Summary of findings from the test you must make client aware of. Turbomister quote this test on their website so they acknowledge it as ok.

When they speak of ESS system they mean the Turbomister

- Page S6 The nozzels on the units plugged up
- Page S6 Mist fouling of the evaporators was a major problem.
- Page S6 The inline filters had to be cleaned numerous times per day to keep the units in operation.
- Page S6 Left unattended, enough mist could be digested into the units to force the impeller blades out of balance.
- Page S6 The devices had to be shut down every couple of days and pressure washed both inside and outside of the housings. This process was time consuming and was an endless task in the course of project operations.
- Page 20 The EES units were operated 24 hours per day, or whenever the winds were blowing below 10 mph.
- Page 20 A siren sounded on the meteorological tower whenever the winds exceeded 10 mph. This signaled the operator to shut down the EES systems.
- Page 20 The operator agreed to accommodate the tower signals 24 hours per day so that operating hours could be maximized. I.E the only way they could operate continuously was to have an operator there all the time.
- Page S9 This foulding results in significant reductions in efficiency of the units along with increased energy costs.
- Page S9 The system should be designed to shut down anytime the winds exceeded 10 miles per hour.
- Page 11 The meteorological tower was equipped with a controller that sounded a siren whenever the wind speed was 10 mph or greater. The site operator would then shut the systems down. A beep tone was sounded once the winds dropped below 10 mph for an extended period. The operator would then place the evaporators back into operation.
- Page 20 The EES units were operated 24 hours per day, or whenever the winds were blowing below 10 mph. During the winter and spring, the hours of operation likely were more limited by wind speed than they were during other times of the year. A siren sounded on the meteorological tower whenever the winds exceeded 10 mph.
- Page 74 It was observed during the course of the Test Base research project that significant gypsum fouling occurred in all closed conduits that carried brine around and between ponds. This was also the case in pumping water to EES units. I.E the pipework from the extra pumps required for the Turbomister foul up
- Page 75 such pipe, and fouling of them would be impossible to avoid without significant pretreatment to remove calcium before pumping through the system. At the Test Base, there was no pretreatment; therefore, the nozzles on the units plugged up regularly with gypsum and had to be cleaned and/or replaced daily.
- Page 75 Mist fouling of the evaporators was a major problem. Any wind from a non- aligned direction resulted in mist surrounding the units. Much of the mist was sucked into the impellers of the turbo fans, resulting in deposits like those shown in figure 5.8. Left unattended, enough mist could be ingested into the units to force the impeller blades out of balance. The devices had to be shut down every couple of days and pressure washed, both inside and outside of the housings. This

process was repetitive and time consuming over the course of project operations.

- Page 76 Photographs of Salt deposits on evaporators from mist ingestion.
- Page 83 During the test the machine could average 54gpm throughput at a power consumption of 93 kwh. Our machine operates at 80gpm using less than 75kwh. The client must understand that this is gallons pumped through the unit not water evaporated.
- Page 92 To reduce, but not completely eliminate, the risk of mist digestion by the EES units, each EES unit would need to be robotically slaved to multiple wind direction, wind speed, and wind shear detection systems. Any fouling by mist digestion by a significant number of EES units would be very expensive and time consuming to clean up.
- Page 93 The system should be designed to shut down any time the winds exceed 10 miles per hour.

lowest portion of the pond was a concrete sump. Entrained brine drained very slowly over the course of a couple of months to achieve the level of dryness desired.

The heaviest brines produced at the Test Base were those left in the disposal pond sump after the EES pre-test that was conducted in 2001. This test produced a thin layer of salts in the disposal pond and the quantity of entrained brines was relatively small. These brines drained towards the sump, where they evaporated over a period of months. These highly concentrated bitterns were pumped to the pond cell. The bitterns were moved before new saturated brines were pumped
into the disposal pond from EES and solar ponds. Over a period of weeks, nearly
all the bitterns were evaporated and precipitates were formed. Although not completely dry, and when mixed with the blowing sands that are omnipresent at the Test Base, the materials were more of a firm mud with an oily consistency than a liquid state. The final characteristics of the bitterns did not change beyond this muddy-like consistency.

EES Problems and Issues

Problems observed at the Test Base project that will have an impact on the design and operation of EES based salt concentration include gypsum and biologic fouling. Following are discussions and recommendations related to these issues.

Significant gypsum fouling occurred in all closed conduits that carried brine around and between ponds, including pumping water to EES units. A large EES project would include many miles of such pipe, and fouling of these would be impossible to avoid without significant pretreatment to remove calcium prior to pumping through the system. At the Test Base, there was no pretreatment and the nozzles on the units plugged regularly with gypsum. The nozzles had to be cleaned and/or replaced daily.

Brine fly populations were very large in the EES test pond. As a result, these flies and brine fly larvae were perpetually picked up by the pump. Two inline filters had to be installed before the EES units could remove this biologic material. Without the filters, the nozzles on the EES units plugged up. The inline filtershad to be cleaned numerous times per day to keep the units in operation.

Mist fouling of the evaporators was a major problem. Any winds at all from a nonaligned direction resulted in mist surrounding the units, and much of it was sucked into the impellers of the turbo fans. Left unattended, enough mist could be digested into the units to force the impeller blades out of balance. The devices had to be shut down every couple of days and pressure washed both inside and outside of the housings. This process was time consuming and was an endless task in the course of project operations.

3.2.2.3 Brine Chemistry Verification

Before the saturated brines produced by the EES units were mixed in the disposal pond with the saturated brines from the solar ponds, it was necessary to verify that the brines were chemically identical. The procedures used were consistent with the approach being taken by Agrarian Research for the East Side Solar Pond Project, located near Niland. It was fully expected that the brines would be identical. Once it was verified that the brines were identical, the EES-generated brines were transferred to the disposal pond in conjunction with continuous feeds of saturated brine from cell 7 of the solar ponds.

3.2.2.4 Saturated Brine Handling

The nearly saturated brine from the EES pond was pumped to the disposal pond using a 6-hp gasoline-powered, plastic trash pump that had a pumping capacity of about 200 gpm. The pumped brine was metered, and beginning and ending meter readings were recorded. Oil changes within the pump engine were made after every 5 hours of use.

3.2.2.5 Energy Usage

Energy usage of the EES units was not metered for most of the project life. However, usage was metered when EES efficiencies were studied in greater detail in the later phases of the project. Metering was not required over the entire period of the project because energy use by the devices was constant from hour to hour. The collected usage data were applicable to extrapolation over any period of use.

3.2.2.6 Wind Monitoring and Operations

The EES units were operated 24 hours per day, or whenever the winds were blowing below 10 mph. During the winter and spring, the hours of operation likely were more limited by wind speed than they were during other times of the year. A siren sounded on the meteorological tower whenever the winds exceeded
10 mph. This signaled the operator to shut down the EES systems. A beep tone sounded at the tower whenever the winds dropped below 10 miles per hour for 15 sustained minutes. The operator agreed to accommodate the tower signals
24 hours per day so that operating hours could be maximized.

3.2.2.7 Core Drilling

The drill used in core removal was a Hilti model DD250 E stand-type drill. The drill bits used were 6-inch inner diameter, and were also manufactured by Hilti. The bits were of the impregnated type. A special cart was constructed to serve as drill platform. This cart was constructed with pneumatic tires and four hand jacks. Weight was added to the platform using sand bags to allow for adequate herein. At the present time, no assessment of these testing results has been made and no recommendation can be made as to which method of construction is preferable.

Bittern management will not have to be considered in a salt deposit disposal project. The very small quantities of bitterns will be entrained in the final salt deposits during the course of operating a facility, as described above. Bitterns are defined as those brines that will be impossible to evaporate and will be very small in volume.

Enhanced Evaporation System

To alleviate gypsum fouling problems in the use of enhanced evaporators, it will be necessary to remove the calcium in the Salton Sea water before delivery to the distribution system. This would be required even with a single pass system whereby Salton Sea water was delivered directly to the evaporators.

Filtering brine fly larva and brine flies would be necessary before distribution to the EES units. Experiences gained at the Test Base project indicate that the loading of brine flies can be large enough to foul the nozzles on the units. This foulding results in significant reductions in efficiency of the units along with increased energy costs.

To reduce the possibility but not completely eliminate the risk of mist digestion by the EES units, it would be necessary to robotically slave each of the EES units to multiple wind direction, wind speed, and wind shear detection systems. Any fouling by mist digestion by a significant number of EES units would be very expensive and time consuming to clean up. For a project forecasted to include hundreds, if not thousands, of these units, such a cleanup event would require thousands of hours of labor.

Based on experience gained in the operation of EES units at the Test Base, it would be necessary to space the devices at least 250 feet apart in long rows. Salt and/or mist from the evaporators can travel 1,300 feet. Therefore, the rows of evaporators should be placed at least 1,300 feet apart. The ideal configuration would be to place the units in long rows over a large pond. The system should be designed to shut down anytime the winds exceeded 10 miles per hour.

Efficiency of the EES units compares performance to a solar pond facility without EES blowers. The energy costs are representative of the operation of the Slimline enhanced evaporators.

One test was performed to monitor time to saturate 3 million gallons of Salton Sea water. This test was run during the winter between December 31, 2001, and April 11, 2002, using both the SMI and Slimline evaporators. It took 102 days for the 3 million gallons to come to saturation and resulted in 198,000 gallons of saturated brine. Operating EES units to concentrate 3 million gallons of Salton Sea water during this time period resulted in a cost of $8,350.

Figure 3.7—SMI Polecat Evaporator.

3.1.2.1 Pond Configuration

The EES pond (cell 2) is 5 acres in surface area and includes a peninsula in the center of the pond, as shown in figure 2.1. This peninsula served as the platform on which the two evaporators were operated.

3.1.2.2 Pumping Facilities

The two evaporators received a combined metered flow rate of 120 gpm peak flow at 115 pounds per square inch (psi) from a 20-horsepower (hp) centrifugal pump through 1.5-inch diameter pressure hose. Water was pumped from the lowest portion of the pond through the units. Water sprayed out from the devices, so that a portion was evaporated and a portion fell back to the pond. The water was recirculated through the evaporators until the brine was nearly saturated.

3.1.2.3 Wind Control

The air quality permit to operate the evaporators required that the devices be shut down any time the wind speeds reached 15-minute average wind speeds of 21 miles per hour (mph) or greater; however, it was found to be more beneficial to the operation if the equipment was shut down when 15-minute average wind speeds reached 10 mph or greater. The meteorological tower was equipped with a controller that sounded a siren whenever the wind speed was 10 mph or greater.

The site operator would then shut the systems down. A beep tone was sounded once the winds dropped below 10 mph for an extended period. The operator would then place the evaporators back into operation.

3.1.3 Disposal Pond

The conceptual design of an on-land salt disposal facility has been made. This concept involves the construction of shallow solar-evaporation ponds impounded by earthfill dikes. These earthfill dikes would probably involve the construction of a starter dike, followed by the construction of additional dike raises after the initial pond filled with salt. The dike raise(s) would use the center-raise design
and construction approach, in which the dike centerline remains fixed and most of the raised dike's earthfill is constructed on the crest and on the downstream slope of the lower dike(s). This approach minimizes the amount of earthfill required
and maximizes the stability of the dike section, compared to the upstream-raise and downstream-raise concepts. The center-raise dike configuration is shown later in this section.

In the center-raise design, the upstream portion of the raised dike would be constructed on top of the salt pond material, creating a "christmas-tree" interface between the upstream edge of the dikes and the downstream edge of the salt pond material. The salt pond material would probably form part of the foundation for the upstream portion of the dike raises. Because of its function as part of the dike(s) foundation, the engineering properties and other characteristics of the salt pond material need to be determined or estimated. Hence, the best approach would be to obtain some Salton Sea salt pond material and perform the appropriate tests to determine its engineering properties and other characteristics.

A test disposal pond was constructed and operated at the Salton Sea Test Base. Although dike raises were not constructed at the site, the test disposal pond provided utility study of the characteristics and engineering properties of salts that would be deposited in a full scale project.

3.1.3.1 Pond Configuration

The disposal test pond (cell 10) was 2 acres in surface area and included a
36-inch-diameter sump that is 4 feet deep at the lowest point in the pond.
Figure 3.8 depicts the disposal pond looking towards the sump. The salt shown in the pictures was deposited during the 700-hour pretesting of the enhanced evaporators performed in 2001.

3.1.3.2 Pumping Facilities

A small ¼-hp sump pump, with 1-inch hose attached, was placed in the bottom of the sump to extract bittern from the pond. Brines pumped from the sump were discharged to cell 11.

3.2.2.3 Brine Chemistry Verification

Before the saturated brines produced by the EES units were mixed in the disposal pond with the saturated brines from the solar ponds, it was necessary to verify that the brines were chemically identical. The procedures used were consistent with the approach being taken by Agrarian

Research for the East Side Solar Pond Project, located near Niland. It was fully expected that the brines would be identical. Once it was verified that the brines were identical, the EES-generated brines were transferred to the disposal pond in conjunction with continuous feeds of saturated brine from cell 7 of the solar ponds.

3.2.2.4 Saturated Brine Handling

The nearly saturated brine from the EES pond was pumped to the disposal pond using a 6-hp gasoline-powered, plastic trash pump that had a pumping capacity of about 200 gpm. The pumped brine was metered, and beginning and ending meter readings were recorded. Oil changes within the pump engine were made after every 5 hours of use.

3.2.2.5 Energy Usage

Energy usage of the EES units was not metered for most of the project life. However, usage was metered when EES efficiencies were studied in greater detail in the later phases of the project. Metering was not required over the entire period of the project because energy use by the devices was constant from hour to hour. The collected usage data were applicable to extrapolation over any period of use.

3.2.2.6 Wind Monitoring and Operations

The EES units were operated 24 hours per day, or whenever the winds were blowing below 10 mph. During the winter and spring, the hours of operation likely were more limited by wind speed than they were during other times of the year. A siren sounded on the meteorological tower whenever the winds exceeded 10 mph. This signaled the operator to shut down the EES systems. A beep tone sounded at the tower whenever the winds dropped below 10 miles per hour for 15 sustained minutes. The operator agreed to accommodate the tower signals 24 hours per day so that operating hours could be maximized.

3.2.2.7 Core Drilling

The drill used in core removal was a Hilti model DD250 E stand-type drill. The drill bits used were 6-inch inner diameter, and were also manufactured by Hilti. The bits were of the impregnated type. A special cart was constructed to serve as drill platform. This cart was constructed with pneumatic tires and four hand jacks. Weight was added to the platform using sand bags to allow for adequate

Figure 5.7—Bitterns after 3 months of evaporation at Salton Sea Test Base

5.1.7 Mix Salts Domination

Observation and analysis of salts deposited in the disposal pond at the Test Base indicate the materials were a continuous mixture of Halite (NaCL) and Bloedite ($Na_2Mg(SO_4)_2 2H_2 0$). No stratification of salts was observed. These deposits are therefore described as mixed salt dominate.

5.2 Enhanced Evaporator Issues

Problems observed at the Salton Sea Test Base research project that will have an impact on the design and operation of EES based salt concentration includes gypsum and biologic fouling. Following are discussions and recommendations related to these issues.

5.2.1 Fouling of Closed Conduits

It was observed during the course of the Test Base research project that significant gypsum fouling occurred in all closed conduits that carried brine around and between ponds. This was also the case in pumping water to EES units. Figure 5.1 presents a cross section of a pipe almost entirely closed because of gypsum deposits. A large EES project would include many miles of such pipe, and fouling of them would be impossible to avoid without significant pretreatment to remove calcium before pumping through the system. At the Test Base, there was no pretreatment; therefore, the nozzles on the units plugged up regularly with gypsum and had to be cleaned and/or replaced daily.

5.2.2 Biological Fouling

Brine fly populations were very large in the EES test pond. As a result, these flies and brine fly larvae were perpetually picked up by the pump. Two inline filters had to be installed before the EES units could remove this biologic material. Without the filters, the nozzles on the EES units plugged up. The inline filters had to be cleaned numerous times per day to keep the units in operation at proper flow rates and pressures.

5.2.3 Mist Fouling of Evaporators

Mist fouling of the evaporators was a major problem. Any wind from a non- aligned direction resulted in mist surrounding the units. Much of the mist was sucked into the impellers of the turbo fans, resulting in deposits like those shown in figure 5.8. Left unattended, enough mist could be ingested into the units to force the impeller blades out of balance. The devices had to be shut down every couple of days and pressure washed, both inside and outside of the housings. This process was repetitive and time consuming over the course of project operations.

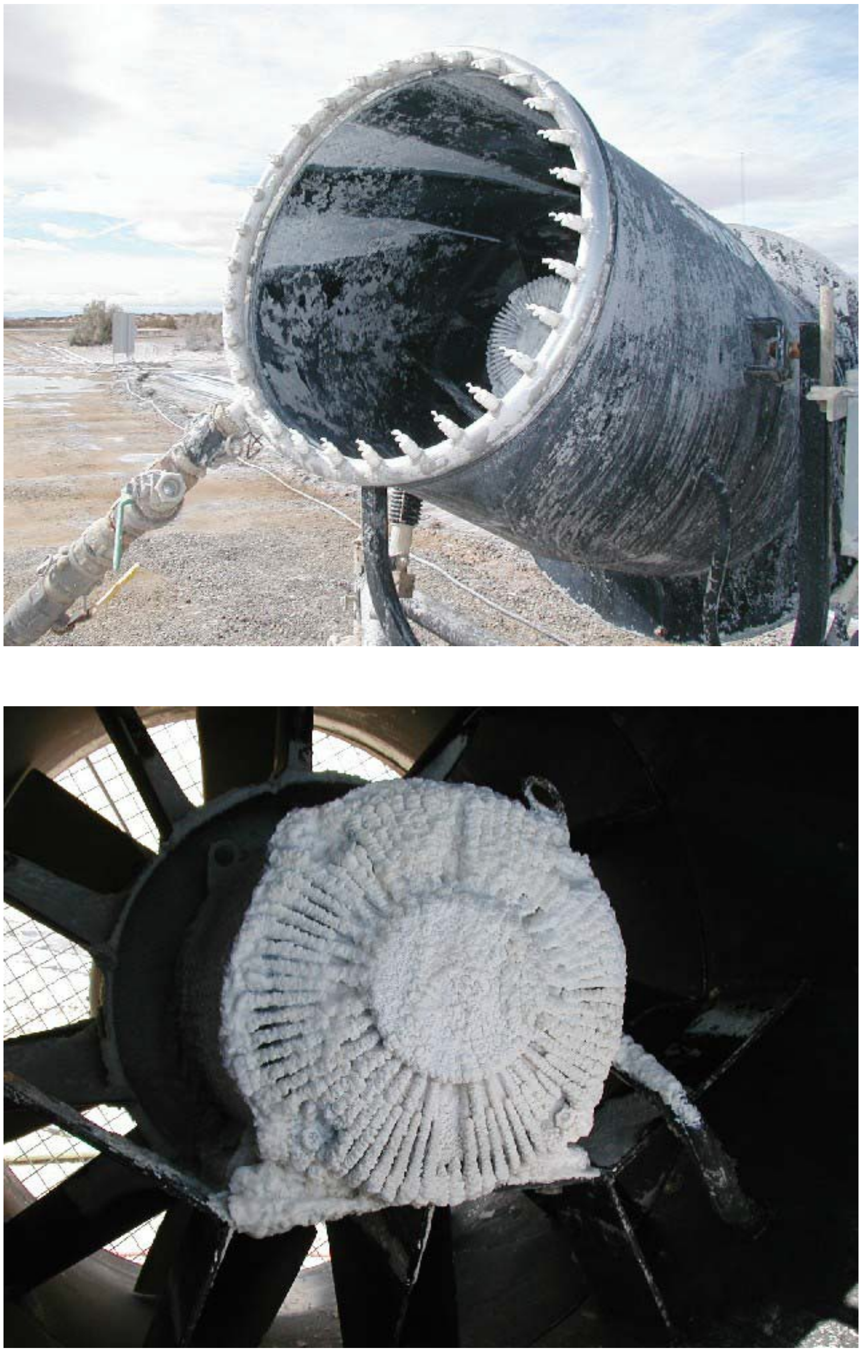

Figure 5.8—Salt deposits on evaporators from mist ingestion.

Table 5.1—Slimline EES power usage

Test date	Duration of test (hrs)	Volume pumped through Slimline EES unit (gal)	Rate (gpm)	Power use by EES unit (kwh)	Power use by feed pump (kwh)	Total energy used (kwh)	Energy use per hour of operation (kwh/hr)	Total Energy cost at $.097/kwh ($)
11/4/02	3.4	10,496	52	46	41	87	25.3	8.44
11/6/02	4.1	15,590	62	55	51	106	25.6	10.28
11/19/02	3.7	10,978	53	49	44	93	24.9	9.02
11/20/02	3.4	9,618	49	46	40	86	25.0	8.34
Average	3.7	11,671	54	49	44	93	25.2	9.02

The efficiency of the evaporators can be measured in comparison to solar pond project without evaporators. Based on the climate conditions that occurred during the period of EES testing at the Test Base, and on the results of the testing, it can be concluded that by placing two evaporators on a 5-acre pond, evaporation and salt production can be increased by 44 percent over a sole 5-acre solar pond. This depicted in figure 5.20.

The efficiency and cost studies presented herein are based on the assumption that the evaporators could be operated 63 percent of the time, as was possible for the December 31, 2001, to April 11, 2002, test. The analyses were also dependent on the power usage and costs associated with the pumps and evaporators used at the Test Base. Other equipment would certainly yield different results.

testing of dike foundation and borrow soils will probably need to include permeability testing, which may need to evaluate the effect of water versus brine fluid as the test's permeating fluid. The dike's design will need to control seepage of the brine fluid and/or entrained moisture out through the dike embankment and foundation, and may need to mitigate the related effect on the dike's static and seismic stabilities.

6.1.7 Bittern Management

Bittern management need not be considered in a salt deposit disposal project. The very small quantities of bitterns will be entrained in the final salt deposits during the course of operating a facility, as described above. Bitterns are defined as those brines that will be impossible to evaporate and will be very small in volume.

6.2 EES Recommendations

6.2.1 Pretreatment Research to Remove Calcium

To alleviate gypsum fouling problems when using enhanced evaporators, it will be necessary to remove the calcium in the Salton Sea water prior to delivery to the distribution system. This would be required even with a single pass system, whereby Salton Sea water would be delivered directly to the evaporators. As the water exits the nozzles, it begins evaporation immediately and gypsum scales up the nozzles. Research and testing of methods to perform pretreatment will need to occur before any serious attempt is made to apply enhanced evaporation system technology to Salton Sea reclamation projects.

6.2.2 Pretreatment Research to Remove Biologic Materials

Filtering of brine fly larva and brine flies will need to occur before distribution to the EES units. Experiences gained at the Test Base project indicate that the loading of brine flies can be large enough to foul the nozzles on the units, which results in significant reductions in efficiency and increased energy costs. Before a large scale EES project could be designed and implemented, it would be necessary to research methods of self-cleaning inline screens.

6.2.3 Robotic Wind Alignment

To reduce, but not completely eliminate, the risk of mist digestion by the EES units, each EES unit would need to be robotically slaved to multiple wind direction, wind speed, and wind shear detection systems. Any fouling by mist digestion by a significant number of EES units would be very expensive and time consuming to clean up. For a project forecasted to include hundreds, if not thousands, of these units, such a cleanup event would require thousands of hours of labor.

6.2.4 Unit Spacing and Configuration

Based on experience gained in the operation of EES units at the test base, it would be necessary to space the devices at least 250 apart. The devices should be placed in long rows. A survey of operations at the Test Base yielded the conclusion that salt and/or mist from the evaporators can travel 1,300 feet. Therefore, the rows of evaporators should be placed at least 1,300 feet apart. The ideal configuration would be to place the units in long rows over a large pond. The system should be designed to shut down any time the winds exceed 10 miles per hour. Otherwise, the 1,300 feet will not be adequate. Determining drift characteristics at speed in excess of 10 miles per hour was not possible at the Test Base. The permits for the operation of the EES units limited operations to 10 miles and hour or less. Additional research into drift distances at higher speeds would be required before a large-scale system could be designed. However, increased drift distances would only translate into much larger pond sizes and row spacing.

6.3 Intake Recommendations

The following recommendation is made based on experience with operations of the intake structure at the Salton Sea.

Future intake structures at the Salton Sea would be much easier to maintain and to operate if they were shoreline based. System elements would include a shoreline stilling basin with a dredged trench from the basin to a significant distance out into the deep water of the Salton Sea. Intake pumps could then extract water from the shoreline basin without the need for a long, difficult-to-maintain pipeline.
Fish screens would, however, still be necessary. The stilling basin would not only provide a deep source for pumping, but it would also act as a sedimentation pond whereby suspended particles would settle before being picked up by the pumps. Protection against barnacle fouling of these screens and inland pipelines could be accomplished through the application of an REF system, as shown in figure 5.11. It would be necessary to give consideration to redundant pump and screen facilities to guarantee reliability of project deliveries. Redundant screens and pumps would also facilitate backflushing of onshore lines to remove settled barnacle shells.

6.4 Proposal for Behavior Model

The behavior of solid salt under load is dependent on time, temperature, pressure, mineral content, liquid brine chemical composition, and ion and vapor exchange with the surrounding environment. Mathematical expressions are sought to predict salt strength and density in terms of the above-mentioned variables, in order to evaluate the stability of retention pond dikes and to improve estimates of the expected capacity of evaporation ponds.

A parametric study is proposed which develops first and second order relationships between time, temperature, pressure, and salt density. It is