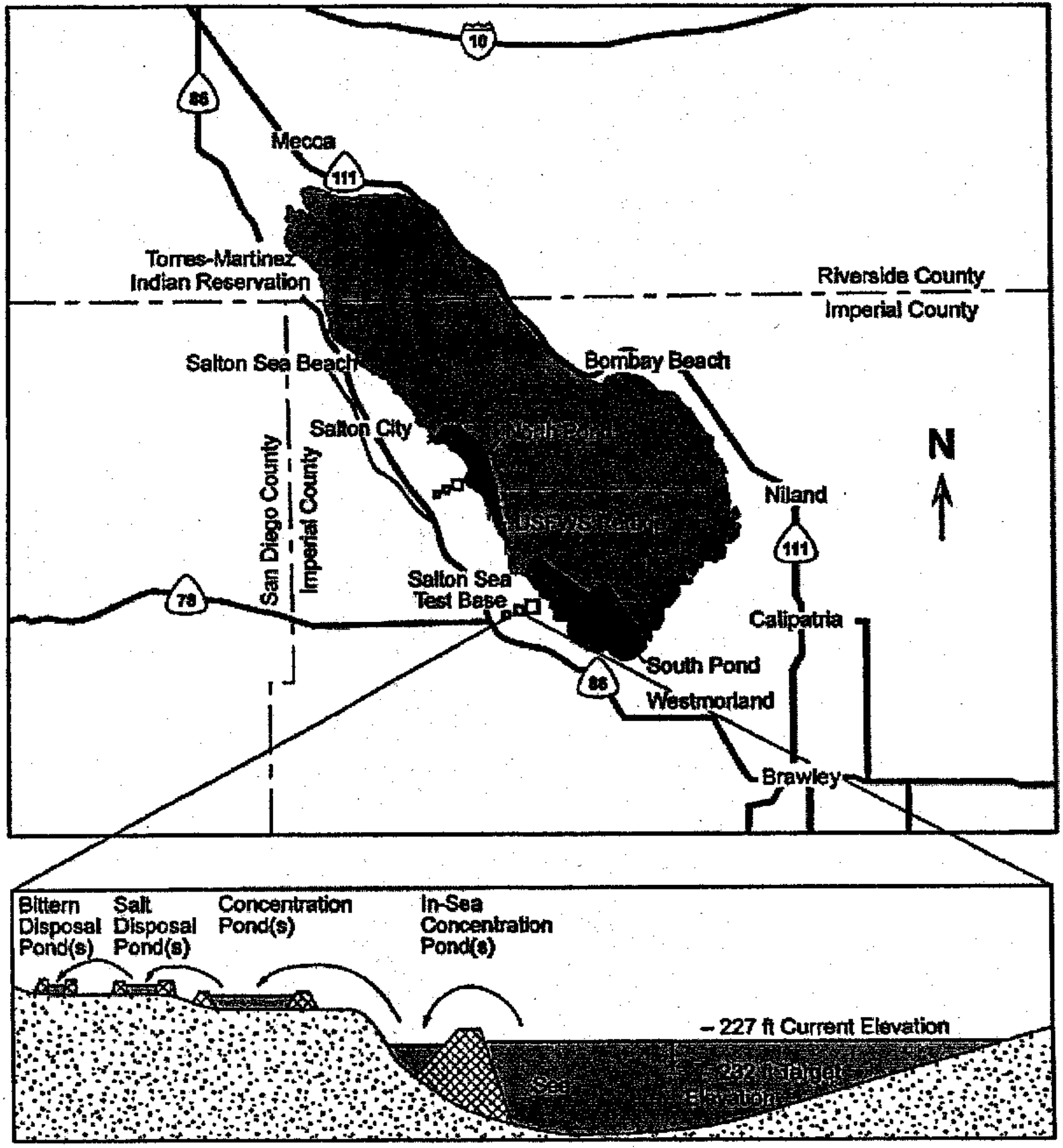

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**Figure 4–9 – Salton Sea Restoration Concept with Series of Evaporation Ponds**

Figure 4–9 shows conceptually how this system would be configured. The facility should be sized to meet elevation and salinity goals and sited on available land in a cost-effective manner.

Two possible revisions are suggested and these illustrate the effect of the changes recommended above. The first revision (Alternative 1R1) would simply operate the ponds slightly below the elevation of the Sea to reduce seismic risk and the consequences of failure (See Section 3.1.1). This would reduce the evaporation rate from the ponds and their effective life.

The second revision (Alternative 1R2) would also operate the ponds slightly below the elevation of the Sea; however, the ponds would be used as the first concentration ponds before completing evaporation of the water in onshore concentration ponds and crystallization ponds. The salt would remain in the crystallization ponds and the bittern would be conveyed to a separate pond or to the bottom of the in-Sea ponds for disposal. An EES could be used in lieu of or in conjunction with the onshore concentration ponds to reduce the area required for onshore evaporation.

Table 4–11 provides a comparison using the north and south in-Sea deep ponds:

- As single ponds operating at an elevation of –227 feet (Alternative 1 in the Draft EIS/EIR).
- As single ponds operating at a reduced level of –232 feet to reduce seismic risks (Alternative 1R1).
- As first concentration ponds at an elevation of –232 feet in conjunction with onshore concentration ponds with separate crystallization (salt disposal) ponds and bittern disposal ponds (Alternative 1R2).

An elevation of –232 feet was used for the revised alternatives for calculation purposes. During actual operation, the concentration ponds would be operated slightly below the elevation of the Sea. In the initial years of operation they would operate near an elevation of –227 feet; thus more water could be evaporated and salt removed if desired.

**Table 4–11 – Alternative 1, 1R1, and 1R2 Evaporation Rates**

| Year | Alternative 1 [a] | | Alternative 1R1 [b] | | Alternative 1R2 [c] | |
|---|---|---|---|---|---|---|
| | Evaporation Rate (TAFY) | Salt Removed (Million Tons per Year) | Evaporation Rate (TAFY) | Salt Removed (Million Tons per Year) | Evaporation Rate (TAFY) | Salt Removed (Million Tons per Year) |
| 1 | 120 | 6.5 | 102 | 5.5 | 102 | 5.5 |
| 8 | 105 | 5.6 | 84 | 4.2 | 102 | 5.5 |
| 13 | 94 | 5.0 | – | – | 102 | 5.5 |
| 25+ | May be Quite Low | May be Quite Low | May be Quite Low | May be Quite Low | 102 | 5.5 |

[a] Operated at –227 feet

[b] Calculations Based on Pond Operation at -232 feet for Illustration Purposes. Should be Operated at Slightly Lower Level than the Sea to Minimize Seismic Risk.

[c] Ponds Operated at –232 feet with concentrated water transferred to onshore concentration ponds (or EES) when salinity reaches 130 ppt.

### 4.6.2.2 *Modify Displacement Dike Design to Create a Shallow or Deep Concentration Pond (All Alternatives)*

As described in the Draft EIS/EIR, the proposed displacement dike would be used only to remove area from the Sea to assist in maintaining the established elevation goals. At this time, the area behind the dike is proposed for use as a wildlife refuge area. Using the area behind the dike as a concentration (solar evaporation) pond with little or no head differential across the dike as described in Section 3.1 would reduce the seismic risk associated with having water (the Sea) on one side of the dike and being dry on the other side. If the displacement dike is to be constructed, it should also be used as a concentration pond. Such a use may allow a greater diversity of wildlife habitat to evolve in this area than what exists today.

The proposed operation of the displacement dike area as a concentration pond would also allow the dike to reduce the quantity of inflow needed to maintain the Sea's elevation and allow other concentration ponds to be downsized, eliminated, or converted to crystallization ponds. In addition, it may allow an onshore EES to be downsized if the displacement area pond is used to evaporate and concentrate the Sea water before it is pumped to the EES.

The surface area of the south pond is approximately equal to the surface area that would be removed from the Sea by the displacement dike. The cost for the south pond is estimated at $195 million whereas the cost for the displacement dike is estimated at $450 million. The South Pond should be considered for use as a displacement dike instead of the displacement dike proposed in Alternatives 2, 3, and 5; however, the same concerns about seismic risk and consequences of failure expressed above still apply.

SECTION

5

# CONCEPTS AND ALTERNATIVES IDENTIFIED FOR FURTHER ANALYSIS

## 5.1 USE SERIES OF SOLAR EVAPORATION PONDS TO REMOVE SALT

The use of a series of solar evaporation ponds is a more efficient way of making salt (removing salt from seawater) than a single solar evaporation pond. Specific alternatives should be developed using available land in and near the Salton Sea.

Water in the initial concentration ponds can be evaporated to a concentration level of up to about 309 parts per thousand (ppt) before crystallization of salt begins. However, it is normally desirable to evaporate to a lower level (100 to 130 ppt) in the first pond and complete the evaporation in additional ponds. This design will achieve the highest evaporation rate and allow highly concentrated brine from the additional ponds to be transferred to crystallization ponds where the salt would precipitate. It should be noted that salinity levels in the above range are known to support aquatic life, such as brine shrimp. Brine shrimp are an excellent source of food for some bird species, such as grebes.

Test ponds and pilot studies are needed to establish criteria for final design and operation. Fine tuning of the operation normally occurs after construction and actual full-scale operation.

The ponds can be constructed entirely in the Sea, on the shore, or partly in the Sea and on the shore. In-Sea ponds, such as the south pond from Alternative 1, would reduce the volume and surface area of the main Sea thus reducing evaporation from the surface of the Sea and the amount of water needed to maintain the Sea within a desired operational range. Shallower in-Sea ponds may be more cost-effective than the south pond and should be evaluated. The actual location of the ponds should consider seismic risk and benefits from reducing the surface area and volume of the Sea as well as the costs of constructing, operating, and maintaining the ponds.

Concentration or solar evaporation ponds depend on surface area for their effectiveness. Dike costs increase with height. For example, a 35-foot high in-Sea dike would cost about three times as much per linear foot as a 17-foot high in-Sea dike. Thus, for an equivalent amount of money, a larger surface area can normally be obtained with shallow solar evaporation ponds constructed on relatively flat terrain than with deep ponds on steeper terrain. In addition, dikes constructed on the shore would generally cost less than dikes constructed in the Sea. However, no displacement of Sea surface area would be obtained.

Items that must be kept in mind when siting shallow solar evaporation ponds on the shore include:

- Soil conditions, especially impermeability.
- Slope of land (2-feet per mile or less is desirable).
- Size of area where ponds can be located (several square miles needed for efficient operation).
- Distance to salt and bittern disposal site(s).

A brief review of topography maps and a tour around the Sea indicate that compromises will need to be made to develop alternatives using solar concentration (solar evaporation) ponds. The land with the flattest is located in and along the shore of the Sea south of Bombay Beach and in the United States Forest and Wildlife Service (USFWS) Refuge area. Agricultural lands south of Niland also have a relatively flat slope. A cost-effective solution will involve using some combination of in-Sea lands for ponds (assist in maintaining elevation in addition to salt removal) and flatter land near the Sea for ponds. Potential sites and areas are generally shown in Figure 5–1.

It should be noted that the most cost-effective in-Sea pond evaluated in the January 2000 Draft Appraisal Report was the south pond. Other in-Sea ponds should be evaluated together with onshore ponds. The north pond and the area behind the currently proposed displacement dike do not appear to be cost-effective at this time.

If enough cost-effective sites for solar evaporation ponds cannot be located, an EES should be considered for some portion of the needed evaporation capacity.

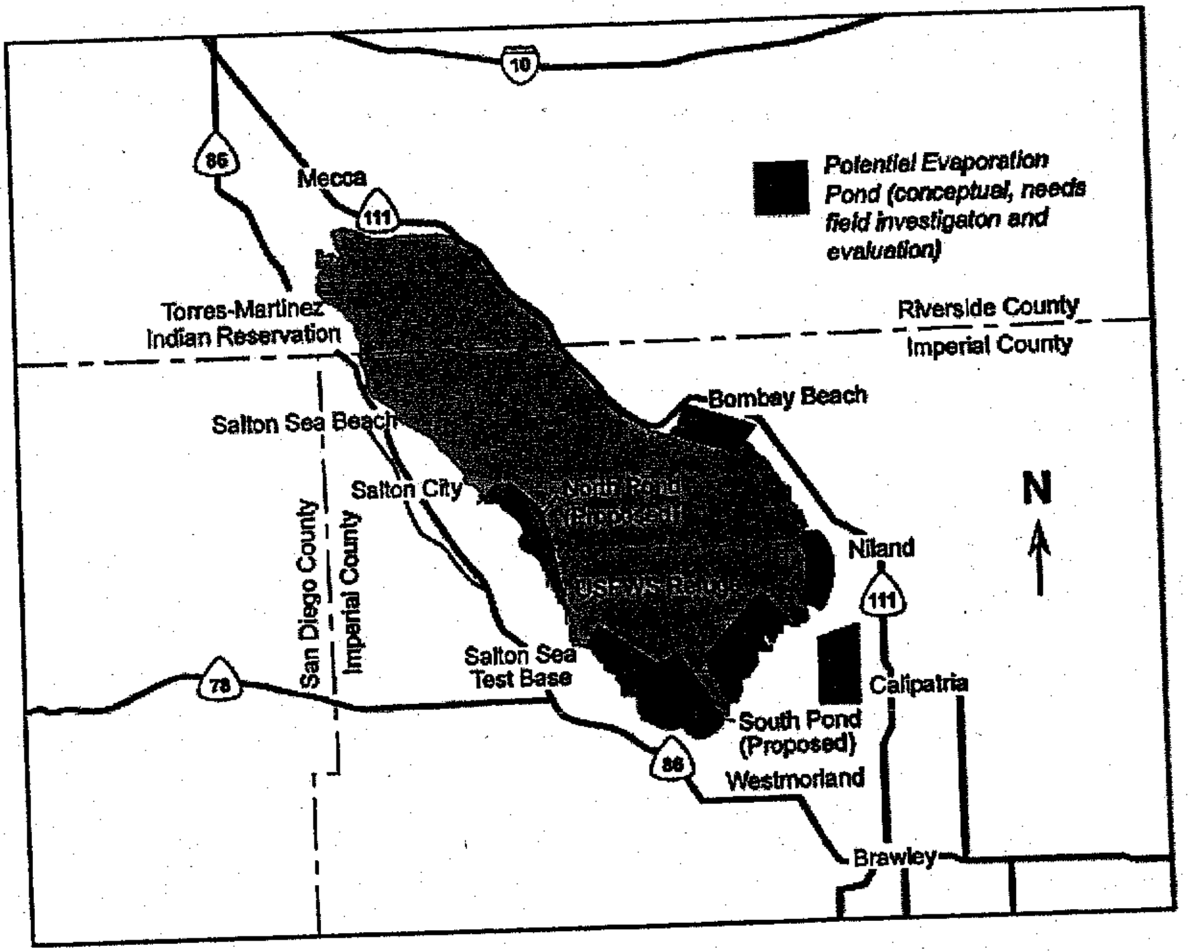

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Figure 5–1 – Salton Sea Overview

## 5.2 USE DEEP PONDS FOR SALT AND BITTERN DISPOSAL

The salt and bittern disposal ponds needed for the Salton Sea Restoration Project will essentially function as landfills. However, the area created when the ponds reach capacity may not be usable for other purposes, because the bittern may not dry out. If the crystallized salt and liquid bittern are disposed of in separate ponds, the salt disposal pond could be capped with soil and might be usable for recreational purposes or some other purpose.

These ponds will need a large volume to store many years of salt and/or bittern. Thus deep ponds are likely to be more cost-effective than shallow ponds. Specific alternatives should be developed using deep ponds if practical. If necessary, these ponds can be located further from the Sea because the volume of concentrated brine pumped to these ponds is significantly less than the volume of Sea water that would need to be conveyed to concentration ponds or an EES. However, land near the Sea tends to be less permeable and more suitable for disposal ponds. Land farther from the Sea may need a clay liner or some other impermeable liner to reduce leakage.

Deep in-Sea ponds are not recommended for crystallized salt disposal because of the potential for dike damage or failure due to earthquakes. Breaching of the dikes would allow Sea water to flow into the ponds and would dissolve the salt back into the Sea. It should be noted that bittern could be placed into the bottom of deep concentration ponds for disposal without significantly affecting the evaporation rate if a method can be found to layer the bittern without mixing. The bittern would tend to stay on the bottom because of its higher density. Dike damage or failure could cause bittern to be returned to the Sea. Although that is not desirable, it might be acceptable. Further research into the effects of bittern being placed (possibly in a layer at the bottom) in the concentration ponds or being inadvertently returned to the Sea is needed.

## 5.3 DREDGING SEA BOTTOM TO RECLAIM LAND FOR SHALLOW PONDS AND/OR DISPLACEMENT OF SURFACE AREA

Further evaluation of displacement facilities is needed. In-Sea evaporation ponds also perform as displacement facilities. However, additional displacement facilities may be needed for the reduced inflow scenarios at some point in the future. An evaluation of the cost of dredging the Sea's bottom and depositing the dredged material at the shore for creation of shallow ponds and/or displacement facilities should be made. Reclaiming part of the Sea with dredged materials would eliminate concerns about the large differential head across the dikes and the consequences of a potential dike failure. It is estimated that hydraulically dredged materials can be placed in the Sea at about one-fourth to one-third the cost of borrowed dike materials. Ideally, the near shore sea bottom should be relatively flat, less than 1 percent slope, so dredging and filling occurs in relatively shallow water. The southeastern part of the Sea appears to be a good location. Since this area is near the mouth of the Alamo River, it might be possible to create a fill area from the Alamo River that can also use the fresh water to create wildlife habitat ponds.

The reclamation could effectively reduce the surface area of the Sea (thereby reducing evaporation losses), and create a shoreline that is less sensitive to Sea level fluctuations. This may be an effective way of creating shallow solar evaporation ponds in the Sea near the shore or of constructing shallow evaporation ponds on the top of the dredged fill with low dikes (3 to 5 feet high).

## 5.4 USE FALLOWING TO MAINTAIN SEA INFLOWS

Past increases in the elevation of the Sea has inundated shoreline property and caused flood damage. The high Sea level has also adversely affected agricultural drainage. Levees have been constructed to control flooding and ongoing costs are being incurred to maintain the levees.

Future inflows to the Salton Sea are expected to decrease due to Imperial Irrigation District (IID) transfers to San Diego and others and because of exports from the Sea to remove salt. This will cause the elevation of the Sea to decrease slowly over time, thus reducing the potential for flood damage and the maintenance cost for the levees.

Agricultural water conservation may be used to obtain water for the above transfers. That will result in increased salt load in the remaining water that enters the Sea. Fallowing of agricultural lands could be used to assist in maintaining future Salton Sea inflows.

The only replacement water currently identified to be available at a reasonable cost to replace inflows to the Sea in the near future is Colorado River flood flows. Central Arizona Salinity Interceptor (CASI) water is a planning concept. If the CASI project is implemented, water is not expected to be available until after 2025. Fallowing can provide water for the Sea until CASI water becomes available or if CASI water does not become available. Fallowing can also provide supply when future Colorado River flood flows are not available.

The feasibility and cost-effectiveness of fallowing as a means of providing water to the Sea should be evaluated.

SECTION

6

# RESEARCH, PILOT TESTS, AND DEMONSTRATION PLANTS

## 6.1 OBTAIN PRELIMINARY GEOTECHNICAL DATA

All cost estimates prepared to date are appraisal level cost estimates.

Very little information has been obtained, or is known, regarding the Sea's sub-bottom conditions. The amount of soft materials that may need to be removed could greatly affect the dike costs, especially for the lower height dikes. Borings should be performed along the alignment of all in-Sea dikes selected for detailed analysis to verify or refine costing assumptions. Also, a preliminary sensitivity evaluation of the proposed designs should be performed to determine how the dikes would react to seismic loads. This would entail computerized simulations of the dike's response to anticipated earthquake ground motions for various dike geometries and materials. The designs can then be fine-tuned to reduce the seismic risk and further refine construction costs.

Soil percolation data should also be obtained for those sites where onshore ponds may be constructed. Even moderate leakage may require larger onshore ponds and higher pumping rates to obtain the same salt removal, because some of the partially concentrated brine will not make it to the crystallization pond area. The cost tradeoff between larger ponds and compacting or clay lining of the pond area should be evaluated.

## 6.2 SOLAR EVAPORATION TEST PONDS

A set of small solar evaporation test ponds should be constructed and operated at the Salton Sea to obtain data for preliminary sizing and development of the solar evaporation pond concepts. Data obtained would allow the assumptions regarding the evaporation rate of the Salton Sea water, the volume of salt produced, the salt density, and the characteristics of the bittern produced to be refined. Those refinements, together with soil percolation information for onshore pond areas will allow concentration and disposal pond sizes to be refined.

## 6.3 EES PILOT PLANT

The types of EES under consideration should be pilot tested at the Salton Sea in order to obtain refined information. The goals of the pilot tests should include obtaining information that can be used to project the annual operation, maintenance, and replacement costs and the annual energy costs. In addition, the evaporation rates for Sea water with different salinities (about 40 g/l up to and including at least 130 g/l) and the area requirements to capture the water droplets that do not evaporate should be obtained.

## 6.4 DEMONSTRATION PROJECTS

After the preferred alternative is identified, a full-scale demonstration project should be constructed and operated for at least one year to obtain more refined data than what can be obtained from test ponds and/or pilot projects. The Salton Sea Restoration Project is a very large project. The moneys spent on refining final design and operational parameters will pay for themselves many times over the life of the project.

## 6.5 POTENTIAL COMMERCIAL USES

It would cost much more to produce commercial grade salt at the Salton Sea than it would cost to remove salt from the Sea. The market for salt is limited by transportation costs. The market for salt on the West Coast is very small because most salt is in the United States used for ice removal in colder climates.

There are, however, some other potential opportunities. For example, brine shrimp are sometimes present in the concentration (solar evaporation) ponds in commercial salt making operations. The brine shrimp and/or their cysts are sometimes harvested and sold for fish food.

Bittern from ocean salt-making operations is sometimes used for dust control purposes. Bittern from Salton Sea salt removal operations will have considerably less magnesium chloride ($MgCl_2$) in it; thus it may not be a good dust suppressant. The effectiveness of Salton Sea bittern as a dust suppressant can readily be evaluated by using bittern from test ponds. Some scientists believe that the salt and/or bittern can be used to make building blocks. Research should be conducted to determine the viability and cost of producing building blocks with salt and/or bittern.

There is some potential to use a portion of the salt and/or bittern from a salt removal operation at the Salton Sea, although it may be very limited because of proximity to major markets. Some revenue from operation of solar evaporation ponds or other salt removal facilities at the Salton Sea could be obtained to offset a portion of the annual operational costs. Limited marketing and research into potential markets should take place for activities that are complimentary to salt removal operations to determine viability and what would be involved in implementation.

## 6.6 STUDY EFFECTS OF CHANGING THE ELEVATION GOALS FROM –230 TO –235 FEET TO –230 TO –238 FEET.

The range of acceptable elevation goals for the Salton Sea has been established at –230 to –235 feet. The target elevation has been established at –230 feet. Many years will be required for the Sea level to be reduced from –227 to –230 feet. That will provide an opportunity for further studies regarding the future Sea's elevation and fine tuning of the operations of the facilities constructed to remove salt from the Sea and stabilize its elevation. It may be desirable to set new elevation goals in the future. A lower elevation goal would reduce the amount of surface evaporation from the Sea's surface and reduce, defer, or eliminate the need for replacement inflows and/or displacement facilities. However, a lower elevation goal would require that more salt be removed from the Sea if the same salinity goal is specified. Thus the effects on Sea salinity need to be evaluated concurrently with elevation.

## 6.7 STUDY EFFECTS OF HIGHER SALTON SEA SALINITY

It will likely be several years before a restoration project is designed and constructed. Because the Sea salinity is increasing at about 1 percent per year [i.e., about 0.5 grams per liter (g/l) per year], the salinity of the Salton Sea is expected to approach 50 g/l before the salt removal actions will begin to lower the salinity towards the target salinity. The Sea's salinity has been greater than 35 g/l since about 1950 and greater than 40 g/l since the early 1970's without apparent adverse effects on fish and wildlife. The Salton Sea Science Subcommittee should utilize this opportunity to conduct focused research on the effects of higher salinity on the fish and other aquatic organisms currently inhabiting and visiting the Sea. If no significant adverse effects on fish and wildlife are observed during this period of focused research, the salinity target range could be revised upward to 40 to 45 g/l to reduce the operational costs of the salt removal actions (more salt can be removed per acre-foot of water).

The common actions in the alternatives should be implemented early to improve the image of the Sea to determine if the number of visitors to the Sea increases. If no significant adverse effects to fish and wildlife occur due to the increased salinity, it may be desirable to increase the salinity goals from 30 to 35 g/l to 40 to 45 g/l to reduce future operational costs.