Salton Sea Long-Range Plan

Appendix G: Investigation of Desalination Methods

April 2024

Rev 1.01

SALTON SEA MANAGEMENT PROGRAM

CALIFORNIA NATURAL RESOURCES AGENCY

DEPARTMENT OF WATER RESOURCES · STATE OF CALIFORNIA

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

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Acronyms

AF	acre-feet
AFY	acre-feet per year
BTU	British thermal unit
Cu-Ni	Copper-Nickel
ft	feet
gpd	gallons per day
gpm	gallons per minute
HDPE	High-density polyethylene
kgallon	kilogallon
kW	kilowatts
kWh	kilowatts per hour
lb	pound
lb/h	pound per hour
LRP	Long-Range Plan
MED	multi-effect distillation
MGD	million gallons per day
NaCl	sodium chloride
NDP	net driving pressure
NF	nanofiltration
ppb	parts per billion
ppm	parts per million
Psi	pounds per square inch
RO	Reverse Osmosis
SHC	Saline Habitat Complex
TDS	total dissolved solids
TVC	thermal vacuum compressor
UF	ultrafiltration
VTE-MED	vertical tube evaporators – multi-effect distillation
ZLD	zero liquid discharge

Appendix G: Investigation of Desalination Methods

As part of the Long-Range Plan (LRP), desalination methods are being investigated to lower the salinity of the Salton Sea and to re-establish the diversity and abundance of wildlife at the Sea. Two approaches have been considered:

- Conventional Reverse Osmosis (RO) or other similar processes.
- The Salton Sea Water Recycling process proposed by Sephton Water Technology, which includes salinity reduction through distillation and other components to make a complete restoration concept for the Salton Sea (including additional groundwater supply, treated water conveyance, and brine ponds for evaporation of residual brines from the desalination system).

Each of these two alternatives is discussed below. Cost analyses described in this appendix were prepared by Tetra Tech engineers, working under contract to the California Department of Water Resources.

1.1. Reverse Osmosis

In the RO process, high feed water pressure drives the water through semi-permeable membranes, producing permeate water and leaving the salts on the feed side of the membranes as a concentrate. The concentration of salts in the RO concentrate depends on the rate of conversion of the feed water to permeate (recovery rate). The seawater RO systems usually operate at a recovery rate of ~50%. At this rate of recovery, the flow rate of the concentrate is about 50% of the flow rate of the feed flow, and salt concentration will be about twice the concentration of salts in the feed water.

Producing permeate water of low salinity from high salinity feed water requires the feed pressure, at any point of the RO membrane unit, to be higher than the osmotic pressure of the water on the feed side of the membrane. For effective operation of a seawater RO system, the pressure of the concentrate stream leaving the RO membrane unit should be at a minimum of 50 pounds per square inch (psi) higher than the osmotic pressure of the concentrate stream. This pressure differential, between feed pressure and osmotic pressure, is called the net driving pressure (NDP). The osmotic pressure of the water solution is directly proportional to the concentration of dissolved salts. The salinity of the Salton Sea water is reported as about 75,000 parts per million (PPM). This salinity corresponds to an osmotic pressure of about 800 psi.

The operation of a conventional commercial seawater RO system is limited by the allowable feed pressure, not exceeding 1,200 psi. Considering the required NDP of 50 psi, at the concentrate exit from the RO unit, the salinity of the concentrate should not be higher than about 110,000 PPM. This is to maintain the osmotic pressure of the concentrate below 1,150 psi.

Starting with feed seawater of salinity 75,000 PPM, the limit of 110,000 PPM salinity of the concentrate stream (corresponding to 1,150 psi osmotic pressure), would limit the recovery rate of the RO process, treating feed water from Salton Sea, to about 30%.

With the expected increase of water salinity in the Salton Sea, the rate of conversion of Salton Sea feed water to permeate, would have to be reduced in the future.

New, semi-commercial, ultra-high pressure RO membrane modules are being introduced to the market. These membrane elements have a feed pressure limit of about 1,700 psi. Operation of the RO unit at a feed pressure of 1,700 psi would allow concentrate stream salinity up to about 150,000 PPM. This higher limit of concentrate concentration would allow operation of the RO unit, treating a feed water salinity of 75,000 PPM at a recovery rate of about 50%. With a feed salinity of 100,000 PPM, the recovery rate would have to be reduced to about 35%, and if a higher salinity occurred, the recovery rate would have to be reduced to an even lower value.

The recovery rate of the desalination process strongly affects the economics of water production. A lower recovery rate would result in a proportionally higher flow rate of feed water pumped from the Sea, which would increase the size of the pretreatment system, the power consumption, usage of water treatment chemicals, and the size of the system required to treat the process wastewater. The seawater RO desalination plant at Carlsbad, CA, which operates at a 50% recovery rate, treats seawater at a salinity of about 35,000 PPM total dissolved solids (TDS), produces potable water at a price of about $2,000/(acre-feet) AF.

The product water from an RO system that would treat Salton Sea water of salinity of 75,000 – 100,000 PPM at a recovery rate of ~30% would be significantly more expensive than the one produced by the Carlsbad desalination plant. Therefore, the application of RO technology to desalinate the Salton Sea saline water does not appear to be economically feasible. Furthermore, with the possibility of inflows to the Sea being reduced further by droughts and climate change, the feed water salinity could exceed 110,000 PPM, which would exceed the accepted technical limit of the RO process.

It is therefore not recommended that RO desalination of Salton Sea water as a restoration concept be considered further unless there are technology improvements in the RO process that would make treating very high salinity water feasible.

1.2. Salton Sea Water Recycling Proposal (Sephton Water Technology)

Sephton Water Technology developed a complete proposal for restoration of the Salton Sea, which uses desalination as a core component. The evaluation of this proposal was performed as follows:

- The process of treating highly saline water from the Salton Sea to produce very low salinity water was described conceptually in the proposal (1).
- Some process steps, necessary for plant operation were omitted from the process description, as are some process parameters. This evaluation provides a review and an independent cost estimate of the system, adding in process steps that would be considered essential for a complete desalination system. The analysis was focused primarily on the desalination component of the restoration, recognizing that the overall

restoration concept proposed includes other components related to the management of the Salton Sea.

- The desalination equipment cost estimate presented here was prepared based on prices from recently received equipment quotes, cost parameters derived from equipment prices of recent desalination projects and economic information published by the US Bureau of Reclamation for similar processes. The values of system cost and product water cost provided in the process description in Reference (1) were significantly lower than this estimation.
- The overall cost estimate provided by Sephton Water technology includes a line item for a water distribution pipeline of $240 million. The proposal also includes a 50,000 acre-foot per year (AFY) groundwater supply. A capital and operating cost estimate was developed using reasonable estimates for well installation, pumping, and conveyance, as summarized in this appendix.
- A cost item was also added to account for the construction of the brine evaporation ponds that would be needed to manage the outflow from the desalination system.

The Salton Sea Water Recycling Proposal by Sephton Water Technology is focused on the removal of the salt from the saline Salton Sea water and the recovery of pure water. The treatment process outlined in the proposal Reference (1) has been reproduced in Figure 1. The objective of the treatment process is to remove divalent ions from the Salton Sea water, using nanofiltration (NF) membranes. The NF permeate is proposed to be concentrated using vertical tube evaporators – multi-effect distillation (VTE-MED) units to produce pure sodium chloride (NaCl) salt and very low salinity water as a distillate. The distillate is proposed to be returned to the Salton Sea to create low-salinity areas in this body of water.

The process consists of a combination of different commercial water treatment technologies that are expected to work individually. However, combining these technologies into one operating system may create significant challenges for process integration. Except for the VTE–MED equipment that is described in some detail in the Sephton Water Technology proposal, other plant equipment and treatment processes are described in broad terms, without the engineering details and without listing relevant process parameters. Some plant equipment (the water intake, for example) was missing essential components. Other, important plant subunits were omitted completely and not accounted for in the plant budget. For example, the solids management system, required for treating of the filtration system backwash water and sludge from lime precipitation unit, was not included in the system description and system cost in the document provided for review. Another example is the cooling water flow, essential for operation of the VTE–MED system, which was indicated on the schematic flow diagram (Figure 1, Reference 1), but the seawater cooling flow rate was not included in the process flow balance and calculation of the total recovery rate. Chemical storage and dosing systems were also omitted.

All the equipment prices, listed in the Sephton Water Technology proposal in Reference (1), are significantly lower than the equipment prices derived from recent and historical quotes or what would be considered as acceptable in the commercial desalination field.

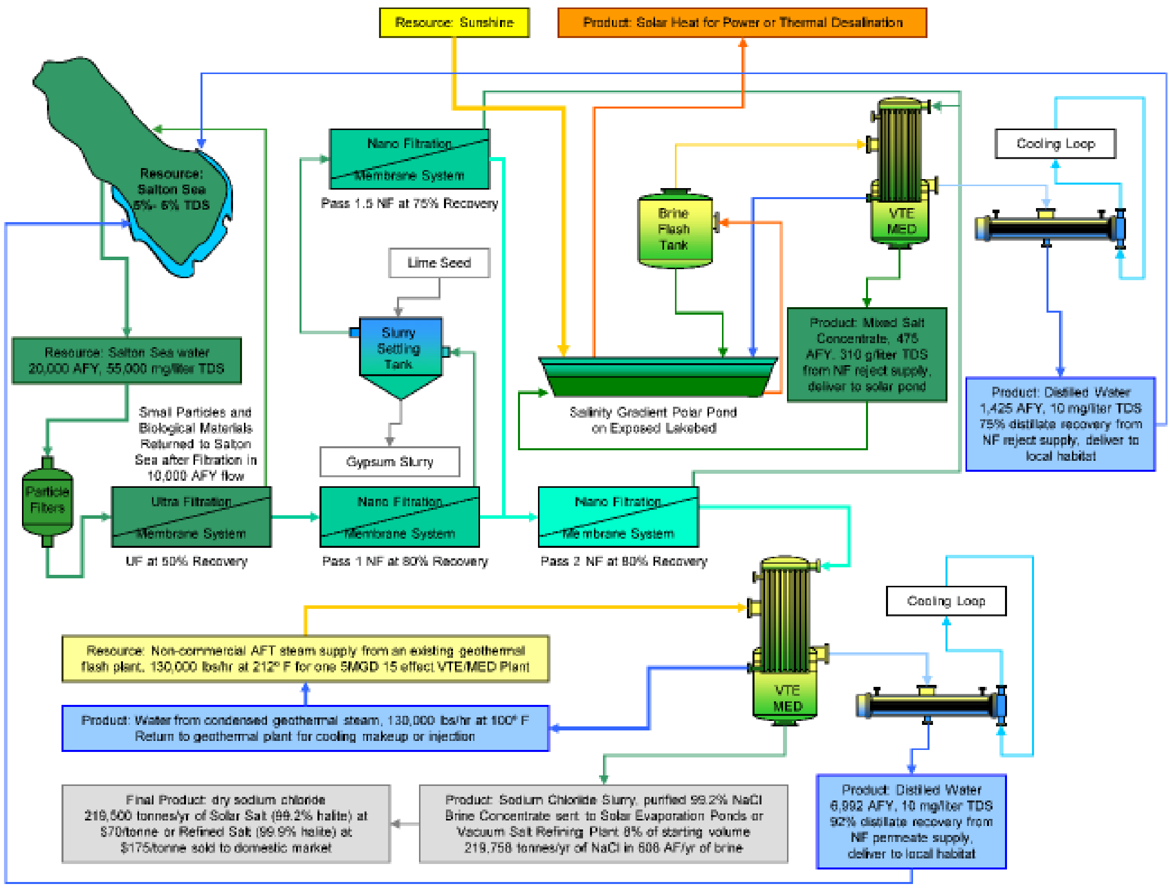

Figure 1. Salt Separation Process Proposed by Sephton Water Technology (Source: Reference 1)

1.2.1. Process recovery rate

The process concept, showing the relevant flow rate was included in the Sephton Water Technology proposal (1), Figure 1. According to this flow diagram, 20,000 AF of water will be pumped from the Salton Sea to produce 6,992 AF + 1,425 AF of low salinity water, which will be returned to the Salton Sea. Accordingly, the process recovery rate will be about 42%, 8,417/20,000 = 0.42085.

Therefore, based Figure 1, a system that would produce 20 million gallons per day (MGD) of low salinity water, would require pumping of 47.5 MGD of water from the Salton Sea. In this evaluation of the process proposed by Sephton Water Technology, we applied parameters for modern membrane filtration processes that would reduce the rate of feed water required for the process to 30.7 MGD (for production of 20 MGD of low salinity water). The result was an increase of the overall process recovery rate to 65%. Without accounting for this process optimization, developed by Tetra Tech, the power requirement for the process proposed by Sephton Water Technology would be significantly higher per unit of water produced.

More recent correspondence from Sephton Water Technology, after the submission of the original proposal in April 2022, includes a suggestion that the overall system process recovery rate should be the same as the recovery rate for the VTE-MED system, which was proposed to be 86%. This would assume that the VTE-MED treats Salton Sea water without any pretreatment.

However, the process flow diagram provided by Sephton Water Technology, reproduced in Figure 1, shows additional treatment steps, prior to VTE–MED: media filtration and membrane filtration. Operation of each of these steps would result in water loss for backwash of media filtration and membrane filtration units in addition to some water loss for membrane cleaning. In addition, there would be some water loss in the calcium sulfate precipitation unit. The combined raw water losses would be close to 35%.

Another component of water use, essential in evaporation desalination systems, is the cooling water for reducing temperature of the water vapor in the last evaporation stage. The process diagram showed in Figure 1 indicates cooling loops, but the cooling water was not included in the calculation of the system recovery rate provided by Sephton Water Technology (1). Including seawater usage in the cooling loop would reduce the value of the calculated process recovery rate.

1.2.2. Sizing of the equipment components

In the updated cost estimation provided by Sephton Water Technology, there is a reduction of the size of the ultrafiltration (UF) and NF units according to an assumed higher recovery rate. In the last set of calculations provided, the UF system would produce a filtrate flow of 22.7 MGD. This flow is the feed to the combined system consisting of NF units and VTE-MED units. According to the flows listed in Figure 1, the VTE system would operate at a recovery rate of 84.2% (10,000 AFY Salton Sea UF filtrate converted to 8,417 AFY of low salinity water). Accordingly, a 22.7 MGD of UF filtrate as a feed to the VTE-MED system would be capable of producing 19 MGD of low salinity water, or only 95% of the designed daily flow capacity of the low salinity product water.

1.2.3. Calculation of the electric power requirement and geothermal steam requirement for the proposed process

In the last submittal by Sephton Water Technology, the electric power requirement was adjusted according to their assumption of a higher recovery rate for the process. As explained above, this assumption is incorrect, and the electric power requirement should be updated. In Reference 2, the Sephton Water Technology submittal lists the geothermal steam requirement for the 20 MGD VTE–MED system as 120,000 pounds per hour (lbs/hr) at a temperature of 403^{o} F, at a price of \$0.0045/lb, calculated as an annual cost of \$4,493,880. This amount was added to the annual operating cost. However, 403^{o} F steam could be used effectively for the generation of electric power. The amount of geothermal steam, listed as required by the VTE–MED system, has the capability to produce 67,907,520 kilowatts per hour (kWh) of electricity annually. At the electric rate price of \$0.12/kWhr this would amount to an annual cost of \$8,148,902. If this electric equivalent value of geothermal steam cost were used, the total water cost produced by the system proposed by Sephton Water Technology would increase by about \$300/AF.

Another issue is the very high thermal performance efficiency assumed by Sephton Water Technology for the proposed VTE–MED system. The listed use of 120,000 lb/h of geothermal steam to produce 20 MGD of distillate (2), is equivalent to a Gain Output Ratio of 58 lb water/lb of steam. Two recently built MED units at Marafiq (Saudi Arabia), which have 7 MGD capacity each, have a Gain Output Ratio of 12.4 lb water/lb of steam (3). These MED units utilize a thermal vacuum compressor (TVC) to improve thermal performance of the MED units. The TVC unit has not been included in the Sephton Water Technology proposal. The largest MED unit in the world is Shoaiba 2 (Saudi Arabia), built by Sasakura in 2018. The MED system has a distillate capacity of 24 MGD capacity with 10 thermal effects and the Performance Ratio of 14.6 lb distillate/1,000 BTU (British thermal unit) (3). By comparison, the energy provided by the geothermal steam listed by Sephton Water Technology as a sufficient energy source for production of 20 MGD of distillate (2) is equivalent to a Performance Ratio of 69.4 lb distillate/1,000 BTU. The above listed MED units (Marafiq and Shoaiba) operate at significantly less demanding process parameters (lower feed and concentrate salinity, lower recovery ratio) than the designed process conditions of the VTE-MED unit, proposed by Sephton Water Technology. Their thermal efficiency is much lower than the thermal efficiency projected for the future VTE–MED system, which will concentrate a very high salinity Salton Sea feed.

There is a significant gap between the thermal efficiencies of the modern commercial thermal desalination units and the VTE–MED system proposed by Sephton Water Technology.

1.2.4. System Cost Provided by Sephton Water Technology

The total cost of the VTE-MED 60-effects unit designed to produce 20 MGD of distillate is listed as $30.64 M (in the Section: Cost Basis of Water and Salt Treatment Facilities, Reference 1, Figure 290. The total plant cost for production of 20 MGD distillate (VTE-MED cost plus additional construction-related costs) is provided by Sephton Water Technology as $49.85 M (Reference 1, Page 37). According to Reference (1), this amount will cover equipment and plant construction.

1.2.5. Revised VTE–MED System Cost Prepared by Tetra Tech

The cost estimation for the desalination system was limited to the equipment cost and the relevant miscellaneous cost items. The cost for development of the site infrastructure and providing necessary utilities was not included. To estimate the cost for the plant site preparation and construction work would require detailed specification of the site, development of plant layout, and survey of the local conditions (soil conditions, availability of electric power connections, waste disposal lines, etc.). Thus, the cost estimates provided below are a subset of the total costs that may be required to implement a desalination system for the proposed scale.

In the Sephton Water Technology submittal, the cost of a 20 MGD VTE-MED is listed at the initial value of $49,849,315. In comparison, the system cost estimated by Tetra Tech is $213,091,023. The Tetra Tech estimation of the VTE–MED cost is based on the cost information included in the "Brine-Concentrate Treatment and Disposal Options Report, Southern California Regional Brine-Concentrate Management, Study – Phase I, Lower Colorado Region, US Bureau of Reclamation (October 2009)," Reference 4. The Reclamation document lists the cost of a 5 MGD capacity brine concentrator. This cost was scaled up according to an empirical relationship, included in the report as a function of system capacity, and adjusted for the price escalation from 2009 to 2022 (6).

According to the experts in the field of the zero liquid discharge (ZLD) applications, the largest brine concentrator units operating in the U.S. are in the range of 1-1.5 MGD. Also, in their opinion, the cost of brine concentrators listed in the Reclamation report are in the correct range for the market prices for this type of equipment. The summary of costs of brine concentrator units is shown in Figure 2. This figure was provided by Mike Mickley, Ph.D., an internationally recognized expert in ZLD applications.

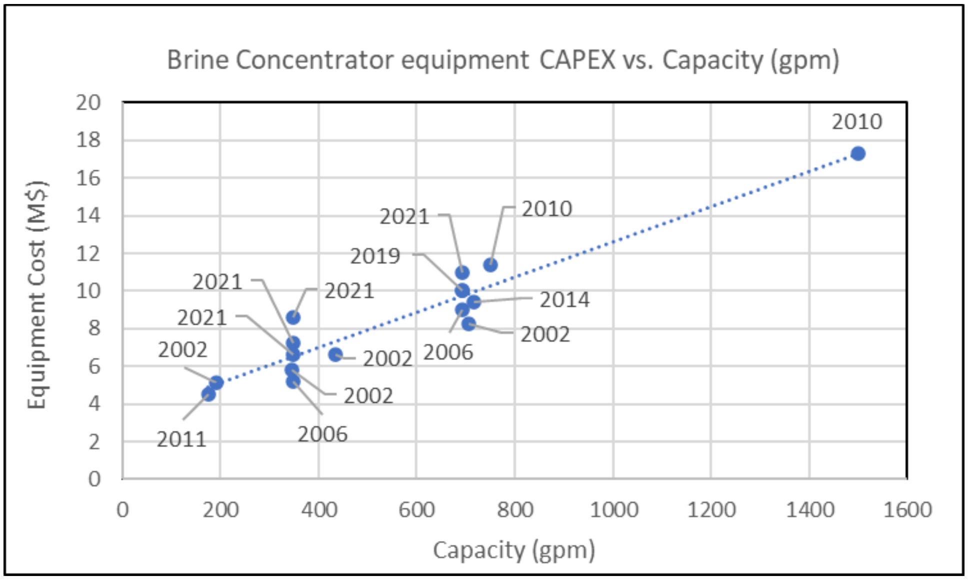

Figure 2. Brine Concentrators Equipment Cost and Year of Construction (Data source: M. Mickley)

The Sephton Water Technology installation cost for a 20 MGD VTE-MED ($49.85M) is similar to the 2009 cost of a 5 MGD brine concentrator, listed in the Reclamation report (4). Applying the index of the equipment cost increase from 2009 to 2022, the proposed cost of the VTE-MED 20 MGD unit would be about 60% lower than the cost of a 5 MGD brine concentrator, as published in the Reclamation report. Alternatively, for a VTE-MED 20 MGD system, the cost developed by Sephton Water Technology is only about 22% of the cost of the system derived from the Reclamation report data.

Another reference point could be the cost of regular MED systems used for desalination of seawater. The estimated cost of such systems manufactured from relatively inexpensive aluminum alloy is about $6/gallons per day (gpd) (8). Applying this cost to the system capacity of 20 MGD, a MED unit would result in a system cost of $120M. The estimated cost of MED systems consisting usually of 10-15 effects and using aluminum as the material of construction is significantly higher than the cost of the VTE-MED equipment, constructed from stainless steel and Copper-Nickel (Cu-Ni) alloys and consisting of 60 effects, provided by Sephton Water Technology.

Currently, the largest commercial MED unit is the Shoiba 2 unit with a capacity of 24 MGD and 10 thermal effects. No commercial MED unit with more than 15 thermal effects has been built and is operational (9).

Yet another issue related both to system cost and durability is the selection of construction materials. The Sephton Water Technology proposal lists stainless steel and Cu-Ni alloy as construction material for VTE–MED. These construction materials are adequate for an evaporation system producing distillate from seawater with salinity in the range of 35,000 – 45,000 PPM. In the case of the Salton Sea seawater, the inlet feed salinity is much higher, and the outlet brine salinity is at saturation. This level of salinity is very corrosive and more resistant alloys would be required as construction material for the system to operate reliably for a period of 20–30 years (7). For example, in brine concentrators manufactured by a commercial developer, RCC Thermal Products, which operate at a similar salinity range as the system proposed to treat Salton Sea seawater, the system components in contact with the high salinity brine are made exclusively from titanium alloy. These components include evaporators and heat exchangers (10, 11).

Additional supporting information regarding proper construction materials for the proposed application was received from the Nickel Institute (12). For treatment of water with a salinity in the range of the Salton Sea feed and system brine, the recommend alloy is Titanium grade 7 or 16. Some nickel alloys can be used but only if the feed water is fully de-aerated with dissolved oxygen concentration below 20 parts per billion (ppb). The process proposed by Sephton Water Technology does not include a deaeration step.

Based on the multiple factors above, the higher cost estimate for the VTE-MED system developed by Tetra Tech, as compared to the original Sephton Water Technology estimate (1), is considered justified. The results of calculation of the plant cost are summarized in Table 1.

Table 1. Summary of Plant Cost Components

System cost item	Flow rate or number of units	Equipment or system cost	Cost references
Salton Sea intake flow, mgd	30.7		
Salton Sea intake flow, gallons per minute (gpm)	21,296		
Wedge screen heads + air burst	2	657,065	Johnson Screen quote 2022 (14)
Required minimum water depth, feet (ft)	10		Jonson screen specifications (14)
Intake screens weight, lb	10,000		
Intake barge		659,782	Poseidon Barge Quote (15)
Intake barge installation and modifications for intake function		500,000	
Intake pumps, gpm	21,296	1,991,493	From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)
Electric power supply			
Intake HDPE pipe, diameter, inches	48		Sephton Water Technology process concept
Intake pipe length, ft	5,280		Tom Sephton, Appendix O Desal Plant Seawater Intake Cost (13)
Intake pipe weight (111 psi), lb/ft	158.5		Jim Eagle catalog, page 10 (16)
Intake pipe total weight lb	836,880		
HDPE polymer price, $/t	1,216		Global HPDE prices 2022 (17)
Additional components and installation, $/lb	1.0		Intake pipe components, intake pipe weights, connecting pipe segments and installation
Pipe placement and securing, $/lb	0.5		Placement of intake pipe and securing to sea floor, connecting to barge
Total intake pipe cost, $/lb	2.05	1,717,331	
Beach crossing and siphon	1.0	1,500,000	Estimation from previous projects

System cost item	Flow rate or number of units	Equipment or system cost	Cost references
Total intake	1.0	7,025,671	
Multimedia filtration feed, mgd	36.9		
Multimedia filtration effluent, mgd	33.3	9,975,739	Based on media filtration system cost of $0.3/gpd
Filtration rate, gpm/ft^2	3.0		
Filtration area required, ft^2	8,553		
Number of filter cells	12.0		
UF membrane filtration feed, mgd	33.3		
UF membrane filtration effluent, mgd	29.9	13,467,248	Based on membrane filtration system cost of $0.45/gpd
UF filtration flux, gfd	45.0		
Number of UF elements	1,209		
1st pass NF feed, mgd	29.9		
1st pass NF permeate, mgd	27.17	32,608,696	Based on NF system equipment cost of $1.2/gpd
Average permeate flux rate, gfd	15		
Number of membrane elements (440 ft^2)	4,117		
Number of pressure vessels (7 M)	588		
NF concentrate flow, mgd	2.75		
NF concentrate seeding system, mgd	2.75	42,284,646	Reference 4, price increase factor 1.667 CCCI (6)
2nd pass NF, feed, mgd	27.17		
2nd pass NF, permeate, mgd	21.74	26,086,957	Based on NF system equipment cost of $1.2/gpd
Average permeate flux rate, gfd	20		
Number of membrane elements (440 ft^2)	2,470		
Number of pressure vessels (7 M)	353		
VTE-MED System	20	213,091,023	Reference 4, price increase factor 1.667 CCCI (6)
Backwash streams to solids management, mgd	3.7	6,395,746	From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)
Electrical, VFD, MCC, instrumentation and control system	13970.1	14,557,961	From quotes for SWRO plant at Carlsbad (2009) multiplied by CCCI 1.667 (6)
Hypochlorite storage and dosing unit	1		
Hypochlorite dosing rate, ppm	3		
Sodium bisulfite storage and dosing unit	1		
Sodium bisulfite dosing rate, ppm	1		

System cost item	Flow rate or number of units	Equipment or system cost	Cost references
Acid storage and dosing unit (for coagulation)	1		
Acid dosing rate, ppm	20		
Coagulant storage and dosing system	1		
Coagulant dosing rate, ppm	20		
Lime storage and dosing system	1		
Lime dosing rate, ppm	50		
Acid storage and dosing unit (for pH adjustment)	1		
Acid dosing rate, ppm	5		
Scale inhibitor for NF dosing unit	1		
Scale inhibitor dosing rate, ppm	2		
Scale inhibitor for VTE dosing unit	1		
Scale inhibitor dosing rate, ppm	2		
Equipment cost for combined dosing units		491,149	Calculated from (seawater RO) SWRO plant at Carlsbad (2009)
Equipment contingency	20%	74,503,872	
Total equipment cost		440,488,707	
State taxes (California)	7.25%	31,935,431	Derived from the budget of the SWRO at Carlsbad (2009)
Engineering	8.00%	35,239,097	Derived from the budget of the SWRO at Carlsbad (2009)
Contractor markup	8.00%	35,239,097	Derived from the budget of the SWRO at Carlsbad (2009)
Startup energy + chemicals	2.00%	8,809,774	Derived from the budget of the SWRO at Carlsbad (2009)
Insurance and bonds	5.00%	22,024,435	Derived from the budget of the SWRO at Carlsbad (2009)
Subtotal		133,247,834	Derived from the budget of the SWRO at Carlsbad (2009)
Contingency	15.00%	19,987,175	Derived from the budget of the SWRO at Carlsbad (2009)
Total plant cost, 20 MGD of treated water production, excluding site work		593,723,716	

1.2.6. Operating Costs and Derived Water Cost

The parameters and calculated values for operating cost components are listed in Table 2. The calculations for the water cost components are based on cost parameters listed in Table 2.

In the calculation of the electric power required for plant operation of the VTE unit, the value listed in Reference 1 was used. For other process equipment, the required electric power was calculated according to common engineering practice.

For thermal energy required to operate the VTE-MED system, the assumption that there will be available low-pressure steam from a local geothermal plant (Reference 1) was utilized. However, there is no independent assessment to confirm if sufficient geothermal steam will be available for the operation of the evaporation unit for product water with a capacity of 20 MGD and eventually a 100 MGD.

The derived operating cost is $4.04/kilogallon (kgallon) or $1,316/AF. Therefore, the capital cost is $6.35 kgallon or 2,069/AF and the total water cost is thus $10.39/kgallon or $3,385/AF.

For comparison, the total water cost listed in the Salton Sea Recycling Project Report (1) is $582/AF.

Table 2. Operating Cost Components and Total Water Cost

Parameter	Value	Notes
Interest rate	5.0%	
Plant life, year	25	
Discount rate	7.10%	
Plant load factor	90%	
Annual water production, kgallon	6,570,000	
Number of operators	10	
Operators' annual salary+ G&A	104,000	
Chief operator	1	
Chief operator's annual salary + G&A	124,800	
Maintenance staff	2	
Maintenance staff annual salaries	166,400	
UF elements cost, $/element	1,650	
UF membranes warranty period, year	7	
NF elements cost, $/element	650	
NF membrane elements warranty, year	5	
Sulfuric acid, $/t (100%)	276	
Ferric coagulant, $/t (100%)	923	
Scale inhibitor, $/t (100%)	2280	
Sodium bisulfite, $/t (100%)	1617	
Sodium hypochlorite, $t (100%)	1209	
Lime, $/t (100%)	245	
Annual maintenance cost, % of equipment	2.0%	Of equipment cost
Regulatory compliance, $/year	500,000	
Pumps efficiency	0.82	
Motors efficiency	0.96	

Parameter	Value	Notes
VFD efficiency	0.98	
ERD efficiency	0.96	
Electricity rate, $/Kwh	0.12	
Seawater delivery, kW	736	
UF membrane feed, kW	399	
1st pass NF membrane feed, kW	2,993	
Concentrate seeding & precipitation, kW	35	
2nd pass NF feed	2,718	
VTE-MED	1,579	Provided by Sephton Water Technology (2)
Solids management system	419	
Chemical dosing units	5	
Air conditioning	20	
Lightning	50	
Controls and Automation	5	
Other Miscellaneous/Contingency transformation and cable losses (2%)	179	
Total power, kW	9,138	
Annual electric power cost, $/year	8,645,621	
Geothermal steam cost, $/year	4,493,880	Provided by Sephton Water Technology (2) (*)
UF elements replacement cost, $/year	285,021	
NF elements replacement cost, $/year	535,244	
Sulfuric acid, $/year	287,818	
Ferric coagulant, $/year	770,392	
Scale inhibitor, $/year	283,880	
Sodium bisulfite, $/year	61,814	
Sodium hypochlorite, $/year	138,621	
Lime, $/year	41,936	
Other chemicals, $/year	264,077	
Labor, $/year	1,497,600	
Maintenance, $/year	8,724,413	
Regulatory compliance, $/year	500,000	
Total annual operation cost, $/year	26,530,317	
Operating cost, $/kgallon	4.04	
Annual capital cost	41,717,981	
Capital cost, $/kgallon	6.35	Does not include the site development cost
Total water cost, $/kgallon	10.39	
Total water cost, $/AF	3,385	

(*) Cost of geothermal steam at 403^{o} F, 120,000 lb/hr, provided by Sephton Water Technology for a 5 MGD and 20 MGD distillate capacity. However, 403^{o} F steam could be used for electric power generation. This amount of geothermal steam has the capability to produce 67,907,520 kWh of electricity annually. At an electric rate of $0.12/kW-hr this will amount to an annual cost of $8,148,902. If this electric equivalent value of geothermal steam cost would be used, the total water cost produced by the system, proposed by Sephton Water Technology, would increase to ~$3,600/AF.

1.2.7. Purity of water harvested from the Salton Sea

According to a report submitted by Sephton Water Technology (1) as well as other published information about the Salton Sea, its water has been degraded and is contaminated. The report submitted by Sephton Water Technology (1) indicates the following:

> Page 3: "The locations where Salton Sea water will be recycled will also produce a stream of concentrated Salton Sea brine containing a mixture of salts and small organic molecules."
>
> Page 4: "In the last century the quality of the salt dissolved in the Salton Sea has been degraded by agricultural drainage and some industrial waste. The sodium chloride in the Salton Sea is now mixed with a substantial portion of sulfate from agricultural drainage, significant amounts of magnesium, and a modest amount of calcium, potassium, and bicarbonate, plus trace amounts of a wide range of elements. Fertilizer runoff stimulates a massive growth of microorganisms that decay to release a wide range of organic molecules."

Notably, fertilizers and pesticides in agricultural runoff could have resulted in the contamination of the seawater. Some residual ionic components of the fertilizers and small molecular size organics are not well rejected by the open-type NF membranes, proposed for this process. There is a concern that the above contaminants will end up in the dried salt, affecting its purity and market value. Currently, potential presence of these impurities is considered to be an uncertainty for evaluating the future economic value of this salt.

1.2.8. Groundwater Supply System

We have developed this evaluation of proposed costs for a groundwater well field system to provide a total of 50,000 acre-feet per year (AFY) of water to the Salton Sea. This proposed well field is expected to be located within two miles of a discharge point into Salton Sea.

Several key issues regarding this potential source of low salinity water to the Salton Sea remain to be identified. These items include:

- Location of the groundwater aquifer
- Water quality, depth, and production values for the groundwater aquifer
- Land availability and cost for well sites, pipelines, power service, etc.
- Required permits, water rights and environmental approvals.

The following sections outline our assumed design criteria based on past projects our staff has performed in Southern California. Extensive further study would be required to develop a more accurate estimated total cost for such a project.

DESIGN CRITERIA Table 3 contains the proposed capacity of the project used to develop our design criteria. Our proposed design criteria are included in Table 4.

Table 3. Project Capacity

Parameters	Capacity
Annual Production	50,000 AFY
Maximum Flow	31,000 GPM
Operating Time	24 Hours per day
Year Operations	365 days

Table 4. Design Criteria

Parameters	Quantities
Number of Well	22 (20 + 2 standby)
Well Flow	1500 GPM
Static Water Level	60 ft
Drawdown	40 ft
Total Lift	100 ft
Pipeline Head Loss	14 ft
Minimum Pipeline Pressure	23 ft
Total Dynamic Head	137
Pump & Motor	75 HP
Power Usage @ 1,500 GPM	43 KW
Pipeline Length	10,560 ft
Pipeline Diameter	54 In

Capital Cost Estimate We have assumed that a total of 20 wells would be required to produce the total flow of 31,000 GPM. Two additional wells would be needed for standby wells. Each well was assumed to have a total depth of 200 feet and a static water level of 60 feet below ground surface. The wells should be constructed of 304 stainless steel with louvered screens. A 50-ft sanitary seal should also be installed. A 1,000-ft long 12- inch connector pipe was included to connect the well to the 54-inch pipeline.

The wells would be equipped with 75-HP vertical turbine pumps, above ground piping, valves, electrical, and instrumentation. All equipment would be on a concrete pad and weatherproof. The pipeline would be sized to minimize head loss and reduce energy costs. It is assumed that the pipeline would be constructed in open ground with only minor utility crossings. The average depth of the pipeline would be assumed to be 4 feet below ground surface.

Table 5 contains the estimated capital cost of the project based on similar projects contracted in Southern California.

Table 5. Capital Cost Estimate

Item	Unit Cost	Quantity	Total
Well Field			
Well Drilling	$403,000	22	$8,866,000
Well Equipping	$628,000	22	$13,160,000

Item	Unit Cost	Quantity	Total
Mobilization, Permits, Startup	$92,000	22	$2,024,000
Subtotal			**$24,050,000**
54-inch Pipeline	$865	10,560	$9,134,000
12-inch Well Connector Pipe	$85	22,000	$1,870,000
Valves & Appurtenances	Lump Sum	1	$200,000
Subtotal			**$11,204,000**
		Total	**$35,254,000**
		Contingency 25%	$8,814,000
		Grand Total	**$44,068,000**

OPERATING COST ESTIMATE Operating costs are based on the calculated energy costs at a rate of $0.12 KWH for the wells to produce 50,000 AFY. We have assumed that the wells will need to be refurbished every 5 years at a cost of $225,000 to pull the pumps, clean the screens and pump the gravel pack. Labor, permits, and water quality sampling have also been included. The operating costs for pipeline labor and maintenance have been estimated based on costs per foot to operate pipeline systems in Southern California. Operating costs are included in Table 6.

Table 6. Operating Cost Estimate

Item	Unit Cost	Quantity	Total
Well Field			
Well Pumping Energy	$0.12 KWH	7,534,000 KWH	$904,000
Well Refurbishment	$45,000/Well	22	$990,000
Operating Labor, Permits, Sampling	$40,000/Well	22	$880,000
Subtotal			**$2,774,000**
54-inch Pipeline Labor	$8/ft	10,560	$84,000
12-inch Well Connector Pipe Labor	$6/ft	22,000	$132,000
Valves & Appurtenances	Lump Sum	1	$50,000
Subtotal			**$266,000**
		Total	**$3,040,000**
		Contingency 25%	$760,000
		Grand Total	**$3,800,000**

1.2.9. Summary of System Costs for the Sephton Water Technology Concept

The total system costs show in Table 7 were estimated based on the need for five desalination plants, each with a water production of 20 MGD, brine evaporation ponds, treated water distribution pipeline, and a groundwater well system to provide an additional 50,000 AFY of water to the Salton Sea.

Table 7. Total System Cost Estimate

Desalination System Capital Costs	2022 $	$M
Capital Cost per Plant excluding site work	$ 593,723,716	$ 594 M
Number of Plants		5
Factor assuming 10% economy of scale		90%
Total Cost of Five Plants		$ 2,672 M
Desalination System Operating Costs		
Cost Per 1,000 gallons	$ 4.04	
Cost MGD	$ 4,040	
MGD	100	
Cost per Day	$ 404,000	
Days per year	365	
Cost per year	$ 147,460,000	$ 147 M
AFY	112,000	
Cost Per AF	$ 1,317	
Brine Ponds Operating and Capital Costs		
Yearly Brine Flow (10.7 MGD per plant)	71,969	AFY
Monthly Brine Flow (10.7 MGD per plant)	5,997	AFM
Winter Evaporation Plus Seepage	0.5	ft/month
Area of Brine Ponds (acres)	11,995	
Cost per acre of brine ponds	$ 33,000	Based on DWR estimate of Saline Habitat Complex (SHC) in 2022 Dollars
Total Cost of Ponds ($)	$ 395,827,307	$ 396 M
Discount (20%)	0.8	Some SHC elements not needed
Pond Operations (5% of Capital Cost)	5%	Consistent with DWR estimate for operating SHC
Pond Operations		$ 16 M
Distribution Pipeline		$ 240 M, Sephton Water Technology estimate
Groundwater Well and Conveyance Pipeline Capital Cost (50,000 AFY)		$ 44 M

Desalination System Capital Costs	2022 $	$M
Groundwater Well System Operating Cost		$ 4 M
Total Capital Cost ($M)		**$ 3,272 M**
Total OMER ($M)		**$ 167 M**

1.3. References

1. Salton Sea Water Recycling Project, Response to Request for Salton Sea Restoration Concepts, Offered by Sephton Water Technology, Inc., April 2020.

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4. Brine-Concentrate Treatment and Disposal Options Report, Southern California Regional Brine-Concentrate Management, Study – Phase I, Lower Colorado Region, US Bureau of Reclamation (October 2009)

5. Equipment quotes and desalination plant budget for the 50 MGD Seawater RO Desalination Plant, Carlsbad, CA (2009)

6. DGS California Construction Cost Index (CCCI) (years 2009–2022)

7. Michael Mickley, Membrane Concentrate Disposal: Practices and Regulation, Final Report for U.S. Department of The Interior, Bureau of Reclamation, September 2001.

8. Information provided by the manufacturer of large MED systems (personal communication).

9. Personal communication with thermal process desalination experts.

10. GE offer for supply brine concentrators for Ft. Irwin project (2012)

11. https://www.ge.com/in/sites/www.ge.com.in/files/GE-recycle-water-with-zero-liquid-discharge.pdf

12. Information provided by the Nickel Institute

13. Tom Sephton, Appendix O Desalt Plant Seawater Intake Cost

14. Aqseptance Group – Johnson screen quote

15. Poseidon Barge Ltd quote

16. Jim Eagle Company – HDPE product catalog

17. HDPE global prices: https://www.statista.com/statistics/1171074/price-high-density-polyethylene-forecast-globally/

SALTON SEA MANAGEMENT PROGRAM

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