

Salton Sea Water Balance

As inflows from the rivers and irrigation drains that have largely sustained the Salton Sea have declined in recent years due to QSA water transfers and other factors, the Salton Sea will continue to shrink until inflows stabilize with the outflows (primarily evaporation loss) to reach equilibrium. The new Salton Sea equilibrium level is likely to be more than 20 feet below the pre QSA surface elevation exposing tens of thousands of acres of potentially emissive playa. The shrinkage of the Salton Sea will also continue to increase the rate of salinity rise. The option of a project to recycle Salton Sea water and remove excess salt is factored in to these equations. The rate of water import needed to build and sustain a desired level in the Salton Sea to cover much of that playa is determined by the water balance in the Salton Sea impacted by the following variables and volume balance equations (to be exact water mass balance is more correct, but the density of water varies only slightly within the ambient temperature range, so volume balance is a reasonable approximation for level calculations):

V_{SS} = Volume of Salton Sea

ΔV_{SS} = Change in Volume of Salton Sea

I_{RD} = Inflow to Salton Sea from all Rivers and irrigation Drains

I_{P} = Inflow to Salton Sea from Precipitation to surface

I_{GW} = Inflow to Salton Sea from Groundwater flows

I_{MW} = Inflow to Salton Sea from QSA Mitigation Water flows

I_{WI} = Inflow to Salton Sea from Water Import

I_{WR} = Return flow to Salton Sea from any water recycling project

O_{WR} = Outflow from Salton Sea to any water recycling project

O_{E} = Outflow from Salton Sea to Evaporation

O_{SP} = Outflow from Salton Sea to Seepage

$$\Delta V_{SS} = (I_{RD} + I_P + I_{GW} + I_{MW} + I_{WI} + I_{WR}) - (O_{WR} + O_E + O_{SP})$$

By the time Water Import conveyance infrastructure can be agreed upon, permitted, and constructed, the Salton Sea will almost certainly be many feet lower than its current elevation. To raise the level of the Salton Sea up to a target surface elevation that covers dust emitting playa the volume of the Sea will need to increase:

$$\Delta V_{SS} > 0$$

$$(I_{RD} + I_P + I_{GW} + I_{MW} + I_{WI} + I_{WR}) - (O_{WR} + O_E + O_{SP}) > 0$$

Or rearranging for net inflows to exceed net outflows:

$$I_{RD} + I_P + I_{GW} + I_{MW} + I_{WI} + I_{WR} > O_{WR} + O_E + O_{SP}$$

Since the rate of outflow to any water recycling project, and any return flows from same, will be largely determined by the salt balance and the other variables are controlled by natural processes, the rate of Water Import is the key controllable variable for Salton Sea elevation building:

$$I_{WI} > (O_{WR} + O_E + O_{SP}) - (I_{RD} + I_P + I_{GW} + I_{MW} + I_{WR})$$

Once a target elevation is achieved, the Volume of the Salton Sea should be held constant, primarily by controlling the Water Import flow:

$$\Delta V_{SS} = 0$$

$$I_{WI} = (O_{WR} + O_E + O_{SP}) - (I_{RD} + I_P + I_{GW} + I_{MW} + I_{WR})$$

Salton Sea Salt Balance

The Salton Sea has varied in Salinity throughout its existence in historical time. This is evidenced by salinity data and studies going back many decades. Salinity variation is evident throughout prior incarnations as Ancient Lake Cahuilla based on alternate use of freshwater fish traps and Native American salt trails to the area and by the New Liverpool and Standard Salt Company operations in the Salton Sink prior the most recent flooding starting in 1905.

The Salton Sea has been receiving approximately four million metric tons of mixed salts annually, drained from farm fields to the north and south and originating mostly from salts carried down the Colorado River from both natural and human sources upstream. The salt content of the Salton Sea is mostly sodium chloride, but is highly elevated in sulfate due to agricultural practices, and also moderately elevated in magnesium, a change from the very pure sodium chloride once harvested from the dry lakebed prior to 1905. Farm drainage also loads the Salton Sea with nutrients and biological materials, but the most critical issue challenging the aquatic ecosystem in the Salton Sea is excess salt.

Any Water Import scheme to the Salton Sea from a natural source would carry with it additional salt that would need to be managed if sustaining aquatic life in the Salton Sea is a goal and requirement. If the goal is simply dust mitigation, then salinity management may not be required. However, precipitated salts will accumulate once the Salton Sea reaches the saturation point for the various components. If salinity management to sustain an aquatic ecosystem, or just to limit salt accumulation, is required, the salinity in the Salton Sea will be impacted by the following variables and mass balance equations:

MS_{SS} = Mass of Salt in the Salton Sea

S_{SS} = Salinity of Salton Sea, averaged throughout the volume expressed as density of TDS (not NaCl only)

ΔMS_{SS} = Change in Mass of Salt in the Salton Sea

S_{RD} = Salinity of Inflows to Salton Sea from all Rivers and irrigation Drains averaged by relative flow

S_P = Salinity of Inflow to Salton Sea from Precipitation, near zero so eliminate

S_{GW} = Salinity of Inflow to Salton Sea from Groundwater flows

S_{MW} = Salinity of Inflow to Salton Sea from QSA Mitigation Water flows

S_{WI} = Salinity of Inflow to Salton Sea from Water Import

S_{WRO} = Salinity of Outflow from Salton Sea to any water recycling project

S_{WRR} = Salinity of return flow to Salton Sea from any water recycling project

S_E = Salinity of Outflow from Salton Sea to Evaporation, near zero so eliminate

S_{SP} = Salinity of Outflow from Salton Sea to Seepage

MS_P = Mass of Salt precipitating out of the Salton Sea annually

$$MS_{SS} = V_{SS}\ x\ S_{SS}$$

$$S_{SS} = \frac{MS_{SS}}{V_{SS}}$$

$$\Delta MS_{SS} = (I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR}) - (O_{WR}\ x\ S_{WRR} + O_{SP}\ x\ S_{SP}) - MS_P$$

Assuming a well-mixed Salton Sea, true after major wind events, but can be moderately stratified and vary by location at other times, the salinity of outflow to any water recycling project and to seepage would be the same as the Sea's average salinity. Salinity data from the Bureau of Reclamation over time show only slight variability in salinity by sampling depth and location supporting the assumption.

$$\Delta MS_{SS} = (I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR}) - (O_{WR}\ x\ S_{SS} + O_{SP}\ x\ S_{SS}) - MS_P$$

The salinity of the Salton Sea already far exceeds that optimal for an aquatic ecosystem able to support fish and fish eating birds. The optimal salinity range identified by the Salton Sea Management Program for aquatic habitat is 30 g/liter to 40 g/liter. The Salton Sea salinity now exceeds 70 g/liter and is expected to rise rapidly. By the time Water Import conveyance infrastructure can be constructed, the Salton Sea will almost certainly be much higher in salinity. Initially a reduction in salinity would be needed if aquatic habitat is a goal within the Salton Sea, hence:

$$\Delta MS_{SS} < 0$$

$$(I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR}) - (O_{WR}\ x\ S_{SS} + O_{SP}\ x\ S_{SS}) - MS_P < 0$$

$$O_{WR}\ x\ S_{SS} > (I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR}) - (O_{SP}\ x\ S_{SS}) - MS_P$$

When target salinity is reached, salt removal and concurrent water recycling would be scaled back to balance with salt inflow:

$$O_{WR}\ x\ S_{SS} = (I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR}) - (O_{SP}\ x\ S_{SS}) - MS_P$$

$$O_{WR} = \frac{(I_{RD}\ x\ S_{RD} + I_{GW}\ x\ S_{GW} + I_{MW}\ x\ S_{MW} + I_{WI}\ x\ S_{WI} + I_{WR}\ x\ S_{WRR})}{S_{SS}} - O_{SP} - MS_P$$