WATER RESOURCES BULLETIN
VOL. 21, NO. 4 AMERICAN WATER RESOURCES ASSOCIATION AUGUST 1985

PREDICTING IMPACTS FROM WATER CONSERVATION AND ENERGY DEVELOPMENT ON THE SALTON SEA, CALIFORNIA[1]

Charles R. Kratzer, William Dritschilo, Lee J. Hannah, and Marlene A. Broutman[2]

ABSTRACT: An input-output model was developed to predict changes in Salton Sea salinity and water level until the year 2000 due to proposed water conservation efforts and geothermal and solar pond energy developments. The model SALINP provided good agreement with the observed salinities for 1960-80. While SALINP was not overly sensitive to one-year changes in any of the major inputs, a change in the historical means of the Imperial Valley runoff and evaporative loss inputs produced a significant effect on future predictions. The proposed water conservation measures caused the predicted Salton Sea salinity for 2000 to greatly exceed 40,000 ppm, the level at which adverse effects to wildlife are believed to occur. The possible geothermal development also produced predicted salinities considerably above 40,000 ppm. The salinity predictions for solar ponds by themselves and in conjunction with geothermal development were below 45,000 ppm for 2000. The solar pond and geothermal combination also resulted in a predicted lowering of the "natural" water level by 5 to 7 feet by 2000.
(KEY TERMS: water quality modeling; geothermal energy; solar ponds; agricultural water conservation; Salton Sea.)

INTRODUCTION

The Salton Sea (Figure 1) was formed accidentally in 1905 through storm-induced failure of the Imperial Valley irrigation system, which temporarily diverted virtually the entire flow of the Colorado River onto the floor of the valley. Initial efforts to restore the area to its original conditions were quickly abandoned, and the Salton Sea came to acquire a community of wildlife species and sport fish (mainly introduced) (Walker, 1961). Today, the Sea is an important habitat for migratory waterfowl displaced by urbanization of coastal wetlands. Increases in salinity and water level threaten the Sea's ecosystem through saline toxicity and inundation of habitat. The present salinity of the Sea is close to 40,000 ppm, the level at which fish reproduction begins to be depressed (Dritschilo, *et al.*, 1983).

Since its accidental formation, the Salton Sea has been maintained primarily by agricultural runoff from the Imperial and Coachella Valleys. Altering this runoff would seriously affect the water and salt balances of the Sea. Management options which are being considered or have been considered for the Sea include water conservation efforts, geothermal energy development and solar pond development. Water conservation efforts (e.g., lining water conveyance canals) and geothermal energy development in the Imperial Valley would alter the water and salt supply to the Sea. A solar pond development would alter the Sea's water and salt balance from within. These effects on the Sea's water and salt balances were determined by a simple input-output computer model.

At present only the water conservation management option appears likely to be implemented in the near future. Some plans still exist for geothermal energy development, but probably not to the extent or as soon as described in this paper. The solar pond development plans described herein did not work out. Of course, future development of this resource is still a possibility. Nevertheless, the purpose of this paper is not to pinpoint effects of definite and specific development plans, but to indicate the potential effects of some possible future development plans. The effect is determined by the input-output model, but the criterion for this effect is the adverse impacts to Salton Sea wildlife believed to occur at a salinity of 40,000 ppm. This information should be considered as an environmental impact in any discussion of these management options. These management options are described in more detail below. The paper then considers the development of the input-output model, its sensitivity, precision, and accuracy, and its application to these management options.

PROPOSED WATER CONSERVATION EFFORTS

In 1981, the Coachella Valley Water District (CVWD) lined a 49-mile segment of the Coachella Canal north of its connection with the All-American Canal (CVWD Testimony at California Water Resources Control Board Hearing in September 1983). This action was estimated to save 132,000 AF/year of seepage loss to the Salton Sea. This change in input to the Sea is considered as the "present level" of water conservation for the computer model projections.

[1]Paper No. 84096 of the *Water Resources Bulletin.* **Discussions are open until April 1, 1986.**
[2]Kratzer, Hannah, and Broutman, Doctoral Candidates; Dritschilo, Adjunct Assistant Professor; Environmental Science and Engineering Program, School of Public Health, University of California, Los Angeles, California 90024.

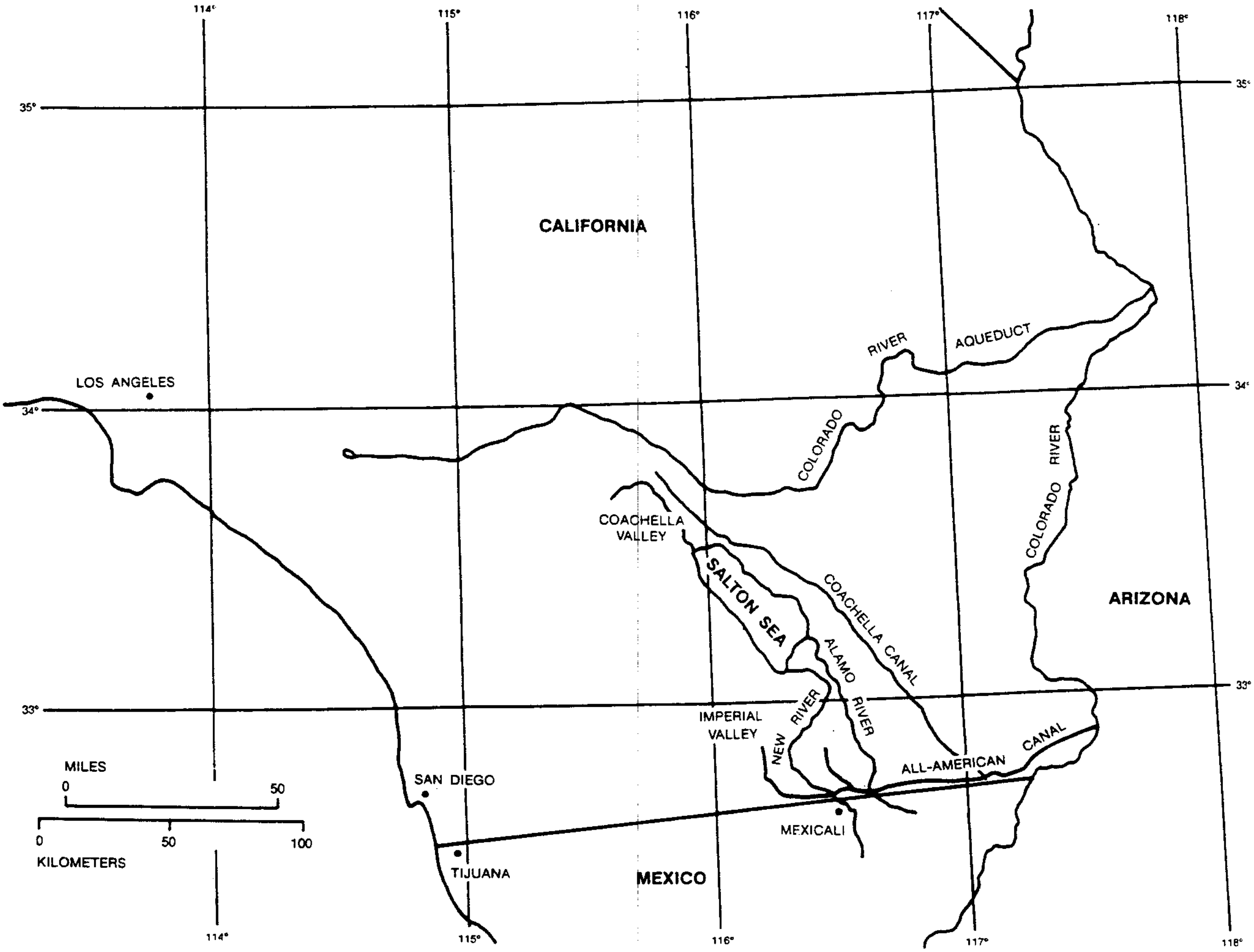

Figure 1. Location of the Salton Sea.

A 1981 study by the California Department of Water Resources (CDWR) estimates that a total of 438,000 AF/yr of water could be saved in the Imperial Irrigation District (IID) through simple conservation methods, such as lined canal banks, improved reservoir control to stop overflows, and scheduled irrigation (California Department of Water Resources, 1981). The U.S. Bureau of Reclamation (USBR) recently estimated the potential savings in the IID at 350,000 AF/year (USBR Testimony at California Water Resources Control Board Hearing in September 1983). The Environmental Defense Fund (EDF) has suggested that the Metropolitan Water District (MWD) make the improvements on the IID system in return for the water saved (Wall Street Journal, September 30, 1983). The MWD has reacted positively to the EDF idea, given their upcoming loss of some Colorado River water to Arizona and the cost of alternate sources.

We estimated the water savings by the IID at 360,000 AF/yr, instead of the 438,000 AF/yr estimated by the CDWR or the 350,000 AF/yr estimated by the USBR. This estimate did not include lining the All-American Canal because of the relatively high cost of this measure. However, we also assume that 30,000 AF/yr could be conserved by similar methods in the Coachella Valley Water District. These savings are in addition to the existing reduction of 132,000 AF/yr by the CVWD from lining the 49-mile segment of the Coachella Canal. Thus, the combined reduced input to the Sea is assumed to be 522,000 AF/yr from the entire Salton Sea basin. The model assumes the changes to occur at a constant rate from 1981 to 1995.

PROPOSED GEOTHERMAL DEVELOPMENT

The geothermal development scenario considered in this study is based on Southern California Edison's (SCE) "best guess" of cooling water requirements and rate of geothermal development in the Imperial Valley (Terry Sciarrotta, personal communication, 1981). The scenario assumes 100 percent use of a binary fluid cycle system. This system uses the geothermal fluid and heat exchangers to heat a low boiling point fluid such as isobutane, freon, or toluene in a closed turbine-feed-boiler cycle. A variation of this system, designed for the caustic hot brines in the Salton Sea area, passes the fluid first through a series of flash vessels in order to separate steam from brine. The brine and noncondensible gases are directly reinjected into the ground. All cooling water must come from an outside source since geothermal steam condensate is to be reinjected with the brine. The SCE estimated cooling water requirement is 64 AF/MWe. This cooling water comes from agricultural waste water in the Imperial Valley with an assumed salinity of 2910 ppm. A geothermal capacity of 1869 MWe is estimated by SCE for the year 2000.

PROPOSED SOLAR POND DEVELOPMENT

A solar pond consists of a body of saltwater which has density and temperature layers. The increasing salt concentration with depth hinders convective mixing and heat loss to the atmosphere. This results in a stable density gradient with very hot, salty bottom water and cooler, fresher surface water. This thermo-saline pond has the combined functions of energy collection and storage. Thermal energy is extracted from a solar pond via a water-conveying circuit and evaporator unit, using a low boiling temperature organic working fluid to drive a turbine. Over time, the salts in a solar pond will tend to break down the concentration gradient by diffusing from the high concentration region at the bottom of the pond to the low concentration region at the top. The salt gradient must be maintained by flushing the pond surface with relatively fresh water and adding concentrated brine through a horizontal diffuser submerged near the pond bottom. This brine can be produced in an adjacent evaporation pond.

Although plans for solar ponds in the Salton Sea were abandoned, it is informative nonetheless to consider the effect such plans might have on the Sea, due to the potential of solar ponds to retard increases in salinity. Ormat Turbines, Ltd. (1981) proposed a schedule for solar pond development at the Salton Sea which called for the phased development of twelve 50 MWe units between 1985 and 1995. At the full 600 MWe capacity, the diked solar pond impoundments would occupy 50 square miles in the southwest corner of the Sea. This represents about 13 percent of the Sea's total surface area. The annual flushing water requirement at full capacity would be 348,000 AF. However, by diking off 13 percent of the Sea's surface area, the evaporation from the Sea and the direct precipitation on the Sea would be reduced by 13 percent as well. This would reduce the net losses from the Sea by 147,400 AF/year. Therefore, the net annual water requirement of the solar pond development would be 200,600 AF.

MODEL DEVELOPMENT

An input-output model was developed in this study to predict the effect of the above management options on two inversely related parameters in the Salton Sea: salinity and water level. The period of 1960-80 was used for model calibration due to the reasonably reliable data available for this period. A detailed discussion of data sources is available in Dritschilo, *et al.* (1982). Groundwater seepage into the Salton Sea was calculated by the difference of the known inputs and outputs. Estimates were made for the salinity of intermittent streams, direct drainage from the IID, and seepage. These estimates were based on salinities for adjacent surface and groundwaters. The estimates made in the water and salt budgets should not greatly affect the model's performance, since these sources of water and salts are very minor compared to the well-measured runoff from the Imperial and Coachella Valleys.

Complete water budgets for the Salton Sea for 1960-80 are presented in Dritschilo, *et al.* (1982). Except for Coachella Valley runoff, the inputs and outputs of water to the Sea did not exhibit any definite trends during this period. Runoff from the Coachella Valley increased significantly during the 1974-80 period as compared to the 1960-73 period. This could be due to many factors, including increased precipitation, increased agricultural acreage, or changing agricultural practices (such as changing from one crop to multiple crops per year). Precipitation on the Salton Sea varied greatly from year to year, with a high of 90,000 AF (4.5 in.) in 1977 and a low of 5,000 AF (0.26 in.) in 1972. The primary determinants of the water level in the Salton Sea are runoff from the Imperial Valley and evaporation. A representative annual water budget for the Sea for the 1960-80 period is shown in Figure 2.

The salinities for each of the salt inputs to the Sea for 1960-80 are available in Dritschilo, *et al.* (1982). Since salt input is the product of salinity and flow, annual variations in inputs depend on both salinity and flow variations. The salinity of runoff water from the Coachella Valley decreased significantly during the 1960 to 1980 period, with a high of 2,870 ppm in 1960 and a low of 1,450 ppm in 1975. This corresponds to a period of increased flows from this region. Salinities for the intermittent streams and seepage for 1960-80 were estimated at 2,000 ppm and 1,000 ppm, respectively. The runoff from the Imperial Valley supplied from 77 percent to 86 percent of the total salt input to the Sea during 1960-80. A representative annual salt budget for the Sea for 1960-80 is also shown in Figure 2.

The first step in developing a predictive model for Salton Sea salinity is to provide acceptable agreement with observed salinities for the 1960-80 time period. We assumed that there are no processes to remove salts from the Sea, such as chemical precipitation or drift (wind produced aerosols of hygroscopic salt particles). The inputs of salts are from Imperial Valley runoff, Coachella Valley runoff, intermittent streams,

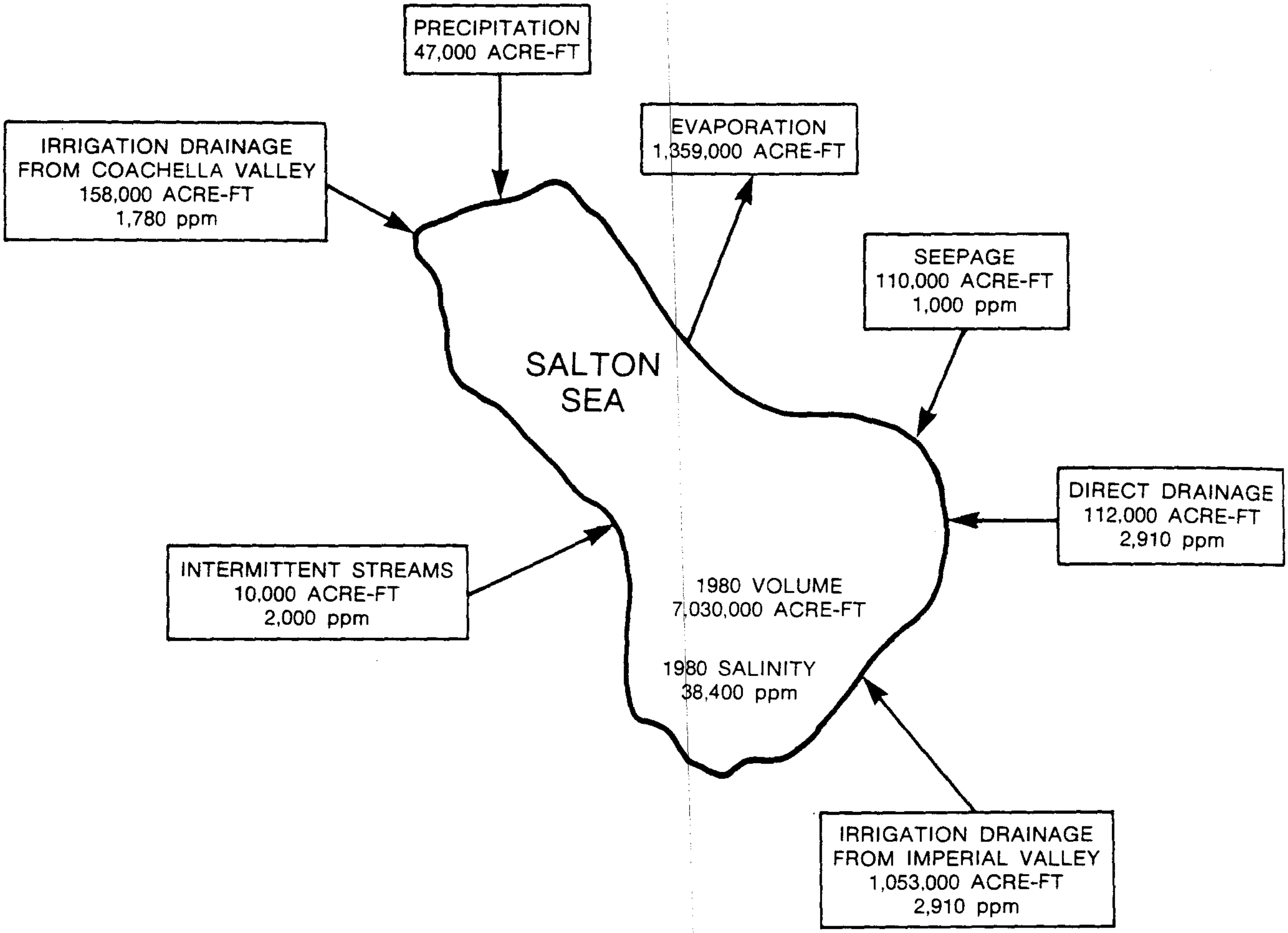

Figure 2. Representative Annual Water and Salt Budget for the Salton Sea, 1960-80.

direct drainage, and seepage. The equation which expresses this model is:

$$\text{SALINP (X)} = \frac{1.23\ [\text{SALT(X)} + \text{INPUT(X)}]}{\text{VOL(X)} + \text{STO(X)}}$$

where,

SALINP(X) = predicted salinity at end of year X, ppm;
SALT(X) = salts in the Sea at beginning of year X, kg;
INPUT(X) = input of salts during year X, kg;
VOL(X) = volume of the Sea at beginning of year X, AF;
STO(X) = change in storage during year X, AF; and
1.23 = unit conversion factor, (AF) (ppm)/kg.

Thus, the model predicts salinity forward from 1960 by adding on each year's salt input to the previous salt storage, and dividing by the previous year's volume with the change in storage added on. For example, for 1961, the prediction would be:

$$\text{SALINP (1961)} = \frac{1.23\ [\text{SALT (1961)} + \text{INPUT (1961)}]}{\text{VOL (1961)} + \text{STO (1961)}}$$

where,

SALT (1961) = SALT (1960) + INPUT (1960)
VOL (1961) = VOL (1960) + STO (1960)

Similar models have been developed by Layton (1978), the U.S. Department of the Interior and the Resources Agency of California (1974), and the U.S. Bureau of Reclamation (David Overvold and David Sobek, Draft Report, 1981). In the Layton (1978) model, the actual flows were not considered in the model. Instead, scenarios of constant flows were used for the predictions based on high, medium, and low projections for crop evapotranspiration. The model was used to determine the effects of water conservation and geothermal energy on the Sea's salinity and water level. In the U.S. Department of the Interior and the Resources Agency of California (1974) model, using average flows, the salinity of the Sea was predicted to increase by 550 ppm each year. The model was used to determine the potential effectiveness of diked impoundments as salinity controls. The U.S. Bureau of Reclamation (Overvold and Sobek, Draft Report, 1981) model used historic inflows from 1948-79 in their historic order of occurrence to predict the effect of water conservation measures on the Sea's salinity and water level for 1980-2012.

Unlike the Layton (1978) model, the present model (SALINP) uses the actual flows for 1960-80 to calibrate the model. The average of these flows is used to predict salinity and water level for 1981-2000. However, unlike the U.S. Department of the Interior and the Resources Agency of California (1974) model and the U.S. Bureau of Reclamation (Overvold and Sobek, Draft Report, 1981) model, SALINP corrects for the increased Coachella Valley inflow beginning in 1974. Also, unlike the U.S. Department of the Interior and the Resources Agency of California (1974) model, SALINP corrects for the change in evaporation or precipitation from/on the Sea due to changes in surface area. This is particularly important for predicting the effect of diked impoundments or solar ponds on the Sea.

The predictions of SALINP are shown with the observed values for 1960-80 in Figure 3. The model generally provides good predictions of the observed salinities. In the regression of predicted versus observed salinities, neither the slope nor the intercept of the regression line was significantly different from the observed salinity = SALINP line at the 95 percent confidence level (equation: Observed Salinity = 1577 + 0.954 SALINP). This fact, combined with the high r^2 value, 0.82, and low coefficient of variation, 4.6 percent, of the regression, suggests the predictions of SALINP are adequate in themselves, and any effort to incorporate the regression constants into the model equation is unnecessary and unjustifiable. Thus, the model appears to incorporate all the important variables. Processes to remove salts from the Sea are either insignificant or are balanced out by underestimated inflow volumes or concentrations.

Without considering changes to the Sea caused by water conservation, or geothermal or solar pond development, salinity and water level predictions for 1981-2000 are made by SALINP based on average values from the 1960-80 period for most flows and salinities. Exceptions to this include the flows from the Coachella Valley and direct drainage from the IID, and the salinities in the Coachella Valley runoff. The average flow for 1974-80 is used for the Coachella Valley, since these flows are significantly higher than the 1960-73 flows. For direct drainage from the IID, the 1969-79 California Department of Water Resources average flow is used. The salinity of the Coachella Valley runoff decreased significantly from 1960 to 1980, especially from 1960 to 1970. Therefore, only the average 1971-80 salinity is used for future predictions. The values used in the model SALINP for 1981-2000 predictions are shown in Figure 2.

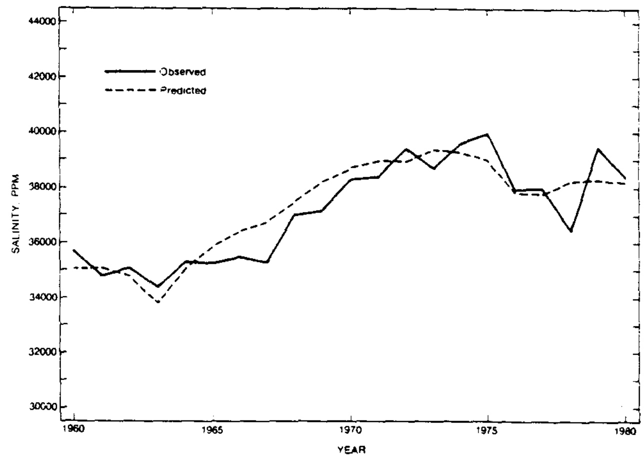

Figure 3. Predicted and Observed Salinities in the Salton Sea for 1960-80.

Besides requiring flow and salinity estimates for the future, SALINP also incorporates estimates for changes in evaporation and precipitation associated with the Sea's changing surface area. The surface area is estimated from the volume (using an area-capacity curve from 1969, U.S. Department of the Interior and the Resources Agency of California, 1974) by the following second-order polynomial equation (Dritschilo, *et al.*, 1982):

$$\text{Surface Area} = 0.0408\ (\text{VOL}) - 2.039 \times 10^{-9}\ (\text{VOL})^2 + 56582$$

with surface area in acres and volume in acre-feet. Changes in evaporation and precipitation from their respective 1960-80 average values of −1,359,000 AF and 47,000 AF are assumed to be directly related to changes in surface area. The proportional change in surface area from its average value of 232,000 acres is multiplied by the average evaporation and precipitation values to calculate the changes in evaporation and precipitation. The annual change in storage is calculated from the difference of all flows, and is used to recalculate the volume each year. The total salt load for a management option is added to the total storage of salts in the Sea each year to calculate the predicted salinity with

SALINP. The water level of the Salton Sea is calculated each year from the following second-order polynomial expression relating water level and volume (Dritschilo, *et al.*, 1982) (again, using the 1969 area-capacity relationship from U.S. Department of the Interior and the Resources Agency of California, 1974):

$$\text{Water Level} = 6.156 \times 10^{-6} (\text{VOL}) - 1.312 \times 10^{-13} (\text{VOL})^2 - 264.56$$

with water level in feet elevation and volume in acre-feet.

MODEL SENSITIVITY, PRECISION, AND ACCURACY

Sensitivity analysis was performed on the three most important model parameters: evaporative loss, Imperial Valley runoff, and Coachella Valley runoff. The SALINP model was not overly sensitive to changes in any of these parameters. Change in evaporative losses produced the greatest change in model output; an output alteration of over 2 percent in response to a 10 percent change in input. A 10 percent change in Imperial Valley runoff produced close to a 2 percent deviation in output. Model responsiveness to changes in Coachella Valley runoff was virtually nonexistent. Thus, since the model was not acutely sensitive to any parameter, the model errors may be discussed without concern for the compounding effects of acute sensitivity.

Four major sources of error in the model may be envisioned as follows: errors of measurement, errors involved with random yearly variation, errors caused by assuming that the historical mean flows (or salinities) correspond to future patterns, and errors within the structure of the model itself. All of these errors might act to reduce either the precision or accuracy of the model output. Errors of measurement are errors which arise in measuring the flows (and salinities) used as input to the model. Errors from random yearly variation arise because the model uses average past values (for flows and salinities) to predict future conditions, and therefore model predictions are themselves averages. Similarly, if the average (historical) input values used in the model are different from the actual future average, the value predicted by the model will be in error. Errors in model structure should be apparent during model calibration and verification.

Measurement errors and random yearly variations would tend to reduce the precision of the model. Errors in means or within the model itself would reduce the accuracy of the model's predictions. The effect of measurement errors on the predictions of the model cannot be quantified due to lack of information concerning flow measurement precision. The effect of random yearly variation on output is more readily assessed. This variation produces scatter around the mean predicted salinity which may be simulated using past random variation as a template. In the present model, historical random variation was assumed to have a normal distribution. Subprograms were then inserted into the computer model which generated random flow data within a normal distribution with a given mean and standard deviation. One such subprogram was used for each of the major parameters (evaporative loss, Imperial Valley runoff, Coachella Valley runoff). The mean for each random flow was set equal to the historical mean and the historical standard deviation was used as the standard deviation. The model was then run repetitively 30 times, the outputs for each year averaged, and the standard deviations taken. The output averages for each year were the non-random model prediction for that year. The largest recorded standard deviation was 1850 ppm (4.2 percent).

Model accuracy will be affected primarily by two factors: input data accuracy and model quality. In the case of the present model, the question of input data accuracy concerns how well historical flows approximate future flows. While the model is not notably sensitive to changes in flow, a consistent change (a change in the mean) will produce a significant effect on predictions for the future. For example, after 20 years a 10 percent change in evaporative loss would produce as much as a 23 percent change in salinity. Similarly, a 20-year 10 percent deviation in Imperial Valley runoff would produce approximately a 15 percent deviation in salinity. It is, therefore, very important that the mean of future flows input to the model be as accurate as possible. Errors in accuracy due to model imperfections cannot be satisfactorily estimated at present, since the assessment of such errors is dependent on a comparison of model predictions to actual observed salinities. However, the model probably overpredicts salinity slightly at high salinities (>70,000 ppm) due to the precipitation of $CaSO_4$ and other minor constituents of the Sea's total salinity.

MODEL APPLICATION TO MANAGEMENT OPTIONS

The predictive model SALINP was used to assess changes in salinity and water level in the Salton Sea for the management options discussed earlier. These include water conservation, geothermal development and solar pond development. The model requires data input on the annual amount of water consumed, the source of the water (Imperial or Coachella Valley runoff, or Salton Sea), and the salinity of the water. Table 1 shows the projected annual water requirements for each management option every five years for 1980-2000. The salinities used are shown in Figure 2, except for water removals directly from the Sea. For these, the annually recalculated Sea salinity is used. This is calculated each year from 1981-2000 by SALINP based on the salt loading and water volume as determined by the historical averages shown in Figure 2, and any applicable management options. The Sea's water level is also calculated each year from 1981-2000 based on the volume determined in SALINP.

TABLE 1. Water Requirements for Management Options (in 10^3 AF). Water sources are Imperial Valley (I.V.), Coachella Valley (C.V.), Salton Sea (S.S.), Evaporation and Precipitation. Negative flows represent reduced inputs and vice-versa.

	Water Conservation		Geothermal	Solar Ponds		
Date	I.V.	C.V.	I.V.	S.S.	Evap.	Prec.
1980	−132	0	0	0	0	0
1985	−252	−10	−15	0	0	0
1990	−372	−20	−40	−70	64	−3
1995	−492	−30	−78	−302	154	−6
2000	−492	−30	−120	−348	154	−6

The results of model runs to predict 1981-2000 salinities for the management options are shown in Figure 4. The Salton Sea depends primarily on relatively freshwater inflows from the Imperial and Coachella Valleys to balance the evaporative loss and prevent a rapid increase in salinity. Thus, for similar diversion quantities, the management option which diverts less saline water will cause the greater increase in the Sea's salinity. The water conservation measures discussed in this paper would increase the Sea's salinity more than the geothermal or solar pond developments by reducing the inflows from the Imperial and Coachella Valleys, and thus upsetting the water balance. The options in Figure 4 without water conservation produce a range of predicted salinities of 40,000-59,000 ppm for 2000. The options with water conservation produce predicted salinities of 56,000-104,000 ppm for 2000. In both cases, the option with geothermal development (lines 2 and 6 in Figure 4) produces the highest predicted salinity. Assuming a salinity of 40,000 ppm in the Sea to be detrimental to fish, none of the geothermal options would allow for a healthy ecosystem, regardless of whether or not water conservation measures are imposed.

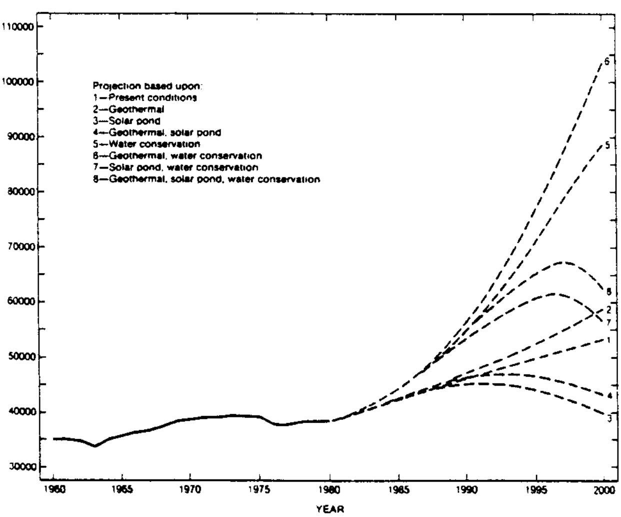

Figure 4. Predicted Salinities for Geothermal Development, Solar Pond Development, and Water Conservation for 1981-2000.

With or without water conservation, the options in Figure 4 with solar pond development produce the lowest predicted salinity. Once several of the solar ponds have been developed, they more than counteract the "natural" (present conditions scenario) increase in Sea salinity by removing Sea water for makeup water without affecting the amount of relatively freshwater inflow. Thus, even with water conservation, the solar ponds cause the predicted salinity to reach a peak and then decrease. Without water conservation, the solar ponds cause predicted salinity to peak at 45,500 ppm in 1991 and decline to 40,000 ppm in 2000. With water conservation, the peak is 62,000 ppm in 1996, decreasing to 56,000 ppm in 2000. Thus, without water conservation, the development of solar ponds in the Sea could reduce and reverse the "natural" increase in salinity to provide a borderline safe level by 2000.

The effects of simultaneous geothermal and solar pond development, with and without water conservation, are also shown in Figure 4. As expected, the predicted salinities of the geothermal development are reduced greatly by the simultaneous solar pond development. The end result is slightly higher predicted salinities than for the solar ponds alone. Without water conservation, the salinity peak is 47,000 ppm for the geothermal and solar pond combination, declining to 43,000 ppm in 2000. With water conservation, the peak is 67,000 ppm, declining to 62,000 ppm in 2000. The combined geothermal and solar pond development reduces the salinity considerably from the "natural" conditions, with or without water conservation. The geothermal development in combination with solar ponds, and without water conservation, appears capable of maintaining the Sea's salinity close to 40,000 ppm.

The effect of management options on the Sea's water level is dependent on the amount of water removed from the Sea, regardless of the source of the water. Thus, the relative effects can be determined from the water requirements in Table 1. Since all the management options remove water from the Sea, they all act to lower the water level. Even "natural" water level would be lowered by about 2 feet by 2000 (Figure 5), due to the 1981 lining of a portion of the Coachella Canal. Water conservation would have the greatest impact on water level, lowering the "natural" level by about 14 feet by 2000. The proposed solar pond development would reduce the water level more than the geothermal development. With and without water conservation, the effects of energy development on "natural" water level would vary from a 3-foot drop for geothermal development to a 7-foot drop for geothermal development combined with solar ponds. The combination of geothermal, solar ponds, and water conservation would lower the "natural" water level by about 20 feet by 2000. This would reduce the "natural" surface area of the Sea by about a third.

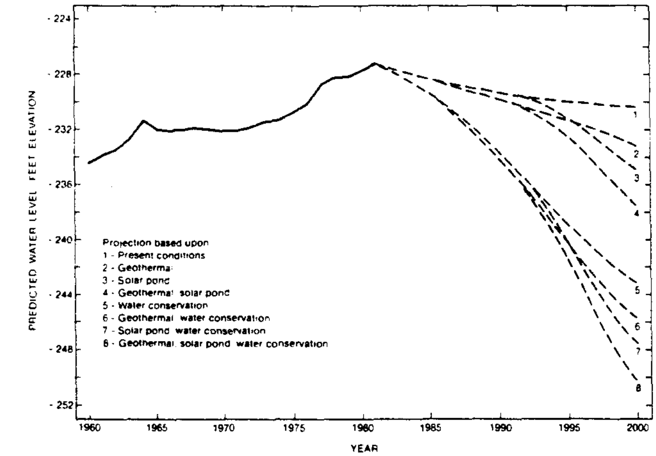

Figure 5. Predicted Water Levels for Geothermal Development, Solar Pond Development, and Water Conservation for 1981-2000.

CONCLUSIONS

Using the salinity and water level predictions of the SALINP model and the critical ecosystem salinity level of 40,000 ppm, the following conclusions can be made with respect to the impacts of water conservation and energy development on the Salton Sea:

(1) The water conservation measures could not be realized without endangering the health of the Sea's ecosystem.

(2) None of the geothermal scenarios could be implemented by themselves without adversely impacting the Sea's ecosystem.

(3) The development of solar ponds by themselves or in conjunction with geothermal development could reverse the trend of increasing salinity in the Sea, and possibly salvage the existing ecosystem.

(4) The management options in (3) would also lower the "natural" water level by 5 to 7 feet by 2000, and would reduce the Sea's "natural" surface area by 7 to 15 percent.

ACKNOWLEDGMENTS

This paper was presented at the AWRA Annual Meeting in San Francisco in October 1982. Funds for this study were provided by Southern California Edison Contract No. C0991901 to UCLA's Environmental Science and Engineering Program. Terry Sciarrotta of SCE provided much helpful information and guidance for the study. Additional UCLA students involved in the overall study were Rita O'Connell, Joe DeVita, Barry Wallerstein and Ken Jennings. Additional faculty involved were Drs. Robert Lindberg, Paul Merifield, Fred Turner and Richard Perrine. Ray Dunham of the California Water Resources Control Board provided valuable information from recent hearings on water use in the Imperial Valley. Special thanks go to Pat Park and Evalon Witt for typing and to Ruth Pordy for drafting.

LITERATURE CITED

Boegli, W. J., M. M. Dahl, and H. E. Remmers, 1982. Preliminary Study of Solar Ponds for Salinity Control in the Colorado River Basin. U.S. Bureau of Reclamation Report No. REC-ERC-82-19.

California Department of Water Resources, 1979. Evaporation from Water Surfaces in California. Bulletin 73-79, Sacramento, California.

California Department of Water Resources, Southern District, 1981. Investigation Under California Water Code Section 275 of Use of Water by Imperial Irrigation District. Los Angeles, California.

Dritschilo, W., R. G. Lindberg, P. Merifield, F. Turner, M. Broutman, L. Hannah, K. Jennings, C. Kratzer, S. Liedle, M. Monroy, J. Mortonson-Liedle, H. Nguyen, R. O'Connell, and B. R. Wallerstein, 1982. Resource Use and Wildlife Issues in Development of Alternative Energy Technology in Southern California Deserts, Volume II: Energy Technology and the Salton Sea Ecosystem. Environmental Science and Engineering Report No. 82-45, University of California, Los Angeles, California.

Dritschilo, W., D. Vander Pluym, J. Mortonson-Liedle, C. Newberry, T. Sostek, and K. Volkmer, 1983. Resource Use and Wildlife Issues in Development of Alternative Energy Technology in Southern California Deserts, Volume V: An Ecotoxicological Model for Effects of Salinity on the Salton Sea Fishery. Environmental Science and Engineering Report No. 83-49, University of California, Los Angeles, California.

Ermak, D. L., 1977. Potential Growth of Electric Power Production from Imperial Valley Geothermal Resources. Lawrence Livermore Laboratory, Livermore, California, UCRL-52252.

Hely, A. G., G. H. Hughes, and B. Irelan, 1966. Hydrologic Regimen of Salton Sea, California. U.S. Geological Survey Prof. Paper 486-C, U.S. Government Printing Office, Washington, D.C.

Layton, D. W., 1978. Water for Long-Term Geothermal Energy Production in the Imperial Valley. Lawrence Livermore Laboratory, Livermore, California, UCRL-52576.

Ormat Turbines, Ltd., 1981. A Study of the Feasibility of a Solar Salt Pond Generating Facility in the State of California, U.S.A., Volumes I and II. Yavne, Israel.

U.S. Department of the Interior and the Resources Agency of California, 1974. Salton Sea Project, Federal-State Feasibility Report. Sacramento, California.

U.S. Geological Survey, 1979. Water Resources Data for California. U.S. Geological Survey Water-Data Report, CA-79-1.

Walker, B. W. (Editor), 1961. The Ecology of the Salton Sea, California in Relation to the Sport Fishery. California Department of Fish and Game, Fish Bulletin No. 113, Sacramento, California.