Chapter 5

Pump-Out / Pump-In Alternatives

The pump-out/pump-in alternatives are those that pump water from the Salton Sea to distant locations and then pump water to the Sea from other locations, in various combinations. Pumping water out removes salt laden water and thus reduces the amount of salt and salinity in the Sea. Using other pipelines, water is then pumped into the Sea. This fresher water decreases the Sea's salinity—in essence, diluting the salinity of the Sea. Some alternatives do not pump water into the Sea. These designs maintain the Sea's water surface elevation by balancing the pumped outflow and pumped inflow with evaporation and natural inflow.

While the salinity and water surface elevation depend on the natural inflow and evaporation, they also depend on the quantity and quality of the water pumped into the Sea. These alternatives assume an average inflow of 1.346 million acre-feet per year entering the Sea from surrounding areas, such as irrigation return flows, rivers, precipitation, and groundwater.

The options studied were not limited to the discrete alternatives presented in the 1997 report. Several of the 1997 alternative elements were incorporated into the 1998 alternatives. Without being limited to the 1997 designs, mixing and matching of various routes and being able to modify the criteria allowed additional preappraisal designs.

All ideas were not fulfilled, and designers did not completely design all ideas. If an alternative was not feasible from a technical perspective, that information is stated.

Salinity and Water Surface Level Interaction

To understand the interrelationship of the salinity concentration and water surface levels, the reader should first look at these as qualities in a natural lake. Most natural lakes have inlets and outlets. Waters entering the lake normally include natural sources (such as groundwater, rivers, and creeks) and manmade sources (such as pipelines and canals). Another water source is precipitation. Water leaves the lake through rivers, diversions, and evaporation.

Water and salts (and pollutants) enter the lake at various concentrations. Water and salts (and pollutants) flow out of the lakes in the rivers with concentrations of salt equal to the concentrations in the lake. Water also exits the lake, without the salts, through evaporation. Therefore, the salinity of the lake is a function of the difference in concentrations of salts coming into and leaving the lake. Some lakes, such as the Great Salt Lake and the Salton Sea, do not have natural outflows. Evaporation is the only means for water to leave the lake. Salt concentrations would continue to increase in such lakes.

The water surface elevation of a lake is also a function of the inflows and outflows. Topography is also a factor. Lakes that have rivers flowing out of them would have a lake elevation the same as the water surface elevation of the river. However, if a lake does not have a river to limit its elevation, then the lake level is a function of the evaporation rate. As the water surface elevation of the lake rises, the surface area usually increases, which, in turn, increases the area from which water can evaporate. Eventually, the lake surface elevation would reach an equilibrium so that the water flowing into the lake equals the water leaving the lake by evaporation. The lake levels would vary as the inflows and the rates of evaporation change. Such variations can be daily, seasonal, or long term.

From the information provided, one can conclude that the salinity of a lake without natural outflows would increase (or decrease) with time, and the water surface would stabilize, depending on the current inflows and evaporation rates.

The Salton Sea is not much different from natural lakes. The waters come from precipitation, natural rivers, groundwater, and irrigation. It has a very high rate of evaporation, but it does not have any rivers flowing out of it. Left to current conditions, the salt concentrations would continue to increase, and the water surface level would eventually stabilize (within normal variations) at a level slightly higher than it is now.

Design Considerations

Some of the items considered in designing the pump-in/pump-out alternatives are discussed in the following sections and include pipeline design, type of pipe, possibility of power recovery, and how saline water reacts with pipelines.

Pump-Out / Pump-In Water Conveyance Functions

We can think of the Salton Sea in the terms described above. The Salton Sea water conveyance systems would either replace or augment the water of the Sea in a way that rivers and streams replace or augment the water of natural lakes. The conveyance system that pumps water from the Sea simulates the rivers that flow from the natural lakes. Depending on the amount of water continually pumped out of the Sea, the salinity and the water surface level would stabilize within its variations. The salinity level could eventually be reduced to the salinity level of the inflows. The water surface elevation could be much lower than it is now.

The conveyance system that brings water into the Salton Sea serves to increase or maintain the water surface elevation higher than what the surface would be without it. It also dilutes the salt concentration. While diluting the salt concentration in the Sea is one goal, it also then dilutes the salt concentrations leaving through the pump-out conveyance system, requiring a larger capacity system to remove a given amount of salt.

This difficulty quickly leads to the conclusion that if water would be pumped into the Sea, then it is more economical to pump out as much water as possible before beginning to pump the fresher water into the Sea. The total amount that can be pumped out before pumping in begins is a function of how low the water surface elevation can be dropped.

Water Import Assumptions

Certain assumptions were made before the alternative designs began. Some sources of water were not available to consider as possible import sources. The designs for the alternatives could not use water from the Colorado River. The Colorado River waters are fully allocated, including groundwater that flows into the Colorado River. The stipulation also excluded boundary groundwaters that flow into Mexico and groundwaters that, if tapped, would cause water to flow from Mexico into the United States.

However, legislation pending before Congress would provide for the delivery of floodflows from the Colorado River to the Salton Sea under some circumstances. Diversion into the All-American Canal for delivery directly to the Salton Sea of floodflows in the Colorado River that are required by the Water Control Manual for Flood Control, Hoover Dam and Lake Mead, Colorado River, NV-AZ, adopted February 8, 1984, and which would pass to Mexico in excess of the amount required to be delivered pursuant to the Mexican Water Treaty and Minute 242 thereunder may be made available to carry out the purpose of this Act. The volume of water diverted pursuant to this subsection shall be limited to the excess capacity of the All-American Canal to carry such floodflows after, and as, it has been used to meet existing obligations.

The alternative designs also could not use groundwater and surface water within the Salton Sea basin. Such waters already flow into the Sea. Ground and surface waters from other States were also off limits. Wastewater from other regions or States, however, could be used.

Power Recovery Potential

Hydropower development should be considered when designing new pipelines. Although this is not the time to study the feasibility of producing hydropower on this system of pipelines, some sites do appear to be prime hydropower sites.

The feasibility of producing hydropower at a particular site depends on several things, including power rates, the type of plant and plant characteristics, discharge, and head. The amount of energy a hydropowerplant can produce is the product of the discharge, head, unit weight of the water, and the efficiency of the plant.

Possible power revenues depend not only on the current market, but also on the type and characteristics of the plant. The requirements of the power grid would vary greatly during the day. Plants that take a long time to reach full generating capacity produce most of the base power—coal-fired powerplants are a good example. Run-of-the-river hydropowerplants can also provide such energy. Grid operators must also provide power above this base load. For a coal-fired plant to meet these daily peaks, it would have to run continually at high enough output to meet the maximum loads, and excess energy would be wasted.

An optimum system would have system output follow the system requirements. A plant must be able to come on-line quickly to provide this peaking power if it is not to burn off the energy. Hydropower can meet these peaking plant requirements, provided that the plant characteristics are appropriate. Many high-head hydropowerplants can do this. Peaking plants can charge much more for the energy they produce than baseline plants.

The time in which a hydropowerplant can come on-line to produce energy is closely related to the surges produced in the penstocks. A plant coming on-line or going off-line too quickly produces great surges. Using surge tanks and designing the pipeline for higher than standard heads can counteract these surges. Both of these add to the plant cost.

The pipelines would flow continually in this design. Flow durations other than this would require larger pipes if the yearly discharge remains constant. Fluctuation of the discharge to supply peaking daytime power would require larger pipes.

The pipes are designed for static head. Greater surges require stronger pipes. A more complete design would include pipes large enough to allow the water to flow over the given distance and burn up the head through friction. Any head used for power production at full flow would require larger pipes.

Future, higher level designs should consider power generation. Run-of-the-river powerplants may be a viable option.

Saline Water Concerns

Saltwater can cause many problems with water conveyance features, such as pipelines, tanks, pumps, and inlets. The ions in the saltwater can greatly accelerate corrosion of steel and metallic surfaces.

Scaling is another major concern. Ocean water and Sea water are extremely "hard." Hard waters deposit calcium and magnesium on the surfaces they contact. Pipelines may become completely clogged even when hardness values are much less than at Salton Sea.

Other salts may precipitate out of the water and become a problem. The salts may be abrasive to the linings. Water in the conveyance system would be subjected to both temperature and pressures changes. The interaction of temperature and pressure must be fully understood before final design.

Most of these problems can be solved. Corrosion, scaling, and abrasion would not harm some polymer coatings. These coatings are quite expensive, and the costs for them have been included in the cost estimate.

Pipelines Only Design

The pump-in/pump-out preappraisal alternatives were designed using only pipelines. Other features could be used to convey water and may be appropriate. Pipelines were used in these designs only to decrease the time required for the design. It is highly unlikely that selection of a particular scheme or route would be affected by using only pipelines in the design. It would be prudent to analyze the feasibility and cost of canals and tunnels in a future analysis to aid in making the best choice.

Canals generally have lower capital construction costs than do pipelines, but their maintenance costs are higher. Canals must maintain a constant slope. The ground surface initially looks favorable for canal construction in the area where other canals already exist. There is a possible problem with geologic faults, however. A canal that crosses a fault may drop to an elevation that would render several miles of canal useless. This problem is particularly important where grabens are present, such as in the Salton Sea. Grabens are geologic blocks, bound by faults on two long sides, that have dropped relative to the surrounding geologic formations. A pressure pipeline, on the other hand, may need only to be repaired at the points of fracture.

Tunnels are more expensive to construct, per linear foot, than either canals or pipelines. Some redeeming qualities, though, are that tunnels are not as winding as canals and pipelines, which may give better hydraulic properties. Tunnels go under mountains, not over them as pipelines do; consequently, the number of pumping plants needed may be decreased, dramatically reducing energy requirements. Tunnels are usually much more environmentally acceptable than pipelines and canals and have shorter routes.

Type of Pipe

The type of pipe is not important at this level of design. It is important that a type of pipe be available that would satisfy design assumptions. These designs are based on using steel pipe with a polymer lining. In the size range of these designs, the pipe is available in any diameter and could easily accommodate the design pressures. In general, the pipe was sized to convey water at 5-foot-per-second velocity with pressure heads not greater than 500 feet of water. A pressure head of 100 feet was added to allow for surges. Pumping plants were designed for about 400 feet of head (lift).

Discarded Components

Some components were found to have problems that were obviously too costly to overcome.

Evaporation Lakes and Ponds. Clark Lake is a dry lakebed west of the Salton Sea. Past studies indicated this could be a location to place an evaporation lake. The area of the dry lake is much smaller than is required for such an operation. The area required engulfed Borrego Springs, population (1990) of 2,244, a State Wilderness Area, and a few landing strips. Three dams would be required for larger areas, one of which would be 560 feet high and more than 10 miles long. Designers deemed this site unsuitable.

The possibility of placing evaporation ponds in the Chocolate Mountains, which is now a military range, was also considered. The area is not very suitable because of the topography. Flat topography lends itself to constructing evaporation ponds. Steeper topography requires higher dikes. Large, one dam evaporation ponds become very expensive in steep topography. Although the cost of pipelines would be less for the Chocolate Mountain site than the Palen Lake site, the cost of dams would be higher and the cost of removing salt would be the same as at the Palen Lake site.

Groundwater for Salton Sea Restoration. Obtaining water from wells was studied in depth, was discarded, and is discussed in this section.

The criteria for locating a groundwater source to use to restore the Salton Sea were that the:

- Groundwater must be within the State of California
- Must not already be allocated to others
- Must not be tributary to the Colorado River or the Salton Sea

Aquifer Systems. Much of Southern California Desert physiographic area—the portion of southern California east of the Peninsular Ranges, the Transverse Ranges, and the Sierra Nevada—contains basin fill deposits consisting of sand, gravel, silt, and clay of continental origin. These sediments are saturated with water and are considered a principal aquifer within the State. The area is sparsely populated, and these aquifers have not been extensively developed. Recharge is largely limited by low rainfall (less than 6 inches per year) for much of the region. Locally, recharge by runoff from streams that originate in the high mountain occurs in isolated areas (U.S. Geological Survey, 1985).

For this subappraisal level assessment, it is prudent to treat recharge as insignificant. As such, any groundwater development would be a “mining operation” where the aquifers are depleted forever. Widespread groundwater development of aquifer systems in Arizona with similar geologic and hydrologic conditions has produced large, continuous declines demonstrating low recharge. Decisionmakers should consider the low recharge when searching for additional water sources.

Water Demands. Preliminary modeling efforts show that the volume of water required depends on the quality of the water. The tabulation below gives water volumes required to meet objectives in the two timeframes for selected concentrations.

Water required to meet objectives

TDS (mg/L)	Water volume (af/yr) Meet objectives in 15 years	Water volume (af/yr) Meet objectives in 30 years
925	100,000	NA
4,000	153,000	73,000
35,000	700,000	400,000

Previous Studies. Steinemann (1989) evaluated the quantity and quality of groundwater from the basin fill aquifers in the Southern California Desert as a potential supply of powerplant cooling water. The principal quantity criterion was that the aquifer could supply 30,000 acre-feet per year for 30 years from a well field. Of the 142 basins in the Southern California Desert initially identified by Koehler and Ballog (1979), only the basins listed in table 3 were deemed “suitable” to supply powerplants.

Table 3.—Basins capable of supplying 30,000 acre-feet annually for 20 years

Basin	Area (mi^2)	Storage (10^6 acre-feet)	Depth (feet)	Saturated thickness (feet)	Well yield Average (gpm)	Well yield Maximum (gpm)	TDS concentration Average (mg/L)	TDS concentration Range (mg/L)
Middle Amargosa Valley	1,300 620	18 8.6	100 CA	900 only	2,500	3,000	1,600	566 - 4,600
Soda Lake Valley	590	4-9.3	8-76	400	1,100	1,700	1,600	297 - 3,330
Caves Canyon Valley	100	2	0-200	?	990	1,990	?	622 - 2,680
Chuckwalla Valley	870	15	?	?	1,800	3,900	2,100	274 - 8,150
Calzona-Vidal Valley [1,2]	310	3.5	250	500	100	to 1,800	?	502 - 1,400
TOTAL		33.1 - 38.4						

[1] Basin is probably hydraulically connected to the Colorado River.

[2] Two separate basins in the work of Koehler and Ballog.

Although the magnitude and duration of the demand for the Salton Sea far surpass those required for a powerplant, Steinemann's work provides an ideal basis for rapid assessment of the potential for groundwater as a possible supply to restore the Sea.

Storage Volume *vs.* Usable Volume. The total volume of water in aquifer storage can never be completely removed. The fraction that can be removed depends on many factors, with the economics of installing wells and pump lifts probably controlling. Inconclusive data from the California DWR (1975) suggests that the usable volume of groundwater ranges from 10 to 50 percent of the total volume of water in storage.

Assuming the usable volume is 25 percent (probably high), the total usable volume of water in storage, excluding the Chuckwalla and Calzona-Vidal Valleys, which are probably hydraulicly connected to the Colorado River (Wilson and Owen-Joyce, 1994), is:

Basin	Usable storage (10^6 acre-feet)
Middle Amargosa Valley (California only)	2
Soda Lake Valley	1 - 2.3
Caves Canyon Valley	.25
Total	3.2 - 4.5

Aquifer Life. In the absence of significant recharge, extracting all usable storage from the four basins combined would sustain pumping from less than 10 years to more than 100 years. Actual values are presented in the tabulation below:

	Usable storage, (af)	
	$6.9x10^6$	$8.2x10^6$
	---- Aquifer life ----	
Demand (acre-feet per year)	(yr)	(yr)
73,000	94.5	112.3
100,000	69.0	82.0
153,000	45.1	53.6
400,000	17.3	20.5
700,000	9.9	11.7

Most basins (136 of 142) were excluded from the original screening for reasons such as lack of information, inadequate water quality, and inadequate water supply. The State (California DWR, 1987) estimates that more than 410 million acre-feet of water may be found in groundwater storage within the Southern California Desert. This estimate is about 10 times the volume of the 5 basins found to be suitable by Steinemann. Assuming a usable storage of 25 percent for the remainder of the area, if wells were drilled throughout the entire Southern California Desert and appurtenant pipelines were constructed, the desert could supply restoration needs for from 100 to 1,000 years.

Pipelines to convey water from these locations would have a total distance of 575 miles. Many more miles of pipelines would be required to collect water from individual wells.

Pipeline Routes

Pipelines to and from the Salton Sea encounter various terrain. In all but the pipeline from Yuma, pumps must lift the water over elevations higher than Salton Sea elevation. These lifts vary from 82 feet m.s.l. to 3636 feet m.s.l. All pipelines flowing to the ocean from the Salton Sea must overcome the 227 feet the Sea is below ocean level.

At this preappraisal level of study, it is common practice to obtain the pipeline length by multiplying the straight-line distance between the two ends by some factor. The actual routes were determined in these designs, thus ensuring the maximum pumping heads were found. Final design routes may be different.

Routes to the Pacific Ocean would encounter the coastal mountain ranges. The assumption was also made that routes would not go through Mexico. The two lowest passes that exist between Mexico and northeast of Los Angeles mark the location of the high points of these pipelines.

Each route location is shown in figure 13 and has its own advantages and disadvantages.

> San Diego, California, Point Loma Wastewater Treatment Plant (WWTP) – The route to Point Loma WWTP in San Diego travels over a pass one-half mile northwest of San Felipe at 3636 m.s.l. in the Laguna Mountains. The route would take the pipeline through approximately 30 miles of cities. Much of the route in San Diego would be under city streets. Tunnels would likely be economical to reduce energy and construction costs in the mountains, if incorporated into future designs. The route favors energy recovery from flow in each direction.

Figure 13.—Pipeline routes to and from Salton Sea.

Pacific Coast south of LAX airport, Hyperion WWTP – The route to the Hyperion WWTP is over a high point of 2630 m.s.l., a mile west of Beaumont. While much of this route is through cities, it follows existing utility corridors. This route does not favor tunneling or energy recovery.

Pacific Ocean – The route to Camp Pendleton, a Marine base at Oceanside, California, is the same east of the mountains as the Point Loma route. It crosses over the same 3636 m.s.l. pass. The routes separate on the west side of the mountains. Little of this route is in cities. Energy recovery is very favorable on this route for flow in each direction. Later designs would probably find that tunnels are very beneficial in reducing both energy costs and, possibly, construction costs.

Gulf of California – The route to the Gulf of California requires little pumping to go over the high point in Mexico of 82 feet m.s.l. This route has very gradual slopes and favors neither tunnels nor energy recovery. Because of energy losses in the pipe, this route does require that the flow velocities be less than the 5 feet per second used on all the other pipelines.

Yuma – Yuma, Arizona, is the destination for water from the potential Tucson Desalination Plant. This project would then pick up water in Yuma. The route (and cost) is for a pipeline from Yuma to the Salton Sea with gravity flow. Pumps would probably not be required. The route follows existing canal rights-of-way, does not favor energy recovery, and should not require any tunnels.

Palen Dry Lake – The route from the Salton Sea to Palen Dry Lake lies through the Chocolate Mountains and between the Eagle Mountains and the Chuckwalla Mountains, and the route reaches an elevation of 1680 m.s.l. before dropping down into the Chuckwalla Valley. Palen Dry Lake lies at 427 m.s.l. Both tunnels and energy recovery may be possible.

Pump-In Sources

To understand the number of possibilities for conveyances of the project, the reader must understand the pump-in sources, pump-out locations, and the routes. Remember that the flow capacities required for both pump-out and pump-in depend not only on the time desired to reach salinity and water surface elevation goals, but also on the salinity of the imported water. The main part of the pump-in/pump-out design is based on obtaining water from one of five sources.

San Diego, Point Loma WWTP – Point Loma is a wastewater treatment plant in San Diego, California, on the tip of a peninsula within the city. This water has a salinity of 1.75 ppt and has an estimated usable discharge of 268,000 acre-feet per year, which is greater than required.

Pacific Coast, Hyperion WWTP – Hyperion WWTP is located on the Pacific coast, south of LAX airport in Los Angeles. This new tertiary plant's effluent has a salinity of 0.925 ppt with an estimated discharge of 470,000 acre-feet per year, which is greater than needed. The design of this plant envisioned the water would be used to irrigate golf courses, parks, and other similar locations. This Hyperion water would cost $7.50 per acre-foot. Los Angeles has a water right of refusal in that the city of Los Angeles has the first option to use the water before it leaves the city.

Pacific Ocean – The pump-in water can come from the Pacific Ocean at various locations between Los Angeles and the Mexican border. Ocean water generally has a salinity of 35 ppt.

Gulf of California – Water coming from the Gulf of California would have a salinity similar to the ocean, but the salts may differ slightly from ocean water.

Yuma, Arizona – The city of Tucson is considering building a desalination plant to decrease the level of salts in the water coming from the Central Arizona Project. At 4 ppt, the effluent of this plant is considered salty when compared with fresh water. It is quite fresh when compared with the water in the Salton Sea. One of the routes considered by the Tucson project conveys the effluent to the Gulf of California via Yuma. Instead of flowing into Mexico, the effluent could flow to the Salton Sea for use in this project. Other cities in the Southwest may also need such repositories in the future with estimated flows of up to 200,000 acre-feet per year. The estimated available water from only the Tucson project, which includes water from Phoenix, is 67,000 acre-feet per year, which does not meet the estimated needs. Water from other sources would also be needed.

The Yuma Desalting Plant also rejects similar effluent but with a salinity of 10 ppt. Future alternative designs may wish to consider using this effluent as a source of water for the Salton Sea. This water may be intermittently available.

Excess flows — Some Colorado River water that is declared excess about every third or fourth year may be available as a source. The amount of water and the reliability of the supply have not been determined. Several complex issues exist. First, the majority of the water is unused Upper Basin State allocations. This water could be available for a few years or

> until the States use all of their allocations. Second, all users of Colorado River water, including excess flows, must have a contract with the Secretary of the Interior.

The requesting user needs are added to the bottom of the priority list that exists when his request is made for excess flows. Those at the top of the list may use all of the excess flows, leaving no water for those at the bottom of the list. Third, the infrastructure required to convey and store the water may have to be quite large. Floodflows, in particular, can be difficult to capture when a large volume moves through the system in a short time span. If significant quantities of surplus water were added to the Sea in a given year, this would add to problems of the surface elevation fluctuation. Such floodflows could be diverted and temporarily stored in a reservoir, allowing a smaller system for moving this water to Salton Sea.

Pump-Out Locations

The pump-out location designs were completed for conveyance systems to remove water from the Salton Sea to five locations. Three of these locations are the same locations discussed above as pump-in sources—Point Loma WWTP, Hyperion WWTP, and the Gulf of California. Another location is the Pacific Ocean off the coast of Camp Pendleton. These locations provide for final disposal, which would require a pipeline to be extended into the ocean and a diffuser attached to the end of it to ensure proper salt dispersal for the ocean environment.

Another location—Palen Dry Lake—that could be used as an evaporation lake is northeast of the Sea. Salt from this evaporation lake would have to be removed to another location at some future time.

The Yuma Desalting Plant's bypass drain was considered and deemed inappropriate. This drain flows to the Santa Clara Wetlands in Mexico. It is currently conveying water that has a salinity of 3.2 ppt. Previous studies have indicated salt concentrations greater than 6.0 ppt are unhealthy to cattails. For this reason, water in the drain must have salinity levels below 6.0 ppt. This precludes using the drain to convey water from the Salton Sea, which has a salinity greater than 40 ppt.

The bypass drain was considered to convey intermittent flows, which would require constructing a turnout at the wetlands. Canal operators estimated that 100 cubic feet per second (ft^3/s) of Salton Sea water could flow down the canal 50 percent of the time. The cycle would have to be about 2 weeks long. A flow of 50 ft^3/s is much less flow than any of the alternatives currently require. For this reason, and the salinity problem, using the bypass seems impractical. If an alternative in future designs uses lower flows than the current alternatives, then the bypass canal should again be considered.

Evaporation Ponds at Palen Dry Lake

The design of the evaporation pond is discussed here. The preappraisal design of the evaporation ponds at Palen Dry Lake used some potentially costly assumptions about the requirements of this site. Geologic investigations would provide data that may change the design and associated costs considerably. The question is whether or not the lakebed should be lined. During feasibility design and thereafter, the design must be sufficient to ensure that the lake would not leak saltwater and pollute the groundwater. The geology contained in the 1974 report indicates that the site contains much fat clay. If this clay exists throughout the site, the lakebed probably would not require lining. Lining would be required, however, where such a barrier does not exist. It was assumed that 25 percent of the lakebed would require lining. This lining would consist of a welded high density polyethylene geomembrane, with clay lining below and a protective soil layer above.

Another potentially costly question, discussed at the beginning of chapter 3, is whether the salt removed must be eventually removed to the ocean. The design assumes that it is hauled to the ocean. There, a pumping plant would mix the salt with ocean water before it would be piped to a diffuser at the end of a pipeline. The exact timing of the salt removal and an associated extra pond were priced as a percentage addition.

An appropriate Palen Dry Lake dam design was provided. Subsequent investigations may determine that a series of lagoons would serve the intended purpose better than a dam.

The lakebed area is the minimum required in meeting the evaporation needs from the Salton Sea.

Complete Designs

The team designed 23 complete alternatives of the pump-in/pump-out options. Figure 13 (previously shown) illustrates all routes, and table 4 shows all the pertinent engineering data about pipeline length, elevation achieved, and discharge flows and pipe sizes.

Table 4.—Pipeline length and maximum elevation

Route	Length	Maximum elevation (feet)	Term elevation (feet)
Los Angeles – Hyperion	165	2630	0
Pacific Ocean – Camp Pendleton	113	3,636	0
San Diego – Point Loma	126	3,636	0
Gulf of California	136	82	0
Palen Lake	49	1,680	427
Yuma	79	180	120

Pipeline discharge and pipe size

Discharge (acre-feet per year)	Discharge (ft^3/s)	Basic pipe diameter (inches)
73,000	101	61
100,000	138	72
130,000	180	81
153,000	211	88
170,000	235	93
200,000	276	101
250,000	345	113
300,000	414	124
303,000	419	124
400,000	553	143
500,000	691	160
600,000	829	175
700,000	967	189

Earlier in chapter 3, table 2 presented the cost data. Construction Field Cost is the cost to construct the facilities in the field. This includes all the contingencies. The Energy Costs column indicates the annual cost of obtaining energy required by the pumps. The Other OM&R column lists the total cost for operation, maintenance, replacement, and energy of equipment over the life of the project. While much of the design is based on constant operation, the present worth values are based on a 100-year life.

As noted above, future designs may reduce the costs for the Point Loma and Camp Pendleton alternatives.

Viewing the table and map allows the reader to understand most of the individual designs. The following provides highlights of some of the major features shown in table 2 and provides other information not included in the tables.

Design Nos. 1 through 10 reach a salinity of 40 ppt in 15 years from construction completion.

Design Nos. 1, 2, and 3 require the greatest flows into and out of the Salton Sea. Greater flows are required because the alternative design uses ocean water to replenish the Sea in the shortest time. Design Nos. 1 and 3 also use the most energy of the 23 designs.

Design Nos. 4, 5, 9, and 10 pump water in from wastewater treatment plants and pump water out into the ocean or gulf. Their construction costs are similar. The energy costs for Design Nos. 4 and 5 are much higher than for Design Nos. 9 and 10 because the latter requires much less head to pump to the Gulf of California than over the mountains.

Design No. 6 receives water from Yuma. This water is the effluent of the proposed reverse osmosis plant in Tucson. A question exists regarding if and when the plant would be built. The alternative design assumes that the water would be available at Yuma at the end of construction. The pipeline travels downhill on a gradual slope from Yuma to the Salton Sea. If hydraulics were the only concern, a canal could replace this pipeline. This is the least costly alternative regarding both construction and energy if the salinity goal is reached in 15 years.

Design Nos. 7 and 8 receive water from wastewater treatment plants and pump water out from the Salton Sea to Palen Dry Lake, where evaporation separates the water from the salt. The costs for the lake liner and dam were prorated from Design Nos. 17 and 18. The required reservoir is the more technically challenging, probably requiring moving several miles of interstate highway and Federal highway. The table does not include these costs. A small town would also have to be moved. The extremely high OM&R cost comes from the high operating costs of removing the salt to the ocean. These designs have the highest total present worth costs.

Design Nos. 11 through 20 closely relate to Design Nos. 1 through 10. These designs require less water to reach the salinity level in twice the time (30 years). The previous comments for Design Nos. 1 through 10 are essentially the same as for Design Nos. 11 through 20, with the exception of Palen Dry Lake. Design Nos. 17 and 18 are probably technically feasible, and cost estimates were prepared to preappraisal precision and accuracy. The costs for Design Nos. 1 through 10 are about 1.6 times the costs for Design Nos. 11 through 20 and are consistent with the change in flow rates.

Design Nos. 21 and 22 are totally different from the first 20 designs. They only pump water out of the Salton Sea. They have the lowest construction costs of any of the alternative designs, and their energy costs are among the lowest. This should be expected because the flows are relatively low and they require only pipes leading away from the Sea. These low costs are associated with a major drawback. The designs reduce the salinity in the Sea very slowly, which is discussed in detail in chapter 2 in the Salinity Model section. Figure 14 illustrates how this concept affects salinity. Pumping out only 69,000 acre-feet per year would eventually have the pump-out salt load equal the current salt load entering the Salton Sea.

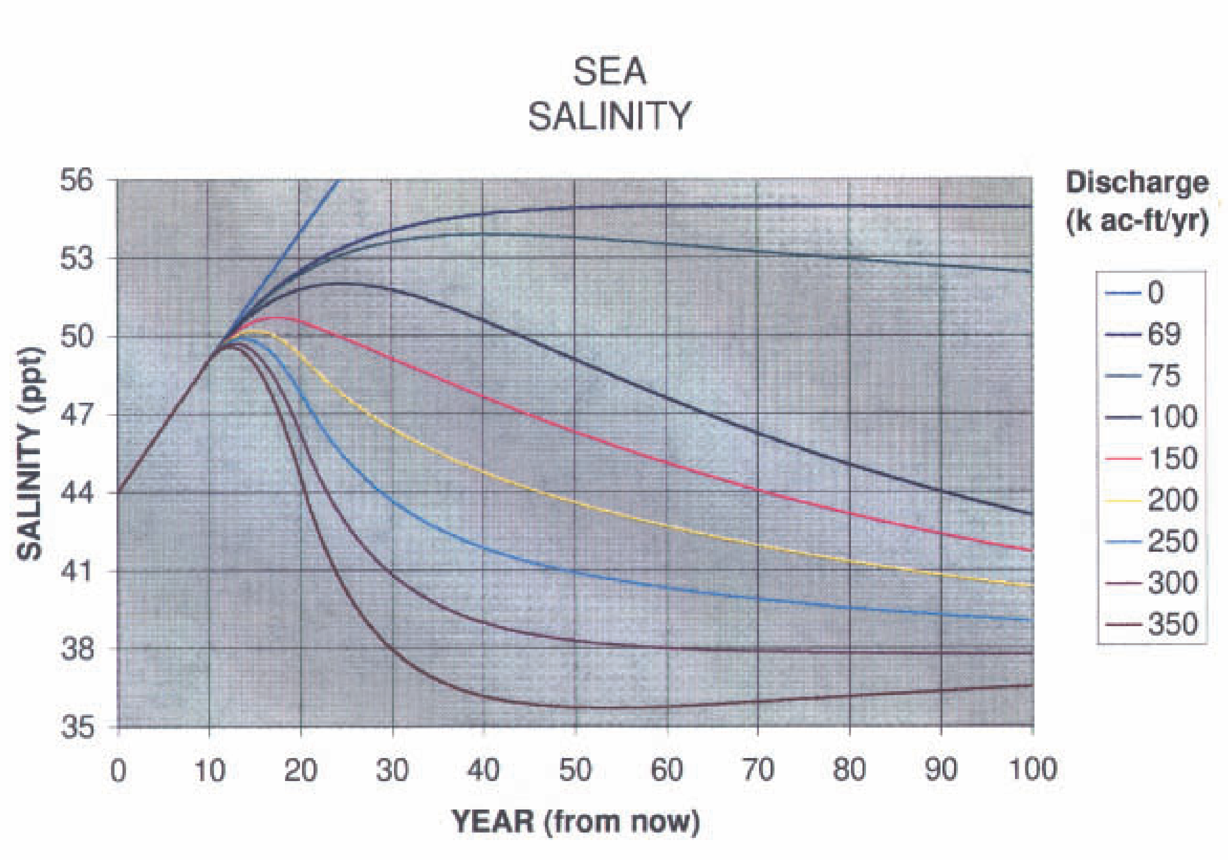

Figure 14.—Sea salinity at various pump-out rates in various years in the future.

Similar Designs

Two alternatives discussed in the 1997 report are very similar to the new pump-out/pump-in alternatives. Alternative 21 is similar to the new alternative 22. While the route for the 1997 alternative 21 travels to the west, along Laguna Salada, for preappraisal level designs, these routes are the same.

The 1997 alternative 22 pumps water out of the Salton Sea to Laguna Salada and pumps water in from the Gulf of California. Six of the new alternatives use ocean water to refresh the Salton Sea. Four of the new alternatives pump water out to a dry lakebed. The discharge quantities of alternative 22 would be similar to the ocean water alternatives, and the dry lakebed would have the same problems as Palen Dry Lake.