Salton Sea Long-Range Plan

Appendix D: Salton Sea Salinity and Elevation Modeling

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SALTON SEA MANAGEMENT PROGRAM

CALIFORNIA NATURAL RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

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Appendix D: Salton Sea Salinity and Elevation Modeling

This appendix lays out the details of the Salton Sea Accounting Model (SSAM) used to produce estimates of future Salton Sea salinity and elevation. Each combination of Long-Range Plan (LRP) restoration concept and estimated future hydrology is represented in a separate Microsoft Excel workbook. There are 57 such combinations—19 concept variants and subvariants with three hydrology scenarios each. Automated scripts were used to operate on template files that contain the union of all the features needed to express the LRP concepts. These scripts were then used to enable only the relevant features, set up the relevant project areas, populate the relevant elevation-area-capacity relationship, and set the estimated hydrology for each individual model run. There are two separate templates: one for the divided sea concepts (Concepts 2a-2d) and one for all other concepts. Once the script populates the template, however, each workbook is a self-contained simulation of the model runs described in this report.

1.1. Primary Model Calculations

The model operates by water and salt mass conservation of the main, dynamically sized portion of the Sea. At each annual timestep, the following quantities of water volume are added (+) or subtracted (-) from the volume that was present at the beginning of the year:

- (+) Freshwater Inflows, a time series input from the relevant estimated hydrology scenario.
- (-) Total Water Volume needed to satisfy evaporation demands of fixed-size conservation projects, including the marine sea of Concept 1, the perimeter lake cells of Concepts 2 and 3, and all planned shallow-water habitat areas.
- (-) Total Water Volume needed to meet dust suppression obligations, defined as 1 acre-ft of water annually per acre of area within the 2003 shoreline not covered by the remaining Sea or any planned habitat projects in a given year.
- (-) Direct evaporation volume from the dynamically sized Sea, dependent on the area and salinity of the Sea in a given year, using the same quadratic polynomial regression in USGS's original SSAM model, which takes a baseline evaporation rate (calibrated to be 69.9 inches annual, see Section 1.2 and 1.4 below) and returns a smaller evaporation rate with increasing salinity.
- (+) Direct precipitation volume on the Sea, set at a constant value of 2.5 inches per year, approximately equal to a historical average of the rain gauge of Imperial, CA.
- (+/-) Any direct imports or exports, such as out-of-basin exports (Concept 4) or imports (Concept 11 -13), or remediation desalination (Concepts 7, 11-13).

Similarly, salt mass has the following additions (+) and subtractions (-) at each timestep, assuming direct evaporation and precipitation to have minimal effect on salt balance:

- (+) Salt coming in with freshwater inflows, using the inflow-dependent regression present in USGS's original SSAM model, which has higher salt concentrations with lower inflow volumes.
- (-) One-time salt withdrawal corresponding to the initial construction of saline habitat/water optimization areas in Concepts 1, 3, and 5.
- (+/-) Any direct imports or exports, such as out-of-basin exports (Concept 4) or imports (Concept 11-13), or remediation desalination (Concepts 7, 11-13).
- (-) Annual salt precipitation of 0.15% of the current salt mass in the Sea.
- (-) Any salt above saturation salinity of 280 ppt.

At any state of the Sea, there is a 1-1-1 relationship between its elevation, area, and capacity (volume), also known as the EAC relationship or EAC curve. This relationship was estimated from the latest available bathymetry data and may vary slightly from scenario to scenario. For each model run, this EAC curve is used to get the initial Sea volume (as the initial conditions are specified as an elevation) and to convert the Sea volume at each timestep to a Sea area and Sea elevation.

For every concept except Concept 2, there is only the one central, dynamically sized water body. This may represent a marine sea type area when certain remediation areas are in place (e.g., Concepts 4 or 7) or it may represent a higher-salinity residual sea area when the primary marine sea instead is a smaller fixed footprint (e.g., Concepts 1 or 3). In Concept 2, both portions of the divided sea are dynamically sized with their own precipitation and evaporation processes, but the whole freshwater inflow process is assumed to be first routed to the southern marine sea. After, there is a transfer process of water at the current salinity to the northern residual sea to equalize both elevations at the end of each timestep.

1.2. Model Inputs

The main inputs that the template scripts are setting to estimate the specifics of each scenario are the following:

- The initial Sea state. All model runs are currently set to begin in 2020 at an elevation of -235.5 ft NAVD88 with an initial salinity of 74,250 ppm.
- Freshwater inflow at each year, specified as a time series from 2020 to 2100. The derivation of the time series for each of the three hydrology scenarios is described in Section 3.1 of the LRP (with more detail provided in Appendix B).
- The baseline evaporation for each year. This was derived as a calibrated average value from historical data from 2004 to 2020. The current value has been set at 69.9 inches per year.
- The schedule for fixed-area projects with an evaporative loss, including Phase 1 habitat projects as well as concept-specific Sea areas that have a fixed footprint. This is specified as an area for each year and a per-area water use rate. Most projects have a single starting year (based on an estimated time to design, permit, and construct). Before that time, they occupy zero area and after that they occupy one repeating fixed value;

however, large habitat projects like the water optimization area in Concepts 1 and 5 have a staggered construction schedule. Open water habitat is currently set to use six feet of water per acre annually, wetland areas use five feet annually, and vegetation areas use 0.5 feet annually.

- The schedule for any imports and exports:
  - Pumpout-type transfers (e.g., Concept 4) that permanently remove water from the Sea do so at the current timestep's salinity. There is a threshold parameter that stops pumping once a target salinity has been met.
  - Import-type transfers (e.g., Concepts 11-13) do so at a fixed volume and salinity.
- Any local remediation desalination (e.g., Concept 7, Concepts 11-13) has six relevant parameters:
  - Starting year, based on estimated time to design, permit, and construct.
  - Salinity threshold, which determines whether desalination should be active in a given year (40 ppt).
  - Desalination volume: the amount of water withdrawn from the Sea at current salinity.
  - Desalinated water salinity (0.2 ppt).
  - Desalination water percent, the percent of the water withdrawn from the Sea to be returned (can be up to 100% if supplemental water use, e.g., from groundwater, is part of the concept design)
  - Damping factor: strong oscillations in Sea salinity can arise if the Sea volume gets sufficiently low (like the desalination volume). This factor decreases the amount of water withdrawn for desalination in these low volume situations to dampen the oscillatory behavior.
- For concepts in which major construction changes the EAC relationship, the year in which this happens is based on estimated time to design, permit, and construct. Water volume is preserved when the EAC curve is changed.

1.3. Model Outputs

The primary outputs of interest are Sea area, elevation, and salinity, which are all straightforward extractions of data columns from the model calculation sheet of the individual scenario workbooks. The maps in the main report involve post-processing these data with GIS tools to obtain breakdown of habitat areas by depth, estimated salt crust sizes, and GHG emissions.

1.4. Calibration of Model Evaporation

No sufficiently robust sources of direct Salton Sea evaporation data exist, so the baseline evaporation rate was treated as a calibration parameter. Daily Sea elevation data from 2004-2021 and periodic salinity data (approximately every three months) from 2004-2020 were available for use in calibration.

The model was initialized to January 2004 based on the average data of the first month of each of the above series. Then, historical inflow from 2004-2020 (see Section 5.3 of the Hydrology Appendix B) was input into the model.

First, evaporation was initialized to 68 inches for all years. Then an iterative calibration process was then applied to each year from 2004 to 2020 to better match observed salinity and elevation data as follows:

- Evaluate the effect of setting the evaporation of the year in question to each value in the set of candidates: {66, 67, 68, ..., 74}. This range was deemed to be consistent with previously used estimates of annual evaporation in other analyses.
- Linearly interpolate the model output within the calendar year since the observed data are daily while the model output is annual.
- Note the rank for each candidate according to best sum of squared error performance on each for salinity and elevation only within the year being evaluated.
- Choose the candidate salinity with the best performance according to the weighted average of three times the elevation rank and one times the salinity rank. The elevation data were given more weight because there is less noise in that dataset.
- Proceed to the next year and repeat the process.

The model was able to match the observed elevation and salinity data well after calibration (see Figures 1 and 2). The resulting average annual evaporation used for all future years was 69.9 inches.

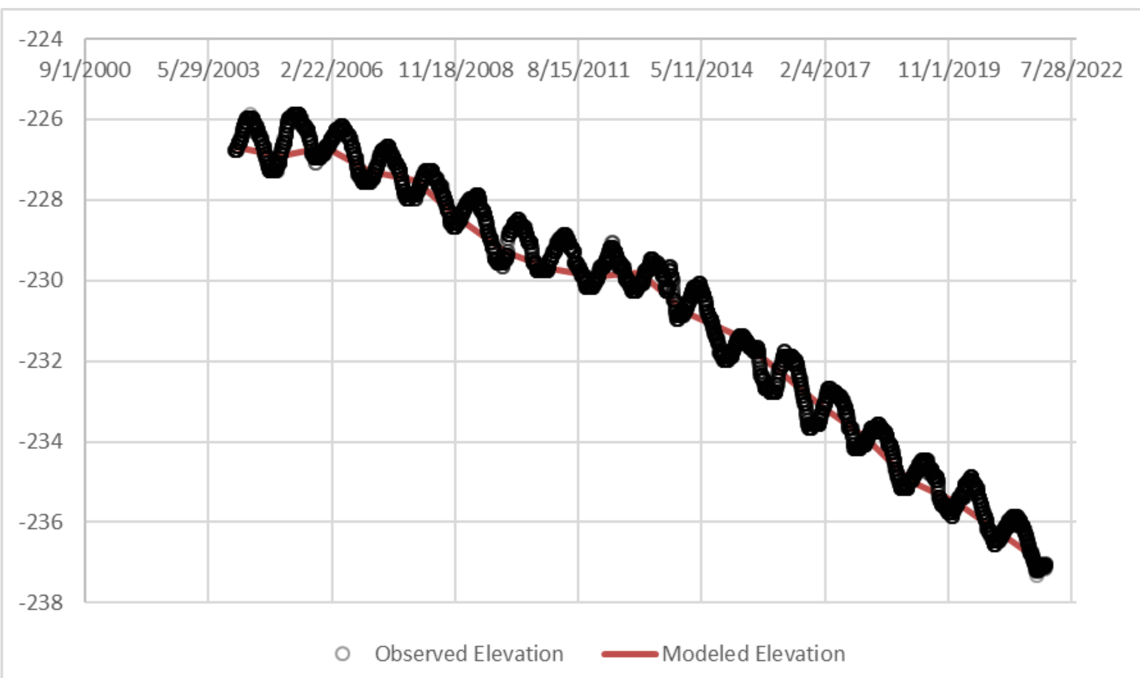

Figure 1. Calibrated Salton Sea Elevation (ft NAVD88)

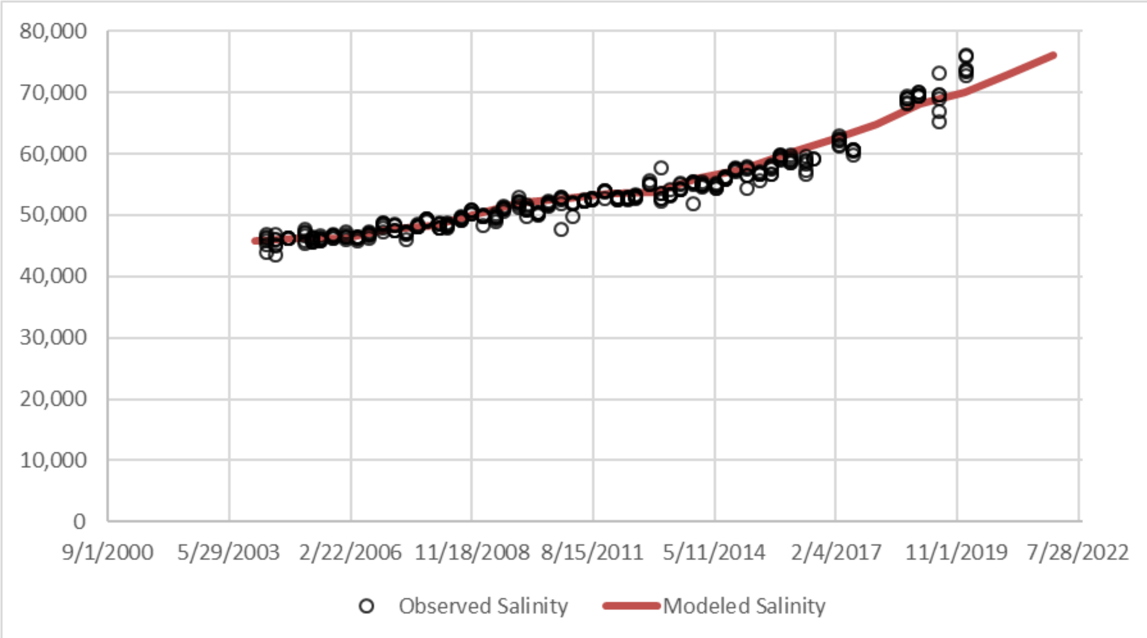

Figure 2. Calibrated Salton Sea Salinity (ppm)

As a sensitivity analysis, we also repeated the entire calibration with best-estimate historical inflows perturbed by +/- 5%. The case with 5% less inflow decreased the calibrated average evaporation to 68.0 inches, whereas the case with 5% more inflow increased it to 71.0 inches.

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