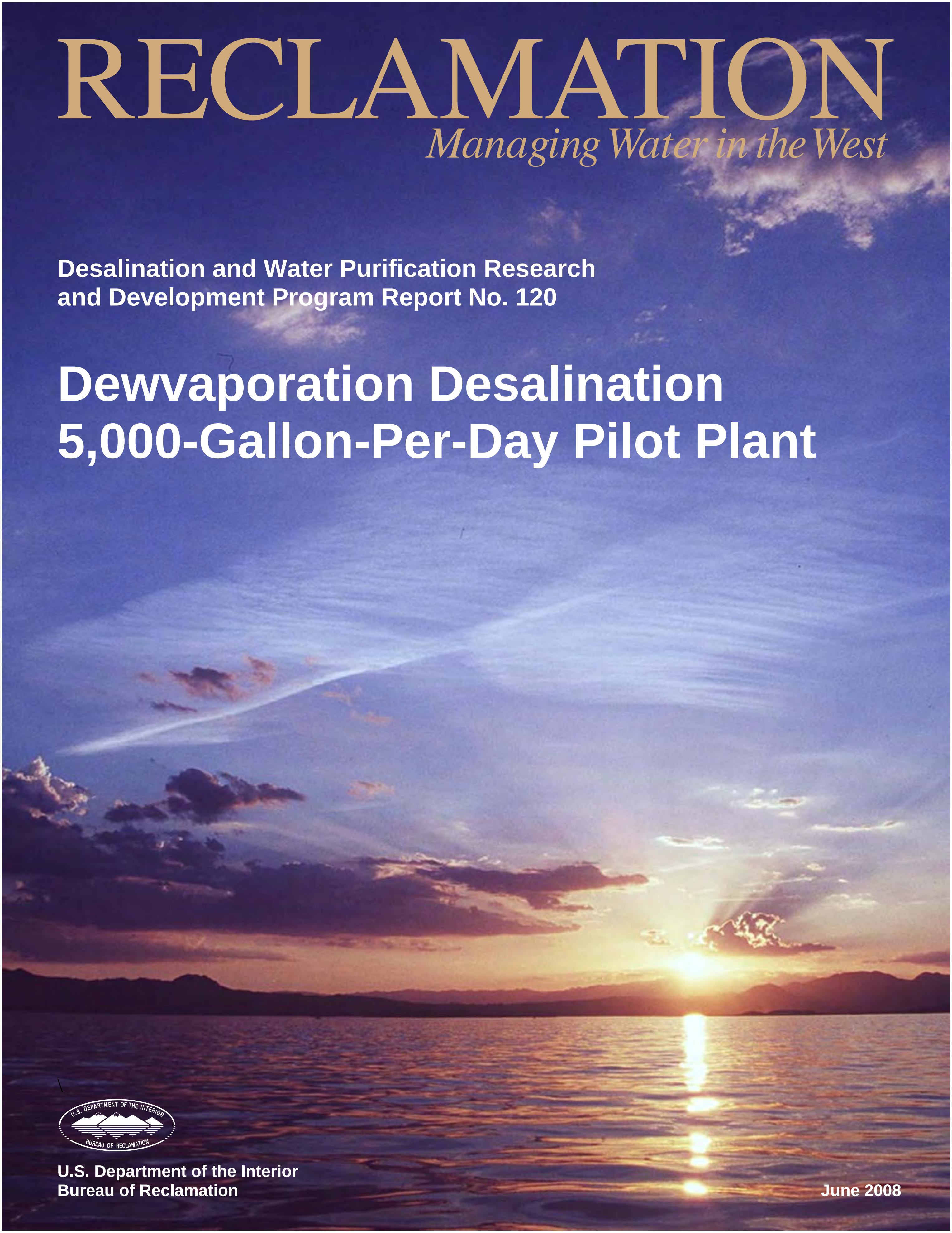

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No. 120

Dewvaporation Desalination 5,000-Gallon-Per-Day Pilot Plant

U.S. Department of the Interior
Bureau of Reclamation

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1937 E. Calle de Arcos
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A 5,000-gallon-per-day dewvaporation pilot plant was designed, built, and operated at the 23rd Avenue Waste Water Treatment Plant (WWTP) in Phoenix, Arizona. The City of Phoenix Water Services Department, along with the Bureau of Reclamation Phoenix Area Office, cooperated to establish a pilot plant site. The pilot plant feed was the concentrate from a Tactical Water Purifier System reverse osmosis (RO) unit with ultrafiltration pretreatment. A 2,000-milligram-per-liter (mg/L) total dissolved solids (TDS) waste water RO concentrate stream was treated by the pilot plant to more than 45,000 mg/L of TDS brine and 10 mg/L of TDS distillate. Recovery varied from 70 percent to 100 percent, with no decrease in distillate rate or increase in distillate contamination. Thermal multiple effects varied from 2.0 to 3.5, which was less than the 5.0 effects demonstrated prior to transport to the WWTP site. Operating cost was highly dependent of the price of fuel. Using the average of the three best thermal multiple effect values of 3.2 and natural gas cost of $0.80 per therm, the operating cost of water would be $20.85 per 1,000 gallons. The use of waste heat or solar thermal would reduce the operating cost to the cost of water pumping and air blowing. Power needs of 0.5 kilowatthour (kWh) per 1,000 gallons at $0.10 per kWh would amount to $0.05 per 1,000 gallons.

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Desalination and Water Purification Research and Development Program Report No. 120

Dewvaporation Desalination 5,000-Gallon-Per-Day Pilot Plant

Prepared for Reclamation Under Agreement No. 03-FC-81-0905

by

James R. Beckman

L'Eau LLC
Tempe, Arizona

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Water and Environmental Resources Division
Water Treatment Engineering Research Team
Denver, Colorado

June 2008

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Disclaimer

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Glossary

A	heat transfer area (ft^2)
c_p	heat capacity (BTU/lbmole ˚F)
B	14 (SI) 16.38 (American Engineering)
F	feed flow rate (lbmole/sec)
G	carrier gas flow rate (lbmole/sec)
$\underline{h}$	molar enthalpy (BTU/lbmole)
h	heat transfer coefficient (BTU/hr ft^2 ˚F)
k	thermal conductivity (BTU/hr ft ˚F)
L	liquid flow rate at any position in the tower (lbmole/sec)
M	mass transfer factor
N	molar flow rate (lbmole/sec)
P_w	vapor pressure of water (psia)
P	total pressure (psia)
Pf	production density (lb/hr ft^2)
Q	energy input at the top of the tower (BTU/sec)
q	heat flux (BTU/hr ft^2)
R	gas constant (BTU/lbmole ˚F)
RH	relative humidity
S	salinity at any position in the tower
T	temperature (˚F)
t	thickness of heat transfer wall (ft)
U	overall heat transfer coefficient (BTU/hr ft^2 ˚F)
V	vapor loading (lbmoles of water vapor per lbmole of gas)
w	width of the flow media (ft)

Subscripts

B	brine stream
D	distillate stream
d	dewformation side
e	evaporation side

Subscripts (continued)

f	liquid film
g	gas
h	top of the tower
0	bottom of the tower
ref	reference point
RH	relative humidity
LM	logarithmic mean

Greek

λ	heat of vaporization of water (BTU/lbmmole)
δ	liquid film thickness (ft)
Γ	gamma (lb/hr ft)
ρ	Density (lb/ft^3)
μ	viscosity (lb/ft sec)

Abbreviations and Acronyms

ABS	acrylonitrile butadiene styrene
ASU	Arizona State University
gpd	gallons per day
gpm	gallons per minute
HDH	humidification/dehumidification
kWh	kilowatthours
lb/hr	pounds per hour
lb/in^2	pounds per square inch
mg/L	milligrams per liter
mm	millimeters
NAS-T	a unit with air flowing up or **N**orth on the evaporation side **A**nd then flowing **S**outh or down on the dew formation side of the **T**ower.
NEWT	a tower where the air flow pattern is first **N**orth on the evaporation side and then **E**ast and **W**est or zigzag on the downward flow path on the dew formation side of the **T**ower.
PXAO	Phoenix Area Office
TDS	total dissolved solids
TWPS	tactical water purification system

1. Executive Summary

Dewvaporation is a specific process of humidification-dehumidification desalination, which uses air as a carrier-gas to evaporate water from saline feeds and form pure condensate at constant atmospheric pressure. The heat needed for evaporation is supplied by the heat released by dew condensation on opposite sides of a heat transfer wall. Since external heat is needed to establish a temperature difference across the wall, and since the temperature of the external heat is versatile, the external heat source can be from waste heat, from solar collectors, or from fuel combustion. The unit is constructed out of thin water wettable plastics and operated at atmospheric pressure.

A 5,000 gallon-per-day (gpd) dewvaporation pilot plant was designed, built, and operated at the 23rd Avenue waste water treatment plant (WWTP) in Phoenix, Arizona. The City of Phoenix Water Services Department, along with the Bureau of Reclamation Phoenix Area Office cooperated to establish a pilot plant site. The pilot plant feed was the concentrate from a Tactical Water Purifier System reverse osmosis (RO) unit with ultrafiltration pretreatment.

A 2000-milligram-per-liter (mg/L) total dissolved solids (TDS) wastewater RO concentrate stream was treated by the pilot plant to more than 45,000 mg/L TDS brine and 10 mg/L TDS distillate. Recovery varied from 70 percent to 100 percent with no decrease in distillate rate or increase in distillate contamination. Thermal multiple effects varied from 2.0 to 3.5, which was less than the 5.0 effects demonstrated prior to transport to the WWTP site. Distillate production rate varied among towers, producing approximately 5 gallons per minute (gpm) per tower, which was less than the target rate of 8.3 gpm. Operating cost was highly dependent on the price of fuel. Using the average of the three best thermal multiple effect values of 3.2, and natural gas cost of $0.80 per therm, the operating cost of water would be $20.85 per 1,000 gallons. The use of waste heat or solar thermal would reduce the operating cost to the cost of water pumping and air blowing. Power needs of 0.5 kilowatthours (kWh) per 1,000 gallons at $0.10 per kWh would amount to $0.05 per 1,000 gallons.

2. Background and Introduction

Many technologies have been used to perform desalination, resulting in preferred technologies based on economics (Fosselgard and Wangnick [1]). For example, in the desalination of mild brackish (less than 1,000 milligrams per liter (mg/L) TDS) water, reverse osmosis (RO) is superior to all desalination technologies. This is mainly a reflection of the fact that other technologies involve phase change (boiling), whereas RO employs low-pressure pumps (less than 100 pounds per square inch (lb/in^2) (7 bar)) to move water through semipermeable membranes, resulting in less energy consumption than that involved in a boiling process. One area where RO is ineffective in water purification is in the treatment of waters containing nonfilterable suspended particulates. For example, the Colorado River contains silt in the 1-micron range, which tends to foul RO membranes, increasing the maintenance and/or pretreatment costs of RO operation.

For the more TDS intense aqueous applications such as RO concentrates (Mickley [2]), waste streams, and seawater, other mechanical and thermal technologies economically compete with RO, as seen by Larson et al. [3], [4]. In the case of seawater desalination, the RO pump pressure increases to 1,200 lb/in^2 (80 bar) and feed waters require extensive pretreatment in order to protect and extend the life of the membranes.

The competitive technologies to RO for seawater desalination include mechanical vapor compression (MVC), multi-stage flash distillation, and multi-effect distillation with and without thermal vapor compression. The MVC needs shaft power to drive its compressor. The motor can be either electrically or thermally driven. For electrically driven MVC, MVC plants consume more electricity than RO units in the same seawater service. The other processes dominantly use and reuse heat as the main driver to affect temperature-driving force between boiling and condensing at staged pressures. The thermally driven plants attempt to reuse the high temperature applied heat as many times as is economically possible to minimize operating costs. This energy reuse factor economically varies from 6 to 12.

2.1 Dewvaporation Philosophy

Thermal processes that operate below the boiling point of water are called humidification/dehumidification (HDH). Younis et al. [5] investigated HDH units using solar energy as the external heat source. Just like the steam-driven external heat operation of an HDH, two heat transfer towers (or zones) are required to transfer heat from a massive flow of water. The water is used as both an internal heat source and internal heat sink. The requirement of two towers makes the HDH process energy inefficient. The dewvaporation technique belongs to the HDH family of technology but requires only one tower making it more energy efficient.

The Arizona State University (ASU) patented technology (Beckman [6]), dewvaporation, is applicable to desalination and reclamation of seawater, brackish water, evaporation pond water, RO plant concentrates, chemical mechanical planarization slurries from the semiconductor industries, volatile organic (methyl tertiary butyl ether, trichloroethylene) contaminant removal from ground, and other impaired sources. Dewvaporation's most economic niche is in small plant applications. Larger plants will evolve in time.

The standard dewvaporation continuous contacting tower is a relatively new, nontraditional, and innovative heat driven process using air as a carrier-gas and remaining at atmospheric pressure throughout the device. The external heat source can be from low temperature solar (131 ˚F [55 ˚C]), waste heat, or combustible fuels (210.2 ˚F [99 ˚C]). Briefly, the process works for brackish desalination, as viewed in figure 1 (Beckman [7]; Beckman, Hamieh, and Ybarra [8]; and Hamieh, Beckman, and Ybarra [9]).

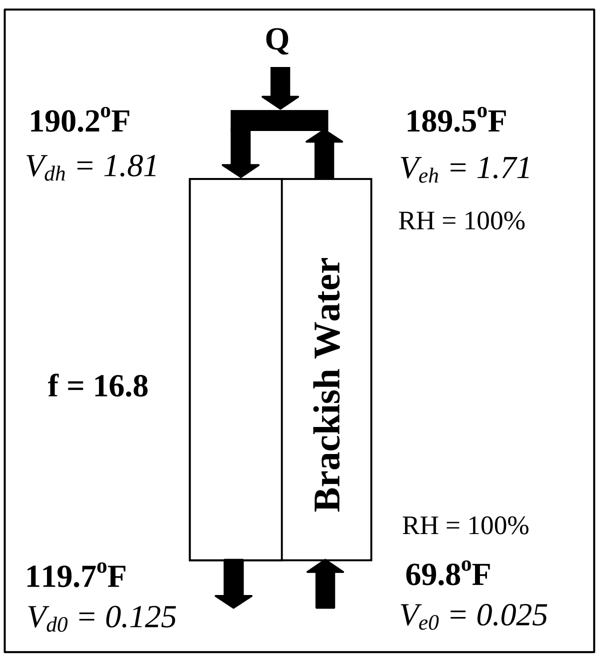

Figure 1. Dewvaporation tower design.

A carrier-gas, such as air, is brought into the bottom of the tower on the evaporation side of a heat transfer wall at a typical wet bulb temperature of 69.8 ˚F (21 ˚C), thereby containing about 0.025 moles of water vapor per mole of air. The wall is wetted by saline feed water, which is fed into the evaporation side at the top of the tower. As the air moves from the bottom to the top of the tower, heat is transferred into the evaporation side through the heat transfer wall, which allows the air to rise in temperature and evaporate water from the wetting saline liquid, which coats the heat transfer wall. Concentrated liquid leaves from the bottoms of the towers, and hot saturated air leaves the tower from the top at 189.5 ˚F (87.4 ˚C) with a humidity of 1.71 moles of water vapor per mole of air. Heat is added to this hot air by an external heat source (steam was used in this investigation), increasing the air humidity and temperature to a vapor loading of 1.81 and 190.2 ˚F (87.9 ˚C), respectively. This hotter saturated air is sent back into the top of the tower on the dew formation side. The dew formation side of the tower, being slightly hotter than the evaporation side, allows the air to cool as condensation heat is transferred from the dew formation side to the evaporation side. Finally, pure water condensate and saturated air leave the dew formation side of the tower at the bottom at 119.7 ˚F (48.7 ˚C). Total external heat needed is made up of the heat added at the top of the tower to establish a heat transfer temperature difference and the heat needed to establish a temperature offset between the saline feed stock and the pure water condensate used to produce steam. The detrimental effect of salt concentration on the energy reuse factor (or gain output ratio), f, is explained in the theory section.

Figure 2a illustrates that volatile organic carbon removal behaves ideally as the distillation of almost pure, brackish, or sea water. The reclamation of evaporation pond waters that are saturated with salts (20 percent by weight), as shown in figure 2b, is more difficult. The feed waters are processed to extinction by the recycle of bottoms brine back to the feed. The two products are distillate and wet salt solids.

Due to the slight desiccant effect of salts, the energy reuse factor decreases with increased salt concentrations. This suppressed vapor pressure of water reduces the relative humidity of saturated air, causing the addition of more steam to make up the air dryness.

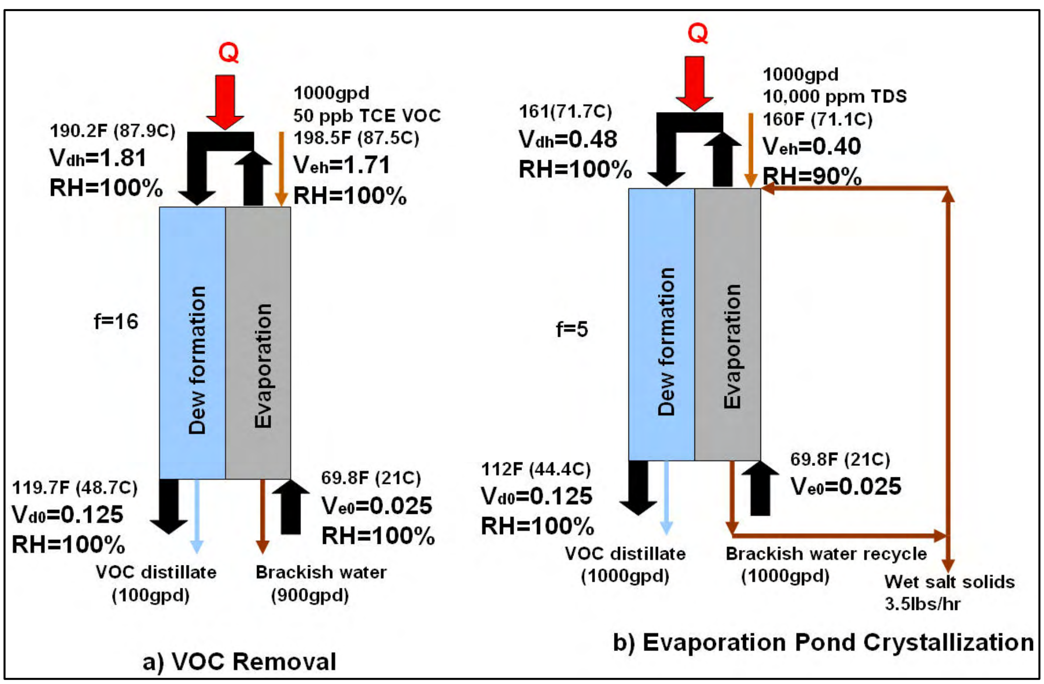

Figure 2. Volatile organic carbon removal and evaporation pond reclamation with dewvaporation.

2.2 Dewvaporation Model

From figures 1 and 2, the mathematical definition of the energy reuse factor, f, is the ratio of the energy transferred through the heat transfer wall to the high temperature energy input, as shown in equation 1 (Beckman [7], [10]):

$$f = \frac{V_{dh} - V_{d0}}{V_{dh} - V_{eh}} \qquad (1)$$

The definition of the molar production flux, Pf , is the gas traffic (mol of air per second) times the water vapor decrease on the dew formation side of the wall divided by the wall area, as shown in equation 2:

$$P_f = \frac{G}{A} \cdot (V_{dh} - V_{d0}) \qquad (2)$$

Typically, the feed/condensate temperature offset is kept to 10 ˚F (5.6 ˚C). This can be accomplished by either an internal or external feed heat exchanger. In this analysis, the energy reuse factor, f, was 16.8. By including the heat needed for the temperature offset, the factor reduces to about 13. Actually, the product of the factor and the molar production flux, Pf , is a constant at parametric Veh. The value of the constant is a function of the operating variables, as shown in the following equations.

The amount of water vapor contained in the air carrier-gas is calculated by specifying the temperature, T, and calculating the vapor pressure, Pw, from equation 3 (Smith and Van Ness [11]):

$$\ln P_w = B - \frac{\lambda_0}{R \cdot T} \qquad (3)$$

where B and λ0 are constants obtained by fitting a straight line to the ln(Pw) versus 1/T for the steam table. For temperature range of 32 – 212 ˚F (0 – 100 ˚C), B is 14 and λ0/R is 5209 °K (Perry, Green, and Maloney [12]). The carrier-gas vapor content (moles of water vapor per mole of air) is:

$$V = \frac{RH \cdot P_w}{P - RH \cdot P_w} \qquad (4)$$

where the relative humidity (RH) is given as a function of salinity, S grams salt/liter, by the following equation (Spiegler and Laird [13]):

$$RH = 1 - 0.000538 \cdot S \qquad (5)$$

The hottest temperature in the evaporating section is specified, allowing the calculation of the largest value of the Veh in the evaporating section of the unit. Then the change in vapor content of the carrier-gas is specified across the top of the tower by:

$$\Delta V = V_{dh} - V_{eh} \tag{6}$$

From these specifications, the temperature difference across the heat transfer wall at any position can be described as:

$$\frac{1}{\Delta T_{LM}\big|_z} = \left[\frac{B^2 \cdot R}{\lambda_0}\right] \cdot \left[\frac{\left(1 + \Delta V + V_e\big|_z\right) \cdot V_e\big|_z}{\Delta V}\right] \tag{7}$$

In this process, both the film heat and mass transfer coefficients are important in establishing the overall effective heat transfer coefficient, U. For simultaneous heat and mass transfer operations involving air and water, the Lewis Number is essentially unity (McCabe, Smith, and Harriott [14]), allowing the coefficients to be related by similitude as ky = hg/cp. The effect of the latent energy associated with the mass transfer of water vapor can be related to the sensible heat transfer associated with the air/vapor mixture by equation 9 after Werling [15].

$$h_f\big|_z = h_g\big|_z \cdot \left(1 + M\big|_z\right) \tag{8}$$

where M is expressed as:

$$M = \left(\frac{\lambda_0}{RT}\right)^2 \cdot \left(\frac{R}{c_p}\right) \cdot V \tag{9}$$

Taking into account both gas film heat transfer coefficients and the thermal resistance of the heat transfer wall, then the overall effective heat transfer coefficient, U, can be expressed as:

$$\frac{1}{U\big|_z} = \frac{1}{h_{fe}\big|_z} + \frac{1}{h_{fd}\big|_z} + \frac{t}{k} \tag{10}$$

The heat transferred through the heat transfer wall is essentially the latent heat, at the system temperature needed to evaporate water as:

$$q\big|_z = G \cdot \lambda \cdot \left(V_e\big|_{z+\Delta z} - V_e\big|_z\right) \tag{11}$$

The area needed for the heat transfer wall is obtained by an energy balance (Bird, Stewart, and Lightfoot [16]).

$$\frac{A|_z}{q|_z} = \frac{1}{U|_z} \times \frac{1}{\Delta T_{LM}|_z} \tag{12}$$

Where:

$$\Delta T_{LM} = T_{yd} - T_{ye} \tag{13}$$

Upon integrating with respect to the overall area and assuming that t/k is small compared to the gas phase resistance, equation 14 then relates the total energy reuse factor, f, and the total production flux, Pf , as follows:

$$f \cdot P_f = \left\{ \left[\frac{\lambda_0}{B \cdot R \cdot T} \right]^2 \cdot \left[\frac{h_g}{C_p} \right] \right\} \cdot \left(\frac{V_{eh}}{2 + V_{eh}} \right) \cdot \left(\frac{\lambda_0}{\lambda} \right) . (18) \cdot F_{RH} \tag{14}$$

Where the detrimental effect, FRH, of reduced relative humidity at the tower top exiting evaporation air stream, RH, is:

$$F_{RH} = 1 - (1 - RH) \cdot (1 + f) \cdot (1 + V_{eh}) \tag{15}$$

Equation 14 shows that as the temperature increases, the product of energy reuse factor and molar production flux become greater. It is also apparent that the energy reuse factor, f, and the molar production flux, Pf, are related hyperbolically in an established unit. The detrimental effect of salt concentration is also included in this expression from equation 15.

Additionally, higher values of V_{eh}; i.e., higher temperatures, improve both f and Pf values, which is economically beneficial to the tower. However, higher temperatures are limited to the heat source temperature and the normal boiling point of water.

On the other hand, by taking into account the heat conduction resistance in the plastic heat transfer wall and the resistances due to the two liquid films on the wall, then:

$$P_f \cdot f = \left(\frac{\lambda_0}{B \cdot R \cdot T} \right)^2 \cdot \left(\frac{h_g}{c_p} \right) \cdot \left(\frac{V_{eh}}{2 + V_{eh}} \right) \cdot \left(\frac{\lambda_0}{\lambda} \right) 18 \cdot F \tag{16}$$

With:

$$F = \frac{1}{1 + F_{RH} + F_{\varepsilon} + F_{RH} \cdot F_{\varepsilon} \cdot \left(\frac{6 + 3 \cdot V_{eh}}{3 + 2 \cdot V_{eh}} \right)} \tag{17}$$

The resulting equation is 18. This expression resembles equation 14, but with an additional term F containing all of the plastic and liquid films resistances to heat transfer. Rearranging these equations into a form that would be linear in a data plot gives:

$$\frac{\left(\lambda_0 / \lambda\right)}{\left(3+2\cdot V_{eh}\right)P_{f\cdot}\cdot f}=\left[\left(\frac{c_p}{h_g}\right)\right]\cdot\left(\frac{2+V_{eh}}{3\cdot V_{eh}+2\cdot V_{eh}^2}\right)+\frac{B^2\cdot R}{6}\cdot\sum\frac{t}{k} \qquad (18)$$

Air Boundary Layer Wall and Liquids

Essentially, the manner in which equation 18 (Hamieh [17]) is used to determine the effective heat transfer area from the data obtained per run. All of the parameters on the right hand side of equation 18 are known. Data from each run contain the temperature at the top of the tower, production rate, and energy consumed. From the tower top temperature, the water vapor to air ratio and energy reuse ratio can be calculated. Therefore, the production density can be assessed on the left hand side of equation 18. Since the production rate is data, then the effective heat transfer area in the tower can be identified. The effective area is a property of the tower mechanical design, as summarized by Hamieh and Beckman [18], [19].

2.3 Tower Details

The plastic heat transfer wall that best offered low-cost economics, dimensional stability, free flow zones, manufacturability, and availability was twin-wall extrusions found in Spring 2001. The twin-wall extruded plastics are available in many sizes (thickness) ranging from 2 millimeters (mm) to 10 mm. Coroplast, Incorporated’s (1-800-666-2241) twin-wall, 4-mm, polypropylene extruded sheet was purchased at $5.25 per 4-foot by 8-foot sheet from local suppliers. This price is for small quantity from a distributor. Projected price for bulk quantity direct from manufacturer is less than $2.50 per sheet. Since both sides of the sheet can be used for heat transfer, the price for the heat transfer wall is $0.039 per square foot. Figure 3 shows an edge-on view of the twin-wall extruded plastic sheet.

The outer surfaces were covered with wetting gauze so that the surfaces would wet with saline feed water. The inner cavity allowed condensation to occur isolated from the saline water. These extruded sheets were cut to size (19 inches wide, 6 feet high) and mounted vertically, as shown in figure 4.

The inner top of the tower is pictured in figure 5. There is a certain level of complexity as shown. Air blows up the saline wet faces of the heat transfer walls and enters the top zone through the sponges, which have holes. The sponges are wetted with saline feed from the feed spouts along the center of the picture.

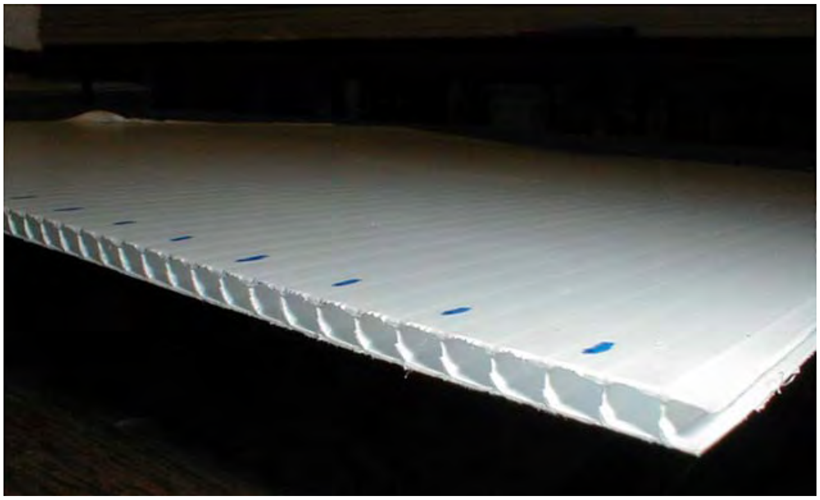

Figure 3. Edge view of 4-millimeter, twin-wall polypropylene sheet.

Figure 4. Tower sections fitted with gauze.

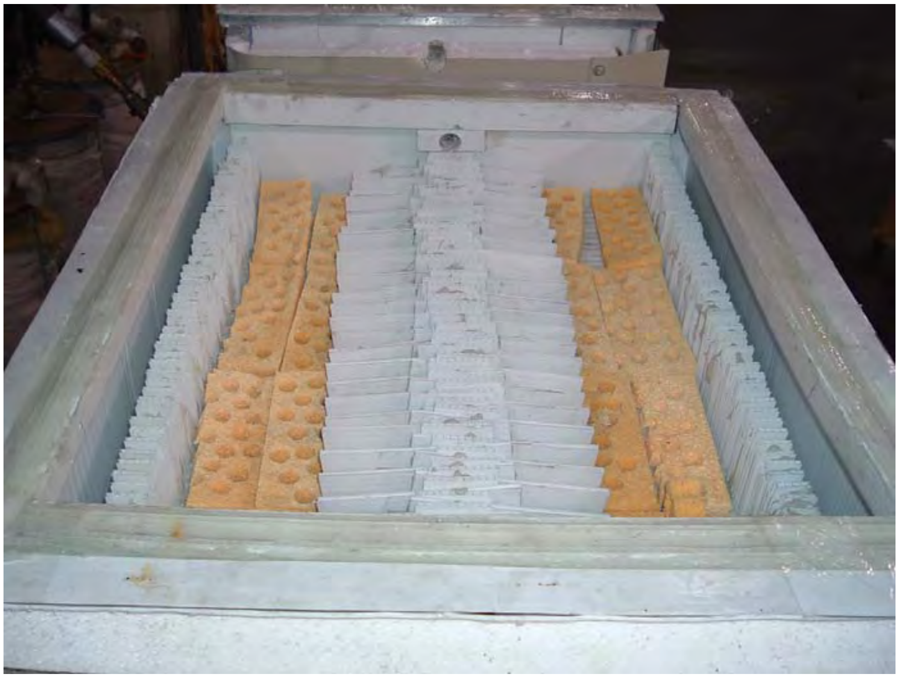

Figure 5. Top view of the tower.

Steam is shot into the air along the center by a steam pipe (not shown). Air with the added steam moves to the far right and left of the picture, where the air re-enters the heat exchange section and flows back down the tower as it cools and condenses dew. Figure 6 shows completed towers at the manufacturing facility.

Figure 6. Towers at the manufacturing site.

2.4 Pilot Plant Construction

The pilot plant was located at the waste water treatment plant (WWTP). Figure 7 shows a picture of the site, selected out of the various site locations available. This site was chosen for its morning shade, sealed ground, proximity to an office area with machine shop capability, and ease of access. There was space for a maximum of 32 towers.

Figure 7. Towers installed at pilot site with generator, tanks, and tactical water purification system.

An electrical steam generator was located onsite, along with the tactical water purification system (TWPS) used to concentrate the tertiary wastewater for the DewVaporation system feed. The first set of towers, along with the steam generator, is shown in figure 8. The steam generator is in the lower left with some of the first towers. Figure 9 shows some of the tanks, the steam generator enclosure, and first tower set.

In the summer of 2005, a storm swept through the Phoenix area, uprooting trees and collapsing the first set of towers. The towers were not salvageable. A second set of 25 towers was purchased by the Phoenix Area Office (PXAO) from the manufacturer.

Figure 8. First tower set with steam generator and tanks.

The towers were connected for liquid flow in many arrangements. The arrangement finally selected for data gathering in the fourth year is depicted in figure 9. Figure 9 shows that the pilot plant was subdivided into three units of eight towers. The final brine streams from all 3 subunits flowed to tower 25. The flow connections were designed to allow gradual increase in brine salinity in the sequential chain setup.

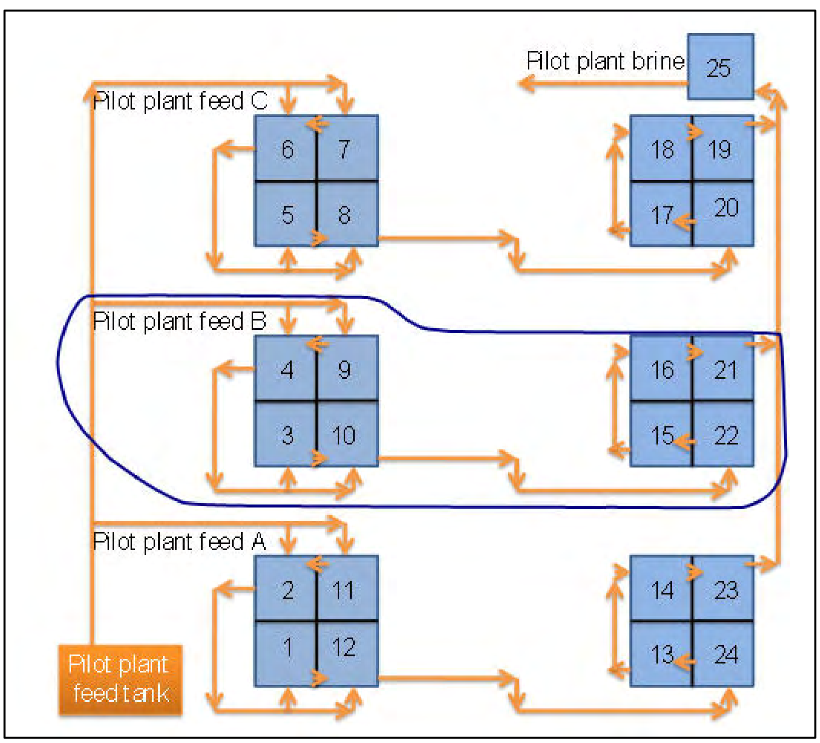

Figure 9. Arrangement of towers for the pilot test.

2.5 Pilot Plant Objectives

2.5.1 Initially Proposed Pilot Plant Approach

The pilot plant was to be composed of ten 1,000-gallon-per-day (gpd) modules. Each module is designed to measure 4 feet by 4 feet by 7 feet and was optimized for manufacturing ease. This modulation is required so as to improve transportability of the skid-mounted modules to the WWTP. Some modules will be connected in a parallel arrangement, and others will be connected in series, to best minimize concentrate recycle tower bottoms to the tower top section. Recycling in this manner increases the salinity of the tower feed, which is detrimental to the energy efficiency but necessary in maintaining a wet heat transfer wall for distillate formation. The modules will be separated and dispersed to other demonstration sites when the pilot study is complete.

The pilot plant towers were designed, built, transported to WWTP, installed, and brought online during the first year. In the second year, there were four major test cases operated for approximately 3 months each:

1. 5,000 mg/L of feed to make 200,000 mg/L of 200-gpd concentrated brine

2. 5,000 mg/L of feed to make 420 lb/day of wet salt solids.

3. 1,500 mg/L of feed to make 200,000 mg/L of 60-gpd concentrated brine.

4. 1,500 mg/L of saline feed to make 125 lb/day wet salt solids.

The runs were made in this order to take advantage of the TWPS RO concentrator being used to produce 5,000 mg/L of saline water from the 1,500 mg/L of WWTP effluent. The TWPS will be leased for 2 to 3 years starting May 2003.

A liquid feed to the pilot plant will be pumped through a rotometer at 7 gallons per minute (gpm) controlled by a globe valve. This feed will be split into two 3.5-gpm streams and balanced by valves. The tower pumps are surge pumps that are activated by a liquid level control switch. The level of each tower basin brine pool is controlled by overflow to the succeeding tower’s surge pump. The surge pump dedicated to the tower is responsible for sending feed water through the tower internal feed heat exchangers to the tower top; therefore, there is one pump per tower. Since flow rates surge, the bucket and stopwatch approach will be used to monitor liquid rates.

Air will be sent to each tower from one blower. Individual air rates will be set by ball valve adjustment and measured by a velocity gas meter at each tower exhaust.

Steam will be delivered to each tower by 10 dedicated water boilers. The steam rate will be set to maximum, and each tower air flow rate will be adjusted to give the desired top temperature.

Temperatures of all liquid and air streams (both wet and dry bulb) will be monitored by thermocouples, displayed, and recorded by real time data acquisition.

2.5.2 Pilot Plant Goals and Objectives

The overall plan for this 10,000-gpd pilot study is to move a new and exciting technology out of the ASU laboratories once again and into the field of the real world. A sizable 10,000-gpd unit is presented that will be professionally designed and fabricated, versatile in its feed water salinity demonstrations, and versatile in its product delivery (10,000 mg/L, 300,000 mg/L, and salt solids). The demonstration will be at the WWTP of the City of Phoenix for about 1-year's duration after 1 year needed for fabrication. A trailer-mounted RO unit will be made available from Reclamation for use in this test. The dewvaporation equipment will be versatile in that WWTP effluent and RO effluent will be treated as feed to the dewvaporation process. The dewvaporation unit needs a fuel such as natural gas ($0.40 per therm), which could be valued as locally available digester gas at no cost. In order to get the site ready, it will be necessary, in time, to assess the electrical power needs/ availability, space allocation, exact site location, and control room needs.

When finished, the portable unit can be transported to other sites for follow-on demonstrations. It would be also possible, due to its modular construction, to send up to ten 1,000-gpd units, or some combination of numbers of modules, to various smaller industrial sites for demonstration. Examples include Cave Creek Desalination Facility and Scottsdale Water Campus.

The objectives that need to be addressed for the successful completion of the first year project include:

1. Design 10,000-gpd pilot plant main unit (ten 1,000-gpd towers).
2. Professionally manufacture main unit.
3. Transport towers sequentially when produced to WWTP.
4. Install/test towers at WWTP.
5. Write quarterly and final reports for year 1.

In the second year, the pilot plant will:

1. Operate unit with RO effluent to produce concentrated brine.

2. Operate unit with RO effluent to produce crystals.

3. Operate unit with WWTP effluent to produce concentrated brine.

4. Operate unit with WWTP effluent to produce crystals.

5. Design, build, and demonstrate advanced tower designs based on initial operational results.

6. Write quarterly and final reports for the total project.

The minimum of 2 years of study at the 10,000-gpd capacity should prove the reliability of the operation, as there are few moving parts, operating costs are low compared to all equivalent technologies that concentrate brine, and brackish discharges are minimized to the extent that waste disposal costs and/or needed land for evaporation ponds can be reduced by an order of magnitude. Successful accomplishment of Objectives 1 through 5 of year 1, and Objectives 1 through 6 of year 2, will act as a foundation to the practical details needed for the commercial design of that and larger systems. The accomplishment of second year Objective 2 will expand the role of the dewvaporation plants to being crystallizers by the reduced feed flow rate, so that the last tower in series produces crystals instead of brine. All together, the new system will act to replace the standard evaporator (concentrators) and crystallizer process pairing used by electric power generating stations throughout the American West. The newly formed company, L'Eau LLC, has plans and potential funding groups that are focused on rapidly accelerating toward commercialization. These achievements will hasten the commercialization process.

2.6 Pilot Plant Operational Risks

Based on all of the redundant research and development and all of the paths taken, the remaining risks to a successful operation have been minimized. The dewvaporation system has minimal moving parts such as a boiler, pump, and fan. These items are very identifiable and separate, so any malfunctions can be readily detected and corrected. The one unproven step is the operational problems that might be associated with the professionally designed and fabricated towers. This new era in tower construction away from the ASU laboratories is not foolproof. Problems such as liquid leaks both interior and exterior, gas flow bypass, and liquid feed seal breakage have all been previous problems that were corrected in the smaller units. It is assumed that early detection of these and other problems can be corrected in towers constructed in the future.

2.7 Projected Dewvaporation Economics

The basic economics have not changed much since the first projections in 1999 [6]. Then, the capital cost was about $ 8,000 per 1,000 gpd for small plants, reducing to $1,000 per 1,000 gpd for large facilities. Operating costs of water reclamation from seawater and saline solutions varied from $3.50 per 1,000 gallons to $0.50 per 1,000 gallons, based on natural gas as a fuel or free waste heat, respectively.

The WWTP will also investigate taking the fed brine to total extinction (crystallization). That is, there will only be wet solids left for disposal and no brine discharge. The capital and operating cost for dewvaporation acting as a crystallizer should not change. The operating cost of an industrial crystallizer (IC) would be an additional $2 per 1,000 gallons of initial feed stock. The total water cost would then be $14 per 1,000 gallons. Capital cost for large crystallizers is an additional $5,600 per 1,000gpd of initial feed stock [18]. The total capital cost for a conventional evaporator with crystallizer would be $31,600 per 1,000 gpd. Dewvaporation capital cost would remain at $8,000 per 1,000 gpd.

2.8 Project Management

The project is based on the cooperation of three different entities: The City of Phoenix Water Services Department, PXAO, and L'Eau LLC. These three entities will be managed by their own personnel.

The City of Phoenix hosted the site and provided concrete slabs, utilities, and personnel to operate a 1,500-gallon-per-hour TWPS needed for enhanced salinity levels as feed to a 10,000-gpd dewvaporation pilot plant.

The Bureau of Reclamation - Denver Office borrowed the TWPS from the U.S. Naval Facilities Engineering Service Center in Pt. Hueneme, California. The system was operated by the PXAO. The PXAO Program Management Division Chief is Robert Michaels. Tom Poulson acted as the main contact and field director for the project.

L'Eau LLC was managed full time by Dr. Scott Stornetta as Chairman of the Board and Chief Executive Officer. Dr. Beckman, part time, was Chief Technical Officer to L'Eau LLC and manager of the pilot plant project. The L'Eau LLC constructed, transported, installed, and operated the 10,000-gpd dewvaporation pilot plant. The engineering staff of L'Eau LLC was present daily to ensure progress in L'Eau's obligations.

2.9 Facilities and Equipment

The WWTP in Phoenix is a 63-million-gallon-per-day facility. The water campus is equipped with chemical testing laboratories capable of total water analysis. Digester gas and natural gas for steam generation needs are available to the pilot plant operation. There is office space adjacent to the concrete pad area. Base level electricity of 1 kilowatt is in place for the pumps, blowers, and display requirements. Natural gas required is 100 therms per day.

2.10 Environmental Impact

The environmental impact for this dewvaporation pilot plant is positive. The pilot plant will treat 1,500 mg/L and 5,000 mg/L of TDS discharge waters to less than 10 mg/L TDS distillate and concentrated brine at 200,000 mg/L TDS of wet crystal solids. The distillate produced can be used to dilute the normal WWTP 1,500-mg/L TDS discharge. A zero environmental impact would be a blending of the distillate and brine to form a 1,500-mg/L TDS WWTP discharge; however, all of the involved entities feel that a more positive application can be found for the distillate of the dewvaporation and the permeate from the RO unit.

2.11 Dismantling the Pilot Plant

Due to the modular construction of the 10,000-gpd pilot plant, the pilot plant could be broken into ten 1,000-gpd units for distribution to 10 sites. The towers are set up in this initial pilot plant to be independent, with dedicated boilers and blowers for individual analysis. This allows the singular distribution possibility. However, combinations of units composed of clusters of the 1,000-gpd units could also be considered. There is need for RO concentrate treatment systems in the Phoenix area (Cave Creek and Scottsdale water campus and other municipal waste water treatment plants or industrial sites).

2.12 Dewvaporation Project Relevance to Desalination and Water Purification Research Objectives

The Desalination Act of 1996 has as its principal focus the development of economical methods to reclaim impaired and saline inland waters. This research proposal is based on two Reclamation awards under this act, which established the dewvaporation process as a highly efficient economical means for water reclamation. Results from those two awards have led to the final lab design of the dewvaporation process. The technique has the potential to reclaim saline and impaired waters with minimal volume concentrate or even solids.

The **Reclamation Program Objectives** are well satisfied in this proposal:

> **Reclamation Objective 1:** "Increase the ability of communities of varying sizes and financial resources to economically treat saline water to potable standards." The dewvaporation units have successfully operated at the 50-gpd size and will operate at 10,000-gpd size with this proposal. The units operate economically: their manufacturing costs are about $1,000 gpd, and fuel costs range from $2.94 to $0.42 per 1,000 gallons.
>
> **Reclamation Objective 2:** "Increase the ability of the United States desalting industry to compete throughout the world by fostering partnerships with them for the development of new and innovative technologies."
>
> **Reclamation Objective 3:** "Develop methods to make desalting more efficient through promotion of dual-use facilities in which waste energy could be applied to desalting water." The dewvaporation process uses low-grade heat and waste heat.
>
> **Reclamation Objective 4:** "Develop methods to ensure desalting technologies are environmentally friendly." The dewvaporation process is a very low energy user in its standard operation. Also, no new electric generating stations need to be built because the electrical usage is low, at less than 1.6 kilowatthours (kWh) per 1,000 gallons (67 kilowatts for a $1-million-gpd plant).

All of these objectives, along with third world benefit, were summarized by ASU Research Magazine [20].

3. Results, Conclusions, and Recommendations

From this investigation into the dewvaporation process, it can be concluded that:

- High recovery values of 100 percent were achieved.
- High distillate purity of 10 mg/L of TDS was achieved with 10,000 mg/L of TDS concentrated waste water feed and 45,000 mg/L TDS brines.
- Distillate quality and production rate did not reduce with increased feed salinity.
- Thermal multiple effects ranging from 2.0 to 3.5 were demonstrated, which were less than the value of 5.0 prior to transportation. The product of distillate rate and multiple effect was 1/13 of the theoretical value, revealing high potential for improved performance with continued research and development.
- Demonstrated amortized capital cost was $3.50 per 1,000 gallons of distillate based on tower purchase from L'Eau and borrowed funds at 8 percent with equipment life of 20 years.
- Demonstrated operating cost ranged from $0.10 per 1,000 gallons to $24 per 1,000 gallons, depending on the price of fuel for steam generation. Currently, natural gas value is $0.80 per therm.
- The target of 5,000 gpd was not achieved due to limitations of the steam boiler capacity and tower efficiency.

It is recommended that:

- Tower air connections be modified to accommodate the "tandem" arrangement to increase multiple effects from 2.0 to 3.5 to 7.0.
- Tower construction design should be changed from the NAS-T to the NEWT.[1] Demonstrated philosophy to improve tower multiple effect to 5.0.

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[1] The acronym NAS-T describes a unit with air flowing up or **N**orth on the evaporation side **A**nd then flowing **S**outh or down on the dew formation side of the **T**ower. The acronym NEWT stands for a tower where the air flow pattern is first **N**orth on the evaporation side and then **E**ast and **W**est or zigzag on the downward flow path on the dew formation side of the **T**ower.

- Solar hot water thermal source should be developed for reduced water costs.

- The liquid desiccant heat pumping feature be developed for reduced water costs.

3.1 Pilot Plant Results

Table 1 is a summary of the pilot plant data generated in year 4 of the project. The data sheets that support table 1 are presented in appendix A.

Table 1. Pilot Plant Design Data

Run Date	Subunit Operated	Subunit Distillate Rate (gpd)	Equivalent Pilot Plant Distillate Rate (gpd)	Multiple Effect Factor f	Percent Recovery
August 30, 2006	A B C	1,470	1,470	—	—
September 22, 2006	A	1,440	4,000	2.1	62
October 5, 2006	A B	1,394	3,873	1.9	58
October 17, 2006	B	1,080	3,000	1.5	65
October 24, 2006	A	900	2,500	1.1	34
November 7, 2006	A	1,360	3,778	1.9	77
November 21, 2006	A	1,600	4,447	3.3	92
November 30, 2006	B	1,522	4,227	3.2	36
December 6, 2006	A B	1,937	2,848	3.1	62
December 8, 2006	A B	2,664	3,918	2.7	67
December 20, 2006	A	1,056	2,933	2.2	50
January 18, 2007	B	1,058	2,940	1.6	45
February 9, 2007	A	1,618	4,495	2.5	66
March 7, 2007	A B	2,347	3,451	2.6	78
April 2, 2007	A	1,608	4,467	1.7	100

More detail of operations is presented in Section 4.6. In summary, table 1 shows that all of the towers could not be operated at the same time due to limitations of the steam generator. Most of the runs operated either subunit A or B, but most of the data was obtained from subunit A. The "Equivalent Pilot Plant Distillate Rate" was projected by ratioing the number of towers in the total plant to the towers in the subunit. Table 1 shows that the highest distillate rate was about 4,500 gpd. The highest thermal multiple effect was 3.3. The recovery (distillate to feed ratio) varied from 34 percent to 100 percent.

The April 2, 2007 operation recycled the pilot plant brine stream back to the feed tank, thereby increasing the salinity from 200 mg/L of TDS to 8,000 mg/L of TDS as the tank emptied. Maximum tower basin saline concentration was found to be 45,000 mg/L of TDS.

3.2 Improvement Recommendations

3.2.1 Tandem Arrangement

In the tandem arrangement shown in figure 10a, a carrier-gas, such as air, is brought into the bottom of the tower on the evaporation side of a heat transfer wall at a typical wet bulb temperature of 70 ˚F (21 ˚C), thereby containing about 0.025 moles of water vapor per mole of air. The wall is wetted by saline feed water, which is fed into the evaporation side. As the air moves from the bottom to the top of the tower, heat is transferred into the evaporation side through the heat transfer wall, allowing the air to rise in temperature and evaporate water from the wetting saline liquid, which coats the heat transfer wall. Concentrated brine leaves from the bottom of the tower, and hot saturated air leaves the tower from the top at 190 ˚F (87.8 ˚C) with a humidity of 1.71 moles of water vapor per mole of air. Heat is added to this hot air by an external heat source, such as atmosphere steam, increasing the air humidity and temperature to a vapor loading of 1.93 and 192 ˚F (88.9 ˚C), respectively. This hotter saturated air is sent back into the top of the tower on the dew formation side. The dew formation side of the tower, being hotter than the evaporation side, allows the air to cool and transfer condensation heat from the dew formation side to the evaporation side. Finally, pure water condensate and saturated air leave the dew formation side of the tower at the bottom at 120 ˚F (48.7 ˚C). Total external heat required is made up of the heat needed at the top to establish a heat transfer temperature difference and the heat needed to establish a temperature offset between the saline feed stock and the pure water condensate.

In the tandem flow pattern, air flow in the tower would be modified as shown in figures 10b and 11. The evaporative air would be routed to the condensing chamber of the subsequent tower. In this manner, each tower could act as a single effect evaporator. Energy into a tower would be used to evaporate and condense water only if the liquids to and from the tower enter and leave at about the same temperature. Since the air is totally recycled between towers, no energy leaves the system by that route.

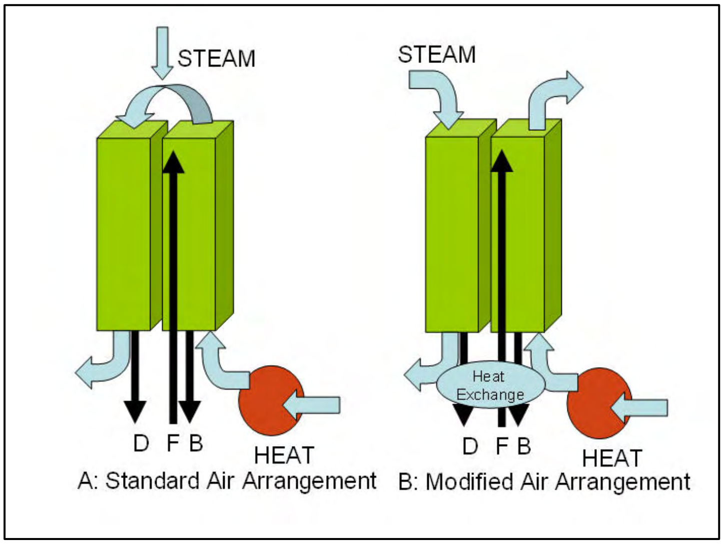

Figure 10. Single tower standard and modified air design.

3.2.2 NEWT Tower Manufacturing

The acronym NEWT stands for a tower where the air flow pattern is first **N**orth on the evaporation side and then **E**ast and **W**est or zigzag on the downward flow path on the dew formation side of the **T**ower. The acronym NAS-T describes a unit with air flowing up or **N**orth on the evaporation side **A**nd then flowing **S**outh or down on the dew formation side of the **T**ower.

The easiest and least expensive towers that can be built are NAS-T towers. NAS-T were built in Mexico and supplied as the second set of towers to the WWTP in year 3 (section 4.5). The main feature that distinguishes these tower designs is the dew formation return air turnarounds. Without turnarounds, 20 or 30 labor hours are saved. There is also a higher possibility of distillate contamination with turnarounds. Theoretically, the NEWTs should be more energy efficient but somewhat more expensive. Figure 12 shows the NEWT turnarounds.

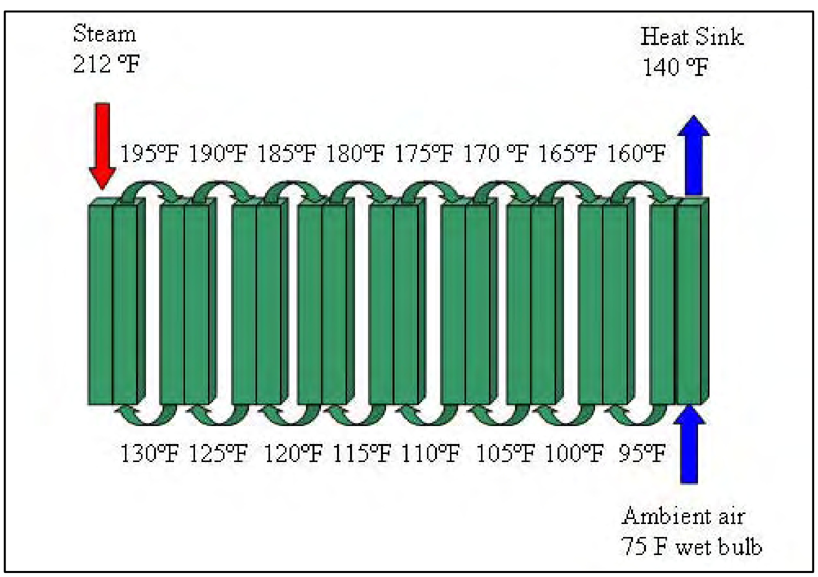

Figure 11. Proposed tandem air flow arrangement.

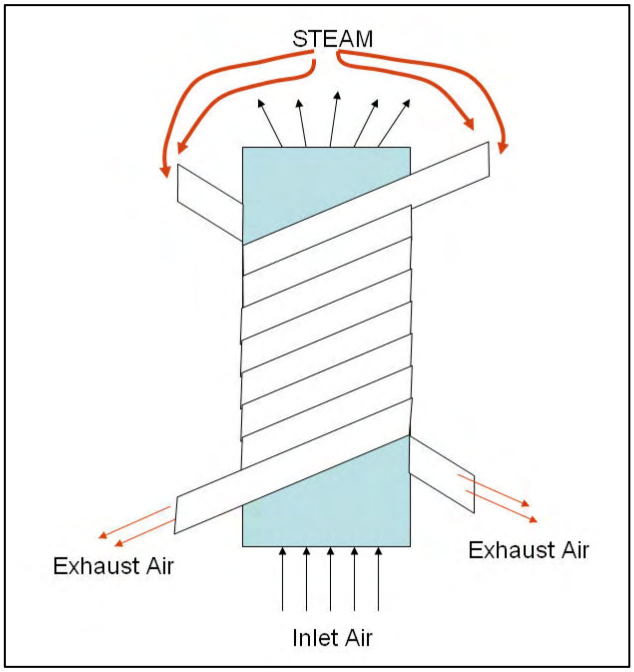

Figure 12. NEWT air turnarounds.

3.2.3 Solar Hot Water

Solar collectors can be used in place of steam to generate water at about 170ºF. The hot water can contact the tower top air, thereby evaporating water into the top so as to eliminate the need for additional steam. The cost of a single glaze solar collector is about $10 per square foot. Assuming an 8-hour solar day and 150 British thermal units (BTU) of collection, then 2,100 square feet of collector would be required to produce 1,000-gpd distillate at a thermal multiple effect factor of 3.3. The amortized water cost would be $6.36 per 1,000 gallons. This cost is less than the cost of steam from natural gas, which is $20.85 per 1,000 gallons. A combination of solar heat utilization, along with NEWT tower development, could reduce the water cost to about $6 per 1,000 gallons, which includes the amortized tower cost. Figure 13 suggests such a solar arrangement.

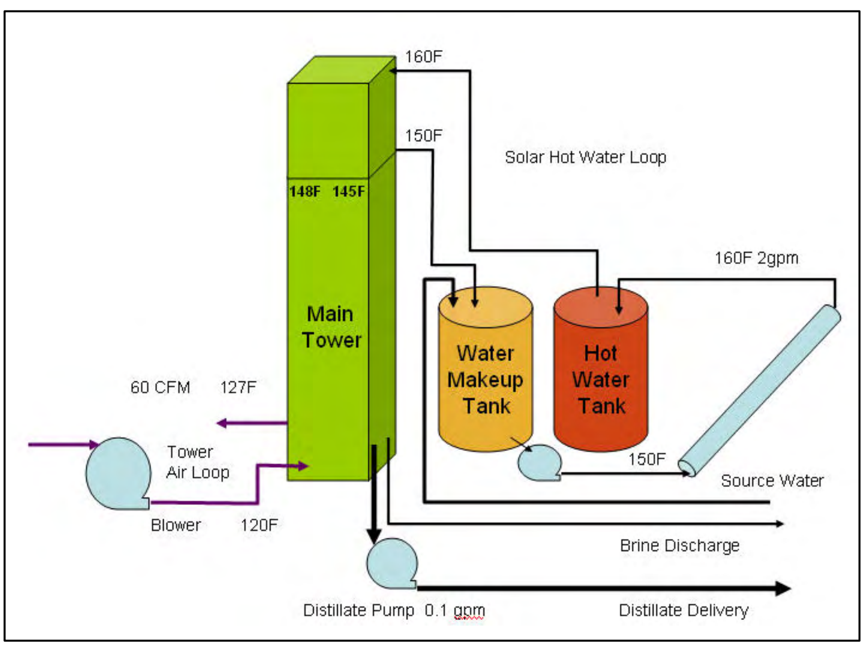

Figure 13. Solar hot water heating.

3.2.4 Desiccant Heat Pumping

The philosophy for using a liquid desiccant to enhance the energy reuse factor is based on the ability of strong salt solutions to absorb moisture from air, thus drying the air and releasing the heat of vaporization. This heat can be released at higher temperatures than the original temperature of the air that was contacted by the desiccant, and that heat can be reused to do an equal amount of water evaporation into another air stream.

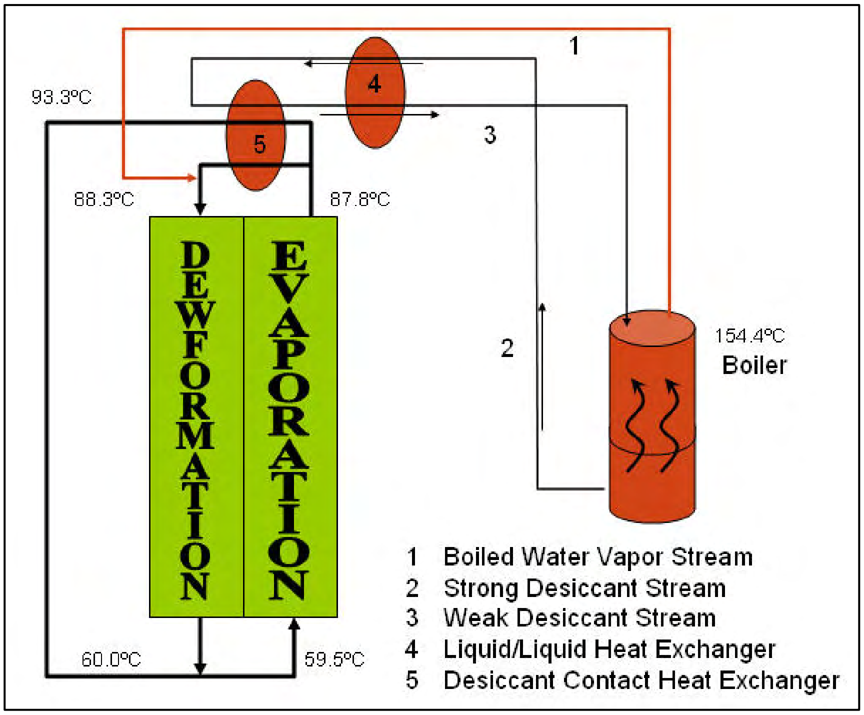

Figure 14. Desiccant heat pumping with boiler.

Figure 15 shows that a slip stream of hot, humid air at the top of the tower is contacted by a strong liquid desiccant stream (stream 2) in the desiccant contact heat exchanger (5). The remaining hot, humid air is further humidified in (5) by evaporation of feed water to vapor by the energy furnished by the desiccant air drying. The now hotter, humid air stream returns to the dewformation chamber, while the dried air goes to the bottom of the evaporation chamber. The desiccant stream, now diluted by the water vapor picked up in (5), returns to the boiler for regeneration. The steam released in the boiler from boiling desiccant liquid is sent to the top of the dew formation chamber to further increase the temperature and humidity of the returning hot, humid air. In this manner, the boiling energy is essentially halved.

The energy needs should be reduced to half by this technique, compared to the standard operation of the dewvaporation towers.

If dry air were available, then the desiccant could be regenerated by contacting the wet desiccant with the dry air for water evaporation, as depicted in figure 15.

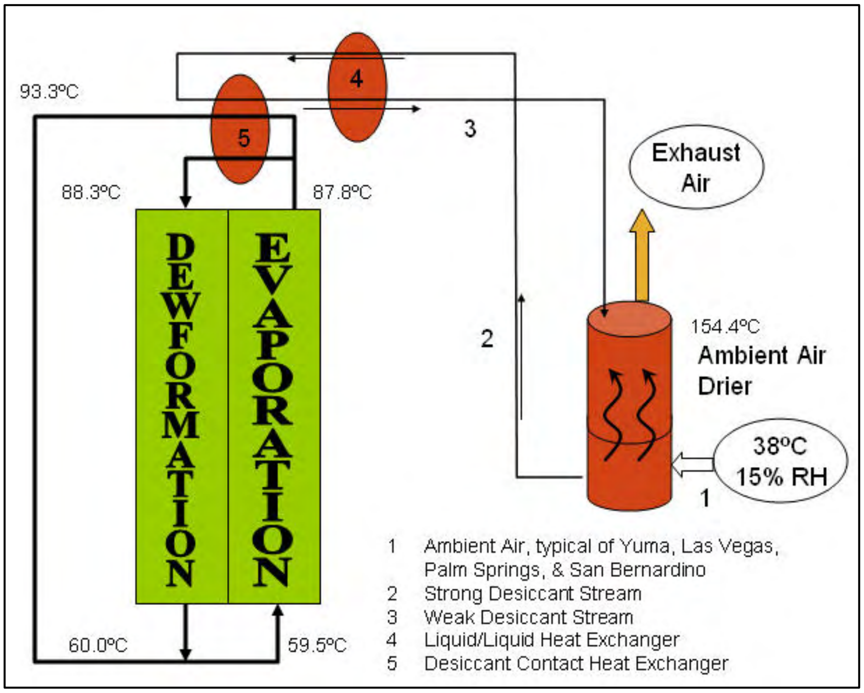

Figure 15. Desiccant heat pumping with air drying.

In this technique of drying liquid desiccants to the original salt concentrations, dry air becomes more humid as the solution looses water. No energy is required other than a fan motor aided by natural wind. The energy needs are reduced to 2.5 kWh of electricity per 1,000 gallons and heat to 80,000 BTU per 1,000 gallons. Less electricity and heat may result due to the action of wind and release of the desiccant dilution heat of solution.

Areas of the world where seawater exists with nearby desert dry conditions are noted but not limited to the cities listed in table 2 (www.bestplaces.net/html/climateus2).

The dry cities were cited as the most advantageous natural areas for drying of desiccant liquids. In these areas, where water is needed most when the air is driest, the air regeneration technique works the best.

The desiccant regeneration technique also works in environments more humid than desert regions. The tower top treated humid air is not dried out as thoroughly in areas of high humidity, resulting in more water being evaporated to the environment by the desiccant regeneration. Therefore, humid areas can still utilize this ambient air desiccant drying technique, but not as effectively as a desert region.

If the environment air is very humid, the ambient air regeneration technique can work if a solar collector is used to heat water, that can be stored, to heat humid air to a temperature of about 20-percent relative humidity. For example, Houston, New Orleans, or Miami, with air at 80 ˚F and 80-percent relative humidity, could be heated to 140 ˚F with 150 ˚F water to a condition of 20-percent relative humidity. Even cooler but humid regions, such as San Francisco, California, could use the desiccant ambient air regeneration by solar heating air to 125 ˚F with 135 ˚F hot water. These low water temperatures could be achieved in inexpensive single glazed flat plate solar collectors.

Table 2 shows cities with year-round relative humidity .

Table 2. Desiccant Drying Cities

City	Relative Humidity	
	January	**June**
USA - Yuma, Arizona	26	15
USA - Phoenix, Arizona	34	12
USA - Tucson, Arizona	31	13
USA - Las Vegas, Nevada	32	10
USA - Barstow, California	34	14
USA - Palm Springs, California	20	15
USA - Ridgecrest, California	34	14
USA - San Bernardino, California	36	15
Egypt - Aswan	29	11
Egypt - Dakhla	36	18
Egypt - Kharga	39	18
Egypt - Luxor	45	17
Israel - Odva	43	19
Israel - Elat	36	15
Saudi Arabia - Bishah	29	9
Saudi Arabia - Medina	28	7
Saudi Arabia - Riyadh	32	8
Saudi Arabia - Tabuk	32	12
	March	**September**
Australia - Mount Isa	32	19
Australia - Tennant Creek	34	16

Rural areas closer to seawater are also candidates for dry air generation, but weather data was not available. Possible areas that could benefit from this desiccant technique in bringing pure water to the American West and Southwest are:

- Desalination of the Sea of Cortez at Yuma, servicing water to Arizona, southern California, and northern Mexico.
- Desalination of Pacific Ocean at San Bernardino, servicing water to Los Angeles basin.
- Desalination of the Salton Sea at Palm Springs.

4. Work Performed

The 2-year pilot plant program extended into a 4-year investigation, with year 1 beginning October 2003 and ending in September 2004. The first year of the pilot plant project focused on site development and tower construction.

The first tower was built by Plastifab, Inc., in Phoenix. The tests confirmed the production rate of one tower could reach 80 pounds per hour (lb/hr) of distillate with a thermal multiple effect of 5, thereby requiring 20 more towers for the 5,000-gpd pilot plant. The L'Eau assembly facility was setting up to produce at least four towers per week beginning in February 2004.

A plastics fabrication company, Plastifab, Inc., was selected as the introductory manufacturer responsible for modifying the ASU tower design for fabrication. Meetings were held with the ASU design team and Larry Wilson of Plastifab, Inc. Plastifab, Inc., was chosen as the initial manufacturer based on its experience with large-sized fabrications similar to our 2-foot by 2-foot by 8-foot quad towers. During the manufacturing meetings, the advanced techniques were discussed and agreed upon by all present. The most significant advance was in the elimination of side wall paring with a tongue-and-groove turnaround side wall. Also, the bottom pan and exterior side walls would be vacuum formed.

Design was achieved by graduate students who met together at ASU research labs, including Dr. Beckman, Victor Banks, Joshua Brown, Andrew Davis, and Robin Roth. These students represented the combined knowledge of a dewvaporation tower design, construction, operation, and analysis team.

The first tower was fabricated and tested at Plastifab, Inc. L'Eau personnel tested the tower for operational performance, and internal and external liquid and gas leaks. Modifications were made to the bottom feed assembly of the professional design to prevent excessive feed leaks into the brine basin. Due to high manufacturing costs, the professional design equipment, along with learned techniques, was moved to L'Eau's new assembly office at 910 S. Hohokam Way, suite 101, Tempe, Arizona. There, the two engineers, Mr. Joshua Brown and Mr. Victor Banks, directed assembly personnel to manufacture towers of lower cost.

4.1 Changing Design Basis from 10,000 gpd to 5,000 gpd

Cost over-runs have also been identified in the tower construction. As L'Eau LLC is a newly formed company, there has been very limited opportunity to purchase assembly equipment to reduce personnel needs. Because of these increased costs (manufacturing and operations), L'Eau LLC and Reclamation mutually agreed that the pilot plant study would proceed at the 5,000-gpd capacity to allow a balanced budget.

The Reclamation/City of Phoenix project has been an invaluable project for the evolution and commercialization of dewvaporation towers. As the towers have been produced, improvements have been devised and engineered that are significantly improving the delivered product. The knowledge gleaned was used to modify the original tower design and enable L'eau to modify the towers built to approach the performance of the current generation towers. The first towers built by L'Eau LLC are presented in table 3.

Table 3. Initial Towers Built

Tower Identification Number	Twin Wall Size	Width	No. of Face Sheets	Gauze Type	Expected Output (lb/hr)
2-1	4 mm	22	60	Cotton	60
2-2	4 mm	22	60	Cotton	60
2-3	4 mm	22	60	Cotton	60
2-4	4 mm	22	60	Cotton	60
3-5	4 mm	33	30	Cotton	100
3-6	4 mm	33	30	Undecided	100
3-7	3 mm	20	60	Cotton	70

4.2 Design Modifications

4.2.1 Independent "Unit Cell" Turnarounds

The first commercial units, built in December, incorporated a common "turnaround panel" that was vacuum formed by Plasti-Fab, Inc. The design has merit, but at the current manual labor-intensive phase of manufacturing, the precision necessary could not be achieved. Thus, the first four towers for Reclamation were built with independent "unit cell" turnarounds. Initial performance of these towers (2-1 through 2-4) was 50 lb/hr, prompting further investigation and design adjustments.

4.2.2 Wide 33-Inch Towers

In an effort to build a single unit capable of producing 1,000 gpd, towers 3-5 and 3-6 were built 33 inches wide. Significant labor savings was anticipated using a wider tower, but the increased width gave more room for lateral temperature gradients. Such gradients could reduce tower performance.

4.2.3 Narrow Gauge 3-MM Twin-Wall

Tower 3-7 was built using a thinner twin wall. The tower was about 23 percent smaller and produced 50 lb/hr, just like its 4-mm counterpart. The main concern for this smaller plastic was an increased pressure drop and blower power requirement. The tower pressure was 10 mm of water, well within reasonable blower capacities.

4.2.4 Parallel Pathways

One tower, built in March, was divided into two smaller towers. Each of these towers produced 45 lb/hr, suggesting that a tower is capable of 90 lb/hr. Currently, efforts are being focused on duplicating this higher performance in existing towers.

4.3 Manufacturing Capacity

Table 4 lists the towers delivered to the Phoenix WWTP and their characteristics. The manufacturing capacity of the Hohokam site nearly doubled during the first quarter. During the month of February, four towers were built, with a total of 1,000-gpd projected capacity. During the month of March, five towers and one 33-inch-wide tower were completed, with another 3- inch-wide tower 50 percent complete. Those towers represent 2,000-gpd capacity. During both months, four laborers were employed and directed by the two L'eau engineers, Joshua Brown, and Victor Banks.

Table 4. Towers Built for Transport to Phoenix

Tower No.	Tower ID	Twinwall Size	Width	No. of Face Sheets	Gauze Type	Pedestal Number	Delivered
1	2-1 NEWT	4 mm	23	60	Cotton	1	Yes
2	2-2 NEWT	4 mm	23	60	Cotton	1	Yes
3	2-3 NEWT	4 mm	23	60	Cotton	1	Yes
4	2-4 NEWT	4 mm	23	60	Cotton	1	Yes
5	3-1 NEWT (orica)	4 mm	22	60	Cotton	2	Yes
6	3-2 NEWT (orica)	4 mm	22	60	Plastic	2	Yes
7	3-3 NEWT (orica)	4 mm	22	60	Cotton	2	Yes

Table 4. Towers Built for Transport to Phoenix (continued)

Tower No.	Tower ID	Twinwall Size	Width	No. of Face Sheets	Gauze Type	Pedestal Number	Delivered
8	3-4 NEWT (orica)	4 mm	22	60	Plastic	2	Yes
9	12-1 NEWT (plastifab)	4 mm	22	60	Cotton	6	Yes
10	5-1 NEWT	4 mm	33	60	Cotton	5	Yes
11	6-1 NAS-T	4 mm	22	55	Cotton	5	Yes
12	6-2 NAS-T, W	4 mm	33	30	Plastic	5	Yes
13	6-3 NAS-T, W	4 mm	33	30	Plastic	5	Yes
14	8-1 NAS-T, C	3 mm	22	60	Cotton	3	Yes
15	8-2 NAS-T, C	3 mm	22	60	Cotton	3	Yes
16	8-3 NAS-T, C	3/4 mm hybrid	22	30	Cotton	3	Yes
17	8-4 NAS-T, C	3/4 mm hybrid	22	30	Cotton	3	Yes
18	8-5 NAS-T, C	3/4 mm hybrid	22	30	Cotton	3	Yes
19	8-6 NAS-T, C	3/4 mm hybrid	22	30	Cotton	3	Yes
20	9-1 NAS-T, C	4 mm	22	60	Cotton	4	No
21	9-2 NAS-T, C	4 mm	22	60	Cotton	4	No
22	9-3 NAS-T, C	4 mm	22	60	Cotton	4	No
23	9-4 NAS-T, C	4 mm	22	60	Cotton	4	No

4.3.1 NAS-T Design and Operation

The acronym NEWT stands for a tower where the air flow pattern is first **N**orth on the evaporation side and then **E**ast and **W**est or zigzag on the downward flow path on the dew formation side of the **T**ower. The acronym NAS-T describes a unit with air flowing up or **N**orth on the evaporation side **A**nd then flowing **S**outh or down on the dew formation side of the **T**ower.

The cheapest towers that can be built are NAS-T towers. Without turnarounds, 20 to 30 labor hours are saved. There is also 100-percent distillate containment. Without the turnarounds, there is not any dew surface area that is blocked. Theoretically, the NEWTs should be more robust.

Effect of face sheet width. Without crossflow, wider towers have greater potential for evaporation and dew formation streams to miss each other, but wide towers have more surface area.

Effect of tower height. The only problem with height is handling the towers and approaching the 8-foot liquid feed heat exchanger limit.

Effect of number of heat transfer walls (sheets) per unit. Increasing the number of sheets may create a parallel flow problem.

Towers to be built. To observe these effects, several towers should be built. A 20-inch-wide tower was suggested as the desired width. Therefore, new 80-inch-tall towers (22 inches taller than current towers) should be built with varying sheet count.

Modification of tower design to better meet Reclamation Objective No. 2. The recently designed NAS-T towers were added to by moving the side liquid feed heat exchangers to the center of the tower. This design change should help eliminate any contamination of the distillate. The new design is referred to as the NAST-CF towers.

The L'Eau construction site was moved to Nogales, Mexico, to better take advantage of reduced labor costs of construction. The construction and testing of the towers were completed prior to shipment.

4.3.2 NAS-T-C Tower Design

The notion of moving the liquid feed heat exchangers into the center of the tower sheets came from the observation that small amounts of feed contamination, on the order of 5 mg/L to 10 mg/L TDS, occurred due to manufacturing misalignments. Moving the liquid feed heat exchangers to the center allows any leaks to contaminate the brine instead of the distillate.

4.3.3 Transportation of Towers to WWTP

As the site preparation at the WWTP is almost finalized, it was decided to transport towers to the WWTP site. Currently, the towers onsite comprise 4,000 gpd of the 5,000-gpd capacity. As the onsite towers are positioned onto the pilot plant pedestals, the remaining towers will be transported to the WWTP site and positioned as well.

4.3.4 Install Towers at WWTP

On February 12, 2004, there was a kick-off meeting at the WWTP for the RO-DEWVAP Pilot Plant Project. This meeting brought together project personnel from L'Eau LLC, City of Phoenix, Reclamation, and Valentine Engineering. The purpose of these meetings was to establish a common understanding of the needs of all constituents and a working together pathway for the development of the entire project. The electrical plug boxes for each pedestal represent the terminus of the electrical lines. Project site engineering establishes the foundations for tower installation.

4.4 Year 2 (October 2004 - September 2005)

4.4.1 NAS-TC Tower Design and Operation

The notion of moving the liquid feed heat exchangers into the center of the tower sheets came from the observation that small amounts of feed contamination, on the order of 5 mg/L to 10 mg/L of TDS, occurred due to manufacturing misalignments. Moving the liquid feed heat exchangers to the center allows any leaks to contaminate the brine instead of the distillate. Current operations show a 10,000 times reduction of TDS from feed to distillate.

4.4.2 Pilot Plant Overview

The 21 main towers (white towers with one blue insulated tower and one acrylonitrile butadiene styrene (ABS) black covered tower) are spread out on six pedestals. The storage tanks in the middle of figure 16 are black to prevent algae growth. The tank on the far right is the distillate hold tank for boiler feed. The two center tanks hold RO concentrate for feed to the pilot plant towers. The tank on the far left contains brine from the pilot plant. The canvas covered object in the bottom of the picture is the RO unit that supplies the pilot plant with RO concentrate.

The RO unit was a 1,500-gallon-per-hour TWPS, which received secondary waste water effluent and produced permeate and concentrate. The concentrate was tested by the dewvaporation pilot plant in subsequent runs. The RO unit is covered in brown tarp in figure 16. In figure 17, a TWPS is shown in transport mode during vibration testing.

Figure 16. Overview picture of the as-built pilot plant.

Figure 17. Tactical water purification system (vibration testing).

4.4.3 Electrosteam Boiler Operational

The electrosteam boiler safety certification caused a 9-month delay in the pilot plant startup. Electrical power requirements necessitated 480 volts to minimize amperage ratings. Since no electrical boilers could be found for outdoor service, an enclosure was designed, fabricated, and installed as shown in figure 18. After the boiler was safety certified, the engineers explored the operational methods to vary the steam generation rate from a maximum of 850 lb/hr to a minimum of 130 lb/hr. The steam boiler was custom designed so that its six boiler elements could be separately activated. During normal operation, 5,000-gpd distillate production should require about 350 lb/hr of steam. The boiler steam production range will allow investigation into the shifting of the multiple effect value and the production density. The multiple effect value impacts operating cost, while the production density establishes capital cost.

Figure 18. Electric steam boiler in its enclosure.

4.4.4 RO Unit Operational

In June, Mr. Mark Silbernagel trained the L'Eau engineers how to start, operate, and shut down the RO unit. The unit must operate at least 2 days per week for membrane protection. During operation times, RO concentrate will fill the pilot plant feed tanks so that RO concentrate will always be available as feed. The 2,000 gallons of feed storage allows almost 10 hours for the RO unit to come onstream after a pilot plant startup.

4.4.5 New Towers on Site

In June 2005, seven new towers were delivered to the WWTP from L'Eau's manufacturing plant. More towers were planned for transport to the WWTP in July and August for increased pilot plant capacity. The new NAST-S towers represent the standard tower product currently being fabricated for sales. The older towers will be enhanced and somewhat replaced by the newer units.

Figure 19 shows some of the newer towers onsite at the WWTP. These commercial towers are manufactured as identical. This is the first standard product of L'Eau. The assembly is compactly held by an external aluminum

Figure 19. Standardized towers from L'eau.

brace and covered with a layer of black ABS plastic for protection. The ABS was removed from all but one tower to inspect for any possible damage due to transport.

4.5 Year 3 (October 2005 - September 2006)

The dewvaporation pilot plant was hit by a microburst storm in July that knocked down all but two of the towers. The downed towers were tested, and three were operational. The PXAO placed an order for 25 new towers as replacements. The new towers represented the most current professional designs and were delivered to the waste water treatment plant in Phoenix.

The dewvaporation pilot plant construction continued. The tower tiedown system was designed and installed. Valentine Engineering installed the horizontal rail system that allowed all of the towers to be strapped in place to prevent any possible future tower destruction due to high-velocity winds. The new tower layout incorporated surface mounting of the towers, thus eliminating the raised platforms upon which the towers were previously placed. This gave more stability.

In February 2006, the contracted company, L'Eau LLC, ran out of financing and ceased to exist as a workable entity. The ASU license was transferred to ALTELA, Inc., so that production and availability of dewvaporation towers could be continued. ALTELA is located in Albuquerque, New Mexico. Press releases disclosed details of the transfer [21], [22].

As the pilot plant construction continued, the PXAO hired Mr. Stephen Poplawski, who was a past employee of L'Eau LLC, to continue the construction of the pilot plant. Twenty-five towers were erected and connected by piping for operations. The steam generator was modified and adjusted for operations. Modifications were made to the water feed pump and solenoid for improved operations. A steam test was set up to determine the steam flow rate to the entire pilot plant. This test will be used periodically throughout the testing period so that the multi-effect factor can be accurately assessed.

Liquid flow accumulators for the feed rate, distillate rate, and brine rate were installed in order to determine the multi-effect factor and to verify a mass balance of liquid flows.

The dewvaporation pilot plant construction concluded. The pilot plant was started up. Initial steam rate was 423 lb/hr. Distillate rate was 760 lb/hr, yielding an energy reuse factor of 1.8. An energy factor this low required an internal inspection of all of the towers to determine if there was damage in transportation or a shifting of the internal structures associated with feed water distribution.

4.6 Year 4 (October 2006 - April 2007)

Significant operation, data collection, and analysis were the major events of the fourth year.

4.6.1 Measurements

There were four measured entities used throughout the investigation: liquid flow rate, tower top temperatures, water TDS, and steam rate.

The liquid flow rates were first measured by a flow totalizer that indicated total water gallons processed. The combined feed rate, distillate rate, and brine rate were traced. The totalizers were becoming fouled with dirt particles, and the technique was abandoned in favor of the "bucket and stopwatch" approach. A 2-quart container was used, requiring from 20-second to 40-second timing. These quantities were accurate enough to monitor the somewhat oscillatory flow behavior inherent in the pilot plant.

The tower top temperatures were monitored with a hand-held thermocouple read out instrument. The thermocouples themselves were tower dedicated and located permanently in top of each tower.

The stream quality, in mg/L of TDS, was probed by a hand-held multiprobe TDS meter. The feed, distillate (individual and composite), and brine outflows were measured.

The steam rate from the electrical steam pressure boiler was adjustable incrementally by setting heater rod toggle switches. The steamer was rated at 850-lb/hr steam production but a maximum steam rate of 420 lb/hr was determined by a commercial-sized bucket and stopwatch technique. A 55-gallon drum was filled with 40 gallons of water at 85 ˚F. Steam flow was timed from 2 minutes to 4 minutes, allowing the water to heat to no more than 135 ˚F. The test procedure was repeated throughout the data gathering period to ensure knowledge of the steam rate that was necessary for thermal multiple effect factor. Quite frequently, the heater elements would burn out, thereby producing less steam than the boiler was set to produce.

4.6.2 General Waste Water Feed Operation

Following the completion of construction, runs were initiated mainly by using waste water secondary effluent as a feed source. During the fall period (August 30, 2006, to February 9, 2007), the thermal efficiency of the towers was improved by various physical changes in the equipment design. Changes such as:

- Air input nozzle location
- Tower top air seals
- Feed pump rate increases and decreases
- Air tower flow rate increase and decreases
- Top sponge compaction
- Tower leveling
- Steam boiler pressure

From table 1, the thermal efficiency changed from an average of 1.7 (August to November 2006) to an average of 2.9 (November to December 2006), with a maximum of 3.3. During the fall 2006 period, all of the runs were constant feed composition (1,000 mg/L TDS) and flow rate until steady state was achieved in 6 to 8 hours.

4.6.3 RO Concentrate Feed Operations

During March and April 2007, the TWPS supplied RO concentrate at 1,900 mg/L of TDS to the pilot plant. In March and April, runs of high recovery were made to demonstrate the dewvaporation tower's ability to process high TDS concentrates with high recoveries. The March 7 run was a steady state operation that produced 4,300-mg/L TDS brine from a 1,500-mg/L TDS RO concentrate feed. The recovery was 78 percent.

From April 2 to April 4, a planned run to achieve 100-percent recovery was made. In order to achieve 100-percent recovery, the brine discharge from the pilot plant was routed back to the feed tank, while the pilot plant distillate was discharged. The feed tank was initially filled with 785 gallons of 1,900-mg/L TDS RO concentrate. With time, the saline concentration in the feed tank increased from 1,900-mg/L TDS to 10,000-mg/L TDS, as the fed tank totally emptied at 100-percent recovery. The feed tank was simulated and matched plant data (figure 20).

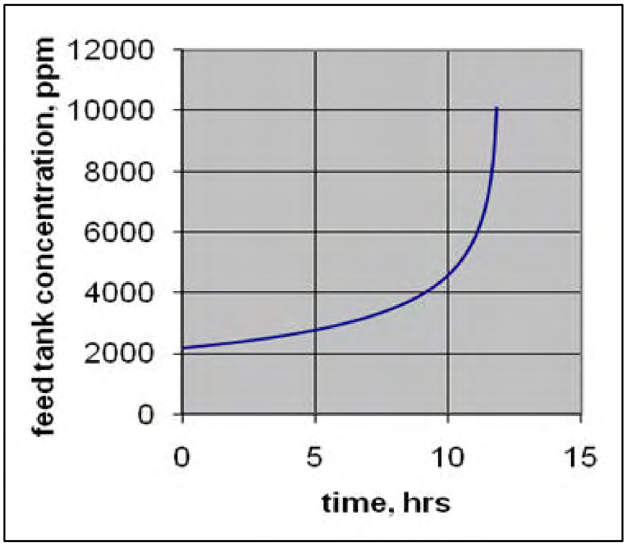

Figure 20. Feed tank salinity – semi batch run.

Analysis of the tower basins showed brine salinity levels as high as 45,000-mg/L TDS, thereby accounting for all of the salt initially in the feed tank that was fed to the pilot plant. Figure 21 shows the process flow connections to and from each tower. It was assumed that the effluent salinity from each tower was the same as the salinity in that tower's basin. However, the tower connections were made in such a way that feed to a tower continued to the next tower in line, and the tower that received the feed used what was necessary for distillate make only. Figure 21 is a schematic of a tower basin, showing two basin compartments. The tower sat in the larger tower basin, while the smaller pump basin hosted a tower feed pump and a brine discharge pump. The brine stream from a previous tower shot directly at the brine discharge pump, thereby allowing most of the brine from a previous tower to bypass the tower. In this manner, the tower simply continued to use some of the liquid for distillate make, allowing the basin brine to continue to increase in salinity throughout the run.

Figure 22 shows the simulated basin salinity concentration buildup for each tower which agreed with the salinity data from each tower basin.

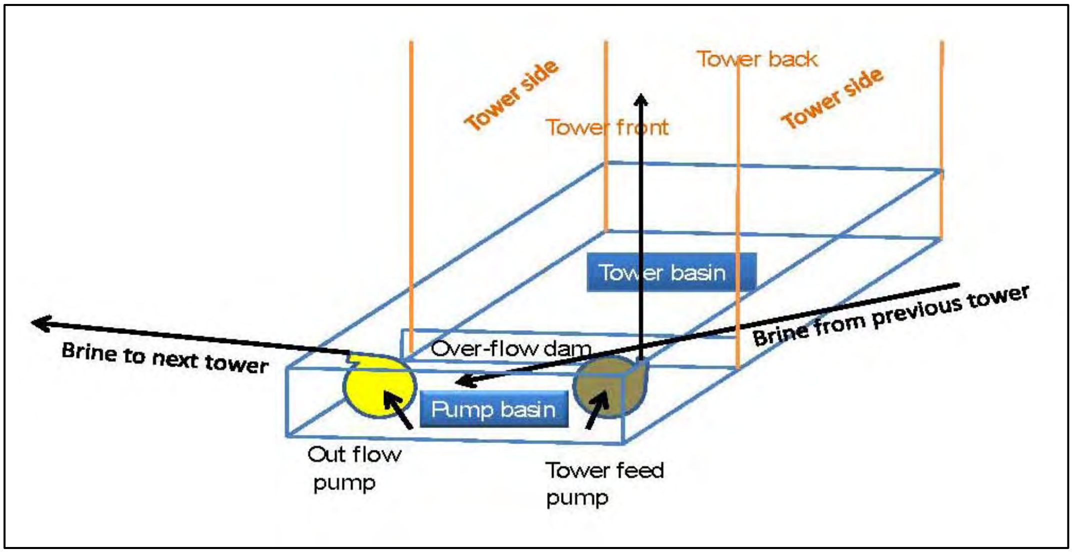

Figure 21. Tower basin design.

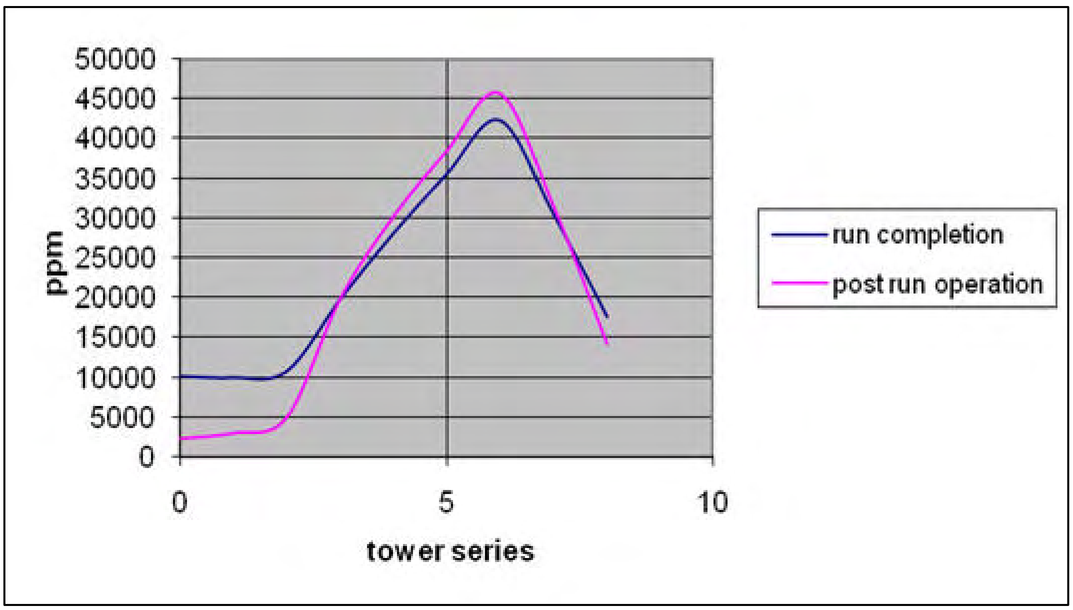

Figure 22. Tower salinity – semi batch run.

5. Economics

Based on the pilot plant data, as presented in appendix B, a nominal 20,000-gpd desalination facility was designed and priced for RO waste water concentrate desalination. Fifty-six towers would be required. The towers can be compacted and positioned as shown in figure 23. The tower air exhaust ears could be mounted on a single side, while the air inlets would be mounted on the same face liquid feed ports. In this manner, four towers would be positioned touching their neighbors as shown. The dimension of the block of four towers would be 4 feet by 4 feet. The tower blocks would be positioned 1/2 foot apart and would require an 8-foot-wide walkway as shown. The footprint would be 77 square feet per 1,000 gpd, which is sizeable. The 20,000-gpd plant would cost $112,000, based on the cost of the 25 towers purchased and located at the WWTP. If money were borrowed at 8 percent with a life of 20 years, then the amortized capital charge for water would be $3.40 per 1,000 gallons.

The cost of additional energy would increase the total water cost. Using the average multiple effect value of the best three runs of 3.2, then the heat needed for 1,000 gallons of distillate production would be 2.6 million BTUs (764 kWh heat). At a natural gas cost of $0.80 per therm, then the operating cost would be $20.85 per 1,000 gallons. If waste heat or solar heat were available, then the operating cost would reduce to the electrical cost of pumps and fans, which was $0.05 per 1,000 gallons for 0.5 kWh per 1,000 gallons.

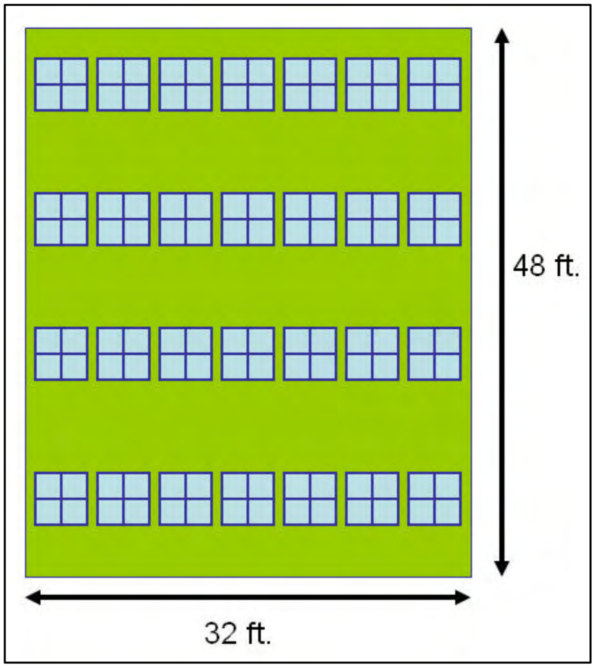

Figure 23. 20,000-gpd dewvaporation plant footprint.

Therefore, the total water cost would be $24.30 per 1,000 gallons, assuming natural gas as the fuel source. The total minimal water cost would be $3.45 per 1,000 gallons for waste heat utilization.

Other advantages of a sizeable plant include: single feed pump for feed to each tower, single steam source with steam plenum to each tower, gravity flow of brines, low maintenance, and modular construction allows incremental plant expansion.

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Appendix A

Pilot Plant Operational

Note: This is the new pumping scheme

Date	24-Oct-06							
Time	11:00 AM		11:50 AM		12:48 PM		1:45 AM	
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status
1	137	good	147	good	147	good	130	good
2	177	good	185	good	166	good	156	ok
3								
4								
5								
6								
7								
8								
9								
10								
11	162	good	162	good	142	poor	148	poor
12	152	good	158	good	176	good	173	ok
13	157	good	171	v. good	177	good	169	good
14	166	good	184	good	140	ok	176	ok
15								
16								
17								
18								
19								
20								
21								
22								
23	162	good	177	good	177	good	174	good
24	169	good	180	v. good	177	v. good	175	v. good
25	135	ok	125	ok	116	poor	107	nothing
AVG	157.4		165.4		157.6		156.4	
Notes	4 elements		4 elements		4 elements		4 elements	

	Seconds	mg/L
11:15 AM	Flow	TDS
Feed		1160
Distillate		48
Brine		1985
11:50 AM	Flow	TDS
Feed		1143
Distillate		14
Brine		1588
12:58 PM	Flow	TDS
Feed		1143
Distillate		12.5
Brine		1505
1:50 AM	Flow	TDS
Feed		1153
Distillate		8.2
Brine		1370
	Flow	TDS
Feed		
Distillate		
Brine		

DewVap Data Sheet

Feed	Brine	Distillate	
17.1	27.6		11:15 AM
16.5	28.9		11:50 AM
16.7	30.0	47.2	12:58 PM
16.1	38.0	48.8	1:50 AM
16.61	32.3	48.0	

Data: number of seconds to fill 2 quart container

cup&time		meter
Feed		
108.4	gph	
Brine		
55.7	gph	
Distillate		
37.5	gph	
Steam		
30.50	gph	

Recovery	27%	
Multiple	1.23	
Losses	45.7	gph

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

		Lbs of steam	Gallons of water	
120 Kwatts	Top switch 3 elements	160	19.2	
140 Kwatts	2nd switch 4 elements		30.5	(not measured but calculated)
150 Kwatts	3rd switch 5 elements	337	40.4	
180 Kwatts	4th switch 6 elements	420	50.4	

Water weighs 8.34 lbs so 400 lbs of steam is 47.96 gallons of water.

Note: This is the new pumping scheme and new Air Flow scheme

Date	7-Nov-06									
Time	10:20 AM		12:00 PM		1:30 AM		2:30 AM		3:30 AM	
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status
1	122	good	157	good	151	good	154	good	156	good
2	176	good	184	good	174	good	179	good	181	good
3										
4										
5										
6										
7										
8										
9										
10										
11	149	good	163	good	161	good	170	good	171	good
12	155	good	170	good	165	good	177	good	175	good
13	137	good	164	good	152	good	162	good	164	good
14	161	good	182	good	173	good	176	good	177	good
15										
16										
17										
18										
19										
20										
21										
22										
23	151	good	176	good	168	good	172	good	171	good
24	142	good	159	good	156	good	162	good	163	good
25	122	ok	107	none	132	ok/poor	182	good	184	good
AVG	146.1		162.4		159.1		170.4		171.3	
Notes	4 elements		4 elements		4 elements		5 elements		5 elements	

	Seconds	mg/L
10:20 AM	Flow	TDS
Feed	24.3	1105
Distillate	50.55	46.5
Brine	32.27	1785
12:00 PM	Flow	TDS
Feed	23.9	1049
Distillate	43.6	25.4
Brine	65.7	1609
1:31 AM	Flow	TDS
Feed	24.2	1030
Distillate	42.3	26
Brine	43.9	1561
2:30 AM	Flow	TDS
Feed	23.7	1027
Distillate	31	24
Brine	97	1643
3:30 AM	Flow	TDS
Feed	25.4	1027
Distillate	32.5	20.5
Brine	105.6	1740

DewVap Data Sheet

	Feed	Brine	Distillate
2:30 AM	23.7	97	31
3:30 AM	25.4	105.6	32.5
	24.55	105.6	31.8

Data: number of seconds to fill 2 quart container

cup&time		meter
Feed		
73.3	gph	
Brine		
17.0	gph	
Distillate		
56.7	gph	
Steam		
30.50	gph	

Recovery	55%	
Multiple	1.86	
Losses	30.1	gph

NOTE: Suspected element burned out.
Used steam production for 4 elements in calculations

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

		Lbs of steam	Gallons of water	
120 Kwatts	Top switch 3 elements	160	19.2	
140 Kwatts	2nd switch 4 elements		30.5	(not measured but calculated)
150 Kwatts	3rd switch 5 elements	337	40.4	
180 Kwatts	4th switch 6 elements	420	50.4	

Date	21-Nov-06		Note: Unit 24 was modified w/double sponges and stuffing in ears					
Time	11:10 AM		12:10 PM		1:10 PM		2:15 PM	
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status
1	145	good	139	good	134	good	131	good
2	160	good	161	good	157	good	160	good
3								
4								
5								
6								
7								
8								
9								
10								
11		poor	148	good	148	good	153	good
12	157	good	139	good	132	fair	155	good
13	148	good	145	good	142	good	147	good
14	157	good	160	good	155	good	159	good
15								
16								
17								
18								
19								
20								
21								
22								
23	151	good	154	good	150	good	155	good
24	147	na	154	good		good	156	good
25	161	good	157	none	156	good	163	good
AVG	153.3		150.8		146.8		153.2	
Notes	4 elements		3 elements		3 elements		3 elements	

	Seconds	mg/L
11:20 AM	Flow	TDS
Feed	24.6	1023.0
Distillate	27.0	22.5
Brine	100.0	2330.0
12:20 PM	Flow	TDS
Feed	24.0	978.0
Distillate	29.9	23.1
Brine	96.0	2480.0
1:15 PM	Flow	TDS
Feed	24.6	962.0
Distillate	32.3	22.1
Brine	88.8	2132.0
2:30 PM	Flow	TDS
Feed		953.0
Distillate	27.0	20.6
Brine	195.0	2150.0
	Flow	TDS
Feed		
Distillate		
Brine		

DewVap Data Sheet

	Feed	Brine	Distillate
11:20 AM			
12:20 PM			
1:15 PM	24.6		
2:30 PM		195.0	27.0
	24.60	195.0	27.0

Data: number of seconds to fill 2 quart container

cup&time		meter
Feed		
73.2	gph	
Brine		
9.2	gph	
Distillate		
66.7	gph	
Steam		
19.20	gph	

Recovery	72%	
Multiple	3.47	
Losses	16.5	gph

		Lbs of steam	Gallons of water	
120 Kwatts	Top switch 3 elements	160	19.2	
140 Kwatts	2nd switch 4 elements		30.5	(not measured but calculated)
150 Kwatts	3rd switch 5 elements	337	40.4	
180 Kwatts	4th switch 6 elements	420	50.4	

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

Note: After the 3rd reading, the air intake into the blower was restricted. The normal intake is approx. 8.3 sq. inch. The first air reduction was to 1 sq. inch. The units stopped producing. The second reduction was approx. 2 sq. inches. The towers continued to warm up, but production dropped slightly

Date	30-Nov-06						**Air Restriction**			Seconds	mg/L				
Time	10:45 AM		11:45 AM		12:40 PM		**2:55 PM**		11:00 AM	Flow	TDS		Feed	Brine	Distillate
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Feed	22.8	976.0				
1									Distillate	30.0	39.5				
2									Brine				23.5	66.0	28.3
3	na	good	157	good	149	good	na	poor				12:45 PM	22.7	60.0	28.5
4	na	good	151	FTG	144	good	161	poor	11:45 AM	Flow	TDS		23.10	63.0	28.4
5									Feed	23.5	971.0		Data: number of seconds to fill 2 quart container		
6									Distillate	28.3	13.2				
7									Brine	66.0	1471.0		cup&time		meter
8													Feed		
9	126	fair	132	FTG	142	FTG	142	poor	12:45 PM	Flow	TDS		77.9	gph	
10	148	good	161	good	151	good	166	fair	Feed	22.7	975.0				
11									Distillate	28.5	11.5		Brine		
12									Brine	60.0	1436.0		28.6	gph	
13															
14									3:00 PM	Flow	TDS		Distillate		
15	148	good	153	FTG	143	good	155	FTG	Feed	16.9	967.0		63.4	gph	
16	159	good	168	good	161	good	170	FTG	Distillate	32.0	6.3				
17									Brine	33.6	1235.0		Steam		
18													19.20	gph	
19										Flow	TDS				
20									Feed						
21	130	fair	146	good	137	good	160	good	Distillate				Recovery	65%	
22	147	fair	155	fair	153	FTG	158	fair	Brine				Multiple	3.30	
23													Losses	5.2	gph
24															
25	153	fair	158	FTG	162	good	168	FTG	DewVap Data Sheet						
AVG	144.4		153.4		149.1		160.0								
Notes	3 elements		3 elements		3 elements		3 elements								
	FTG = fair to good														
					Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**							
120 Kwatts		Top switch 3 elements			160	19.2									
140 Kwatts		2nd switch 4 elements				30.5	(not measured but calculated)								
150 Kwatts		3rd switch 5 elements			337	40.4									
180 Kwatts		4th switch 6 elements			420	50.4									

Date	6 Decmber 2006											Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	10:00 AM		11:00 AM		12:30 PM		2:00 PM		3:20 AM		10:10 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Feed	47|45.9	967.0	77.5	61.3%	2.2	29.6	15.8%
1	117	good	130		135	good	129	good	132	good	Distillate	27.2	35.5	66.2				
2	154	good	153		160	good	150	good	152	good	Brine	147.0	2650.0	12.2				
3	136	good	146		153	good	145	good	147	good	Steam			30.5				
4	136	good	141		151	good	137	good	143	good	11:00 AM	Flow	TDS		Recovery	Multiplier	Losses	% left
5											Feed	47|45.9		77.5	69.4%	2.5	26.2	8.8%
6											Distillate	24.0	28.6	75.0				
7											Brine	265.0	3022.0	6.8				
8											Steam			30.5				
9	126	good	126		139	good	128	good	132	good	12:30 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10	152	good	146		160	good	152	good	153	good	Feed	24.2|24.3		148.5	41.2%	2.4	35.2	47.2%
11	139	good	142		151	good	140	good	141	good	Distillate	24.4	26.8	73.8				
12	136	good	146		161	good	147	good	151	good	Brine	25.7	1615.0	70.0				
13	97	poor	98		108	poor	103	fair	144	good	Steam			30.5				
14	123	poor	123		134	poor	128	poor	155	good	2:20 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15	135	good	144		154	good	144	good	150	good	Feed	25.2|26.0	945.0	140.6	47.2%	2.6	47.2	30.7%
16	150	poor	159		168	good	157	good	163	good	Distillate	22.3	31.2	80.7				
17											Brine	41.7	1334.0	43.2				
18											Steam			30.5				
19											3:30 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20											Feed			140.6	62.9%	2.8	30.1	26.3%
21	103	ftp	117		144	good	135	good	140	good	Distillate	15.8	19.7	113.9				
22	135	poor	136		160	good	151	good	155	good	Brine	48.7	1446	37.0				
23	124	fair	127		143	fair	132	fair	152	good	Steam			40.4				
24	110	fair	110		127	fair	120	fair	150	good								
25	152	good	138		134	fair	125	fair	136	fair	DewVap Data Sheet							
AVG	130.9		134.2		146.0		136.6		146.8									
Notes	4 elements		4 elements		4 elements		4 elements		5 elements									
	FTG = fair to good																	
	FTP = fait to poor				Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**										
120 Kwatts		Top switch 3 elements			160	19.2												
140 Kwatts		2nd switch 4 elements				30.5	(not measured but calculated)											
150 Kwatts		3rd switch 5 elements			337	40.4												
180 Kwatts		4th switch 6 elements			420	50.4												

Date	8 Decmber 2006									
Time	10:00 AM		11:00 AM		1:00 AM		2:00 PM		3:00 PM	
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status
1	134	good	128	good	132	good	147	good	136	
2	155	good	154	good	154	good	167	good	154	
3	146	good	149	good	149	good	165	good	150	
4	140	good	143	good	146	good	156	good	144	
5										
6										
7										
8										
9	128	good	129	fair	135	good	146	good	137	
10	147	good	151	good	153	good	166	good	156	
11	134	good	142	good	144	good	157	good	135	
12	136	good	142	good	147	good	160	good	151	
13	138	good	146	good	142	good	158	good	143	
14	148	good	154	good	154	good	166	good	158	
15	141	good	149	good	149	good	160	good	151	
16	152	fair	163	good	161	good	172	good	162	
17										
18										
19										
20										
21	130	good	139	good	141	good	151	good	142	
22	145	good	150	good	155	good	163	good	155	
23	124	good	131	fair	134	good	154	good	147	
24	141	good	148	good	148	good	154	good	147	
25	146	good	126	fair	124	good	159	good	158	
AVG	140.3		143.8		145.2		158.9		148.6	
Notes	5 elements		5 elements		5 elements		5 elements		5 elements	
	FTG = fair to good									
	FTP = fait to poor				Lbs of steam	Gallons of water				
120 Kwatts		Top switch 3 elements			160	19.2				
140 Kwatts		2nd switch 4 elements				30.5	(not measured but calculated)			
150 Kwatts		3rd switch 5 elements			337	40.4				
180 Kwatts		4th switch 6 elements			420	50.4				

	Seconds	mg/L	Gallons/Hr	%		gph	Brine
10:15 am	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Feed	31.2|28.9	971.0	121.6	51.7%	2.1	38.3	32.9%
Distillate	21.5	43.0	83.7				
Brine	45.0	2016.0	40.0				
Steam			40.4				
11:15 AM	Flow	TDS		Recovery	Multiplier	Losses	% left
Feed	33.5|31.0	974.0	111.6	64.4%	2.4	25.3	25.9%
Distillate	18.4	38.6	97.8				
Brine	62.3	1898.0	28.9				
Steam			40.4				
1:00 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Feed	29.3|27.7	969.0	126.3	64.7%	2.7	31.1	22.1%
Distillate	16.7	17.5	107.8				
Brine	64.6	1735.0	27.9				
Steam			40.4				
2:05 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Feed	28.8|29.0	964.0	124.6	67.8%	2.8	44.5	7.0%
Distillate	16.1	18.0	111.8				
Brine	207.0	1720.0	8.7				
Steam			40.4				
3:00 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Feed	31.6|27.9	963	121.0	67.2%	2.7	43.9	7.5%
Distillate	16.6	17.4	108.4				
Brine	198	1775	9.1				
Steam			40.4				

DewVap Data Sheet

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

Experimenting with four varibles: A. Double steam; B: Shrouds to bring steam from ears; C: Increased air flow; D: Restricted water

	Date	20 Decmber 06						**Double Steam**			Seconds	mg/L	Gallons/Hr	%		gph	Brine
	Time	11:00 AM		12:00 noon		2:00 PM		3:40 PM		11:00 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
	Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Feed	22.6	965.0	79.6	44.4%	2.3	0.9	67.9%
	1	104	poor	110	na	124	na	144	na	Distillate	41.0	25.0	43.9				
	2	159	good	161	fair/good	156	good	160	good	Brine	33.3	1310.0	54.1				
	3									Steam			19.2				
	4									12:00 noon	Flow	TDS		Recovery	Multiplier	Losses	% left
	5									Feed	22.0	965.0	81.8	45.2%	2.4	9.9	55.6%
	6									Distillate	39.4	17.4	45.7				
	7									Brine	39.6	1252.0	45.5				
	8									Steam			19.2				
	9									2:00 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
	10									Feed	21.8	960.0	82.6	50.7%	2.7	23.1	32.8%
	11	136	fair/good	147	good	147	good	158	good	Distillate	34.9	16.6	51.6				
	12	143	fair/good	147	fair/good	147	fair	163	good	Brine	66.4	1151.0	27.1				
Increase air	13	105	poor	114	poor	114	fair			Steam			19.2				
decreased water	14	147	fair/good	150	fair/good	150	fair			3:40 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
	15									Feed	22.0	same	81.8	44.3%	2.3	24.7	38.5%
	16									Distillate	40.2	13.5	44.8				
	17									Brine	57.1	1195.0	31.5				
	18									Steam			19.2				
	19										Flow	TDS	gph	Recovery	Multiplier	Losses	% left
	20									Feed					2.3		#VALUE!
	21									Distillate	40.5		44.4				
	22									Brine							
	23	143	fair/good	149	fair/good	149	fair/good			Steam			19.2				
return steam	24	145	na	150	na	152	na										
	25	153	good	157	good	152	good	166	good	DewVap Data Sheet							
	AVG	137.2		142.8		143.4		158.2									
	Notes	3 elements		3 elements		3 elements		3 elements									
						Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**								
	120 Kwatts		Top switch 3 elements			160	19.2										
	140 Kwatts		2nd switch 4 elements				30.5	(not measured but calculated)									
	150 Kwatts		3rd switch 5 elements			337	40.4										
	180 Kwatts		4th switch 6 elements			420	50.4										

Individual measurments

Unit 13	Increased Air Flow				
ml/2 min	ml/2 min	gal/hr	gal/hr	gal/hr	
east	west	east	west	total	
100	150	0.79	1.19	1.98	
Unit 14	Reduced water				
east	west	east	west	total	
360	490	2.85	3.88	6.74	
Unit 23	Control Unit				
east	west	east	west	total	
420	400	3.33	3.17	6.50	
420	440	3.33	3.49	6.82	
				6.66	Average
Unit 24	Steam return shrouds				
east	west	east	west	total	
540	460	4.28	3.65	7.93	
650	450	5.15	3.57	8.72	
				8.32	Average

Date	18-Jan-07							Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	12:00 PM		1:40 PM		2:45 PM		12:20 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Feed	23.7		75.9	36.5%	1.4	27.6	49.8%
1							Distillate	47.8		37.7				
2							Brine	47.6		37.8				
3							Steam			27.1				
4							1:50 PM	Flow	TDS		Recovery	Multiplier	Losses	% left
5	132	good	136	good	151	good	Feed	25.0		72.0	44.5%	1.6	27.2	38.6%
6	154	good	150	good	163	good	Distillate	40.8		44.1				
7	141	good	150	good	157	good	Brine	64.8		27.8				
8	150	good	157	good	166	good	Steam			27.1				
9							1:12 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10							Feed	24.7		72.9	44.1%	1.6	33.9	30.2%
11							Distillate	40.8		44.1				
12							Brine	81.8		22.0				
13							Steam			27.1				
14								Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15							Feed							
16							Distillate							
17	152	good	148	good	162	good	Brine							
18	126	fair	138	good	150	fair/good	Steam							
19	132	good	157	good	168	good		Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20	146	good	147	good	161	good	Feed							
21							Distillate							
22							Brine							
23							Steam							
24														
25					171	good	DewVap Data Sheet							
AVG	141.6		147.9		161.0									
Notes	3 elements		3 elements		3 elements									
					Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**						
120 Kwatts		Top switch 3 elements			226	27.1								
140 Kwatts		2nd switch 4 elements			320	38.4	(not measured but calculated)							
150 Kwatts		3rd switch 5 elements			373	44.7								
180 Kwatts		4th switch 6 elements			446	53.5								

Date	9-Feb-2007							Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	11:30 AM		12:45 PM		2:00 PM		11:30 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Feed	23.9		75.3	63.8%	2.4	16.3	27.5%
1	151	good	164	good	160	good	Distillate	27.6		65.3				
2	166	good	170	good	165	good	Brine	86.8		20.7				
3							Steam			27.1				
4							12:50 PM	Flow	TDS		Recovery	Multiplier	Losses	% left
5							Feed	23.8		75.6	65.6%	2.5	11.8	31.1%
6							Distillate	26.7		67.4				
7							Brine	76.5		23.5				
8							Steam			27.1				
9							2:00 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10							Feed	24.1		74.7	65.5%	2.5	16.5	24.9%
11	155	good	168	good	165	good	Distillate	27.0		66.7				
12	164	good	167	good	165	good	Brine	96.6		18.6				
13	156	good	169	good	165	good	Steam			27.1				
14	164	good	168	good	165	good		Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15							Feed							
16							Distillate							
17							Brine							
18							Steam							
19								Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20							Feed							
21							Distillate							
22							Brine							
23	166	good	167	good	164	good	Steam							
24	153	good	164	good	161	good								
25	169	good	170	good	166	good	DewVap Data Sheet							
AVG	160.4		167.4		164.0									
Notes	3 elements		3 elements		3 elements									
					Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**						
120 Kwatts		Top switch 3 elements			226	27.1								
140 Kwatts		2nd switch 4 elements			320	38.4	(not measured but calculated)							
150 Kwatts		3rd switch 5 elements			373	44.7								
180 Kwatts		4th switch 6 elements			446	53.5								

Date	4-Mar-07		Brine to Feed Tank		Feed tank initial TDS = 2776 mg/L			Start: 7:00 AM				Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	7:30 AM		8:30 AM		10:30 AM		11:30 AM		12:30 PM		7:30 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Feed	15.5	2903.0	116.1	41.6%	1.7	24.6	55.6%
1	149		149		153						Distillate	28.3	69.0	63.6				
2	165		162		165						Brine	27.9	8920.0	64.5				
3											Steam			36.6				
4											8:30 AM	Flow	TDS		Recovery	Multiplier	Losses	% left
5											Feed	15.5	3256.0	116.1	41.4%	1.7	39.0	43.5%
6											Distillate	28.5	66.1	63.2				
7											Brine	35.6	5714.0	50.6				
8											Steam			36.6				
9											10:30 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10											Feed	16.0	3635.0	112.5	45.4%	1.8	37.1	39.4%
11	168		165		167						Distillate	26.6	76.1	67.7				
12	153		149		155						Brine	40.6	5325.0	44.3				
13			159								Steam			36.6				
14	158		158		161						11:30 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15											Feed	19.3	4048.0	93.3	47.8%	1.7	43.0	26.5%
16											Distillate	29.0	84.0	62.1				
17											Brine	72.7	5948.0	24.8				
18											Steam			36.6				
19											12:30 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20											Feed	20.1	4427	89.6	50.1%	1.7	36.0	30.2%
21											Distillate	28.5	105	63.2				
22											Brine	66.6	6574	27.0				
23	152		153		155						Steam			36.6				
24	150		156		156													
25	155		159		158						DewVap Data Sheet							
AVG	156.3		156.7		158.8		#DIV/0!											
Notes	4 elements		4 elements		4 elements													
					Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**										
120 Kwatts		2 Switches 3 elements			247	29.6												
140 Kwatts		3 Switches 4 elements			305	36.6												
150 Kwatts		4 Switches 5 elements			398	47.7	(not measured but calculated)											

Date	4-Mar-07		Brine to Feed Tank		Feed tank initial TDS = 2776 mg/L							Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	1:30 PM		2:30 PM		3:30 PM		4:05 PM				1:30 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Feed	20.4	4931.0	88.2	57.4%	2.0	53.1	0.0%
1											Distillate	25.1	105.0	71.7				
2											Brine	1000000.0	7229.0	0.0				
3											Steam			36.6				
4											2:30 PM	Flow	TDS		Recovery	Multiplier	Losses	% left
5											Feed	18.3	5785.0	98.4	44.3%	1.6	40.5	35.2%
6											Distillate	30.1	130.0	59.8				
7											Brine	52.0	7932.0	34.6				
8											Steam			36.6				
9											3:30 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10											Feed	18.7	6852.0	96.3	47.0%	1.7	31.4	40.5%
11											Distillate	28.8	130.0	62.5				
12											Brine	46.2	8980.0	39.0				
13											Steam			36.6				
14											4:05 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15											Feed	56.2	8795.0	32.0	83.8%	1.6	11.1	0.0%
16											Distillate	31.3	125.0	57.5				
17											Brine	1000000.0	10150.0	0.0				
18											Steam			36.6				
19												Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20											Feed					0.0	36.6	
21											Distillate							
22											Brine							
23											Steam			36.6				
24																		
25											DewVap Data Sheet							
AVG																		
Notes	4 elements		4 elements		4 elements													
					Lbs of steam	Gallons of water		**Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm**										
120 Kwatts		2 Switches 3 elements			247	29.6												
140 Kwatts		3 Switches 4 elements			305	36.6				Note: 1000000 put in when flow was so small it could not be measured								
150 Kwatts		4 Switches 5 elements			398	47.7	(not measured but calculated)			Note: At 1:30 PM & 2:30 PM 3 "ears" were disconnected which were high in TDS.								
										The distillate flow was calculated (18/15).								

Date	7-Mar-07							Seconds	mg/L	Gallons/Hr	%		gph	Brine
Time	11:00 AM		12:30 PM		1:45 PM		11:00 AM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Unit	Temp	Status	Temp	Status	Temp	Status	Feed	37.9	1493.0	95.0	58.2%	2.0	6.9	51.5%
1			162		178		Distillate	23.2	42.4	77.6				
2			178		198		Brine	36.8	3633.0	48.9				
3			136		146		Steam			38.4				
4			132		141		12:30 PM	Flow	TDS		Recovery	Multiplier	Losses	% left
5							Feed	38.8	1520.0	92.8	67.6%	2.3	34.7	8.5%
6							Distillate	20.3	29.5	88.7				
7							Brine	229.0	4042.0	7.9				
8							Steam			38.4				
9			155		167		1:45 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
10			173		192		Feed	41.4	1512.0	87.0	78.0%	2.5	20.9	7.7%
11			174		192		Distillate	18.4	27.7	97.8				
12			145		191		Brine	270.0	4310.0	6.7				
13			173		184		Steam			38.4				
14			171		184			Flow	TDS	gph	Recovery	Multiplier	Losses	% left
15			148		162		Feed							
16			184		186		Distillate							
17							Brine							
18							Steam							
19								Flow	TDS	gph	Recovery	Multiplier	Losses	% left
20							Feed							
21			136		152		Distillate							
22			149		164		Brine							
23			139		157		Steam							
24			161		168									
25			165		150		DewVap Data Sheet							
AVG	#DIV/0!		157.7		171.3									
Notes	4 elements		4 elements		4 elements									

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

		Lbs of steam	Gallons of water	
120 Kwatts	Top switch 3 elements	226	27.1	
140 Kwatts	2nd switch 4 elements	320	38.4	(not measured but calculated)
150 Kwatts	3rd switch 5 elements	373	44.7	
180 Kwatts	4th switch 6 elements	446	53.5	

Date	2-Apr-07		**Brine to Feed Tank**		Start TDS 1920 mg/L		Start: 11:45 AM			
Time	1:00 PM		3:00 PM							
Unit	Temp	Status	Temp	Status	Temp	Status	Temp	Status	Temp	Status
1	159		171							
2	169		175							
3										
4										
5										
6										
7										
8										
9										
10										
11	181		184							
12	180		184							
13	157		163							
14	168		160							
15										
16										
17										
18										
19										
20										
21										
22										
23	163		158							
24	165		169							
25	168									
AVG	167.8		170.5		#DIV/0!		#DIV/0!			
Notes	4 elements		4 elements		4 elements					

	Seconds	mg/L	Gallons/Hr	%		gph	Brine
1:00 PM	Flow	TDS	gph	Recovery	Multiplier	Losses	% left
Feed	24.8	2056.0	72.6	58.5%	1.7	45.3	0.0%
Distillate	28.2	92.2	63.8				
Brine	1000000.0	9782.0	0.0				
Steam			36.6				
3:00 PM	Flow	TDS		Recovery	Multiplier	Losses	% left
Feed	35.0	2222.0	51.4	75.7%	1.8	21.4	0.0%
Distillate	27.0	98.8	66.7				
Brine	1000000.0	10540.0	0.0				
Steam			36.6				

Start Volume (gallons)		TDS mg/L		Total Pounds of Salts
785	70	1920		13.70

Gallons w/salts out		TDS mg/L		lbs salts removed
79.79	10.94	92.2		0.07

Gallons w/salts out		TDS mg/L		lbs salts removed
133.33		95.5		0.11

Goal is 5000 gpd of distillate: at a 80% recovery of 6250 gpd feed or 4.34 gpm

		Lbs of steam	Gallons of water	
120 Kwatts	2 Switches 3 elements	247	29.6	
140 Kwatts	3 Switches 4 elements	305	36.6	
150 Kwatts	4 Switches 5 elements	398	47.7	(not measured but calculated)

Appendix B

City of Phoenix Water Analysis

23rd Ave Salinity Samples
D. Allen 05/01/07

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007013180	3/7/2007 14:31:00	DISTILLATE	SM20 2340	Calcium Hardness	<2.5	mg/L		2.5		
2007013180	3/7/2007 14:31:00	DISTILLATE	SM20 2540 C	Total Dissolved Solids	18	mg/L	1	10		
2007013180	3/7/2007 14:31:00	DISTILLATE	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013180	3/7/2007 14:31:00	DISTILLATE	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013180	3/7/2007 14:31:00	DISTILLATE	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013180	3/7/2007 14:31:00	DISTILLATE	EPA 200.7	Calcium Total	<1.0	mg/L	1	1.0		
2007013180	3/7/2007 14:31:00	DISTILLATE	EPA 300.0	Chloride	5.0	mg/L	1	1.0		
2007013180	3/7/2007 14:31:00	DISTILLATE	EPA 180.1	Turbidity	0.85	NTU	1			
2007013181	3/7/2007 14:21:00	FEED	SM20 2540 C	Total Dissolved Solids	1270	mg/L	1	10		
2007013181	3/7/2007 14:21:00	FEED	SM20 2340	Calcium Hardness	240	mg/L		2.5		
2007013181	3/7/2007 14:21:00	FEED	EPA 200.7	Calcium Total	96	mg/L	2	2.0	D2	
2007013181	3/7/2007 14:21:00	FEED	SM20 2340	Hardness - Total	392	mg/L		6.6		
2007013181	3/7/2007 14:21:00	FEED	EPA 300.0	Chloride	374	mg/L	2	2.0	D2	
2007013181	3/7/2007 14:21:00	FEED	EPA 200.7	Magnesium - Total	37	mg/L	2	2.0	D1	
2007013181	3/7/2007 14:21:00	FEED	EPA 200.7	Sodium - Total	277	mg/L	4	40.0	D2	
2007013182	3/7/2007 14:27:00	BRINE	SM20 2340	Calcium Hardness	250	mg/L		2.5		
2007013182	3/7/2007 14:27:00	BRINE	EPA 200.7	Magnesium - Total	108	mg/L	2	2.0	D2	
2007013182	3/7/2007 14:27:00	BRINE	SM20 2540 C	Total Dissolved Solids	4030	mg/L	1	20	N1	Filtered 25ml of sample.
2007013182	3/7/2007 14:27:00	BRINE	SM20 2340	Hardness - Total	694	mg/L		6.6		
2007013182	3/7/2007 14:27:00	BRINE	EPA 300.0	Chloride	1360	mg/L	10	10	D2	
2007013182	3/7/2007 14:27:00	BRINE	EPA 200.7	Sodium - Total	1050	mg/L	15	150	D2	
2007013182	3/7/2007 14:27:00	BRINE	EPA 200.7	Calcium Total	100	mg/L	2	2.0	D2	
2007013183	3/7/2007 15:35:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007013183	3/7/2007 15:35:00	Distillate	EPA 300.0	Chloride	5.9	mg/L	1	1.0		
2007013183	3/7/2007 15:35:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007013183	3/7/2007 15:35:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013183	3/7/2007 15:35:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013183	3/7/2007 15:35:00	Distillate	SM20 2540 C	Total Dissolved Solids	10	mg/L	1	10		
2007013183	3/7/2007 15:35:00	Distillate	EPA 180.1	Turbidity	0.95	NTU	1			
2007013183	3/7/2007 15:35:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013184	3/7/2007 15:25:00	Feed	SM20 2540 C	Total Dissolved Solids	1260	mg/L	1	10		
2007013184	3/7/2007 15:25:00	Feed	SM20 2340	Hardness - Total	401	mg/L		6.6		
2007013184	3/7/2007 15:25:00	Feed	SM20 2340	Calcium Hardness	245	mg/L		2.5		
2007013184	3/7/2007 15:25:00	Feed	EPA 200.7	Magnesium - Total	38	mg/L	2	2.0	D1	
2007013184	3/7/2007 15:25:00	Feed	EPA 200.7	Sodium - Total	273	mg/L	4	40.0	D2	
2007013184	3/7/2007 15:25:00	Feed	EPA 200.7	Calcium Total	98	mg/L	2	2.0	D2	
2007013184	3/7/2007 15:25:00	Feed	EPA 300.0	Chloride	389	mg/L	5	5.0	D2	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007013185	3/7/2007 15:20:00	Brine	EPA 300.0	Chloride	1440	mg/L	10	10	D2	
2007013185	3/7/2007 15:20:00	Brine	SM20 2540 C	Total Dissolved Solids	4370	mg/L	1	20	N1	Filtered 25ml of sample.
2007013185	3/7/2007 15:20:00	Brine	SM20 2340	Hardness - Total	728	mg/L		6.6		
2007013185	3/7/2007 15:20:00	Brine	EPA 200.7	Magnesium - Total	113	mg/L	2	2.0	D2	
2007013185	3/7/2007 15:20:00	Brine	SM20 2340	Calcium Hardness	262	mg/L		2.5		
2007013185	3/7/2007 15:20:00	Brine	EPA 200.7	Calcium Total	105	mg/L	2	2.0	D2	
2007013185	3/7/2007 15:20:00	Brine	EPA 200.7	Sodium - Total	1110	mg/L	15	150	D2	
2007013521	3/9/2007 11:05:00	DISTILLATE	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013521	3/9/2007 11:05:00	DISTILLATE	SM20 2540 C	Total Dissolved Solids	32	mg/L	1	10		
2007013521	3/9/2007 11:05:00	DISTILLATE	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007013521	3/9/2007 11:05:00	DISTILLATE	EPA 180.1	Turbidity	0.75	NTU	1			
2007013521	3/9/2007 11:05:00	DISTILLATE	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007013521	3/9/2007 11:05:00	DISTILLATE	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013521	3/9/2007 11:05:00	DISTILLATE	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013521	3/9/2007 11:05:00	DISTILLATE	EPA 300.0	Chloride	7.7	mg/L	1	1.0		
2007013522	3/9/2007 10:55:00	FEED	SM20 2540 C	Total Dissolved Solids	1260	mg/L	1	10		
2007013522	3/9/2007 10:55:00	FEED	SM20 2340	Calcium Hardness	225	mg/L		2.5		
2007013522	3/9/2007 10:55:00	FEED	EPA 200.7	Sodium - Total	251	mg/L	4	40.0	D2	
2007013522	3/9/2007 10:55:00	FEED	SM20 2340	Hardness - Total	369	mg/L		6.6		
2007013522	3/9/2007 10:55:00	FEED	EPA 200.7	Magnesium - Total	35	mg/L	4	4.0	D1	
2007013522	3/9/2007 10:55:00	FEED	EPA 200.7	Calcium Total	90	mg/L	4	4.0	D2	
2007013522	3/9/2007 10:55:00	FEED	EPA 300.0	Chloride	367	mg/L	5	5.0	D2	
2007013523	3/9/2007 11:00:00	BRINE	SM20 2540 C	Total Dissolved Solids	3300	mg/L	2	20	N1	Filtered 25 mL of sample.
2007013523	3/9/2007 11:00:00	BRINE	EPA 200.7	Magnesium - Total	73	mg/L	15	15	D1	
2007013523	3/9/2007 11:00:00	BRINE	EPA 200.7	Calcium Total	94	mg/L	15	15	D2	
2007013523	3/9/2007 11:00:00	BRINE	EPA 200.7	Sodium - Total	769	mg/L	15	150	D2	
2007013523	3/9/2007 11:00:00	BRINE	SM20 2340	Hardness - Total	535	mg/L		6.6		
2007013523	3/9/2007 11:00:00	BRINE	EPA 300.0	Chloride	1160	mg/L	10	10	D2	
2007013523	3/9/2007 11:00:00	BRINE	SM20 2340	Calcium Hardness	235	mg/L		2.5		
2007013620	3/9/2007 12:50:00	Distillate	SM20 2540 C	Total Dissolved Solids	42	mg/L	1	10		
2007013620	3/9/2007 12:50:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013620	3/9/2007 12:50:00	Distillate	EPA 180.1	Turbidity	0.70	NTU	1			
2007013620	3/9/2007 12:50:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007013620	3/9/2007 12:50:00	Distillate	EPA 300.0	Chloride	6.1	mg/L	1	1.0		
2007013620	3/9/2007 12:50:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013620	3/9/2007 12:50:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007013620	3/9/2007 12:50:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013621	3/9/2007 13:00:00	Feed	SM20 2540 C	Total Dissolved Solids	1710	mg/L	1	10		
2007013621	3/9/2007 13:00:00	Feed	SM20 2340	Hardness - Total	503	mg/L		6.6		
2007013621	3/9/2007 13:00:00	Feed	EPA 200.7	Sodium - Total	384	mg/L	5	50.0	D2	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007013621	3/9/2007 13:00:00	Feed	EPA 300.0	Chloride	497	mg/L	5	5.0	D2	
2007013621	3/9/2007 13:00:00	Feed	EPA 200.7	Magnesium - Total	47	mg/L	4	4.0	D1	
2007013621	3/9/2007 13:00:00	Feed	SM20 2340	Calcium Hardness	310	mg/L		2.5		
2007013621	3/9/2007 13:00:00	Feed	EPA 200.7	Calcium Total	124	mg/L	4	4.0	D2	
2007013622	3/9/2007 12:55:00	Brine	SM20 2540 C	Total Dissolved Solids	2810	mg/L	2	20	N1	Filtered 25 mL of sample.
2007013622	3/9/2007 12:55:00	Brine	EPA 300.0	Chloride	1980	mg/L	10	10	D2	
2007013622	3/9/2007 12:55:00	Brine	EPA 200.7	Magnesium - Total	49	mg/L	15	15	D1	
2007013622	3/9/2007 12:55:00	Brine	EPA 200.7	Sodium - Total	699	mg/L	15	150	D2	
2007013622	3/9/2007 12:55:00	Brine	SM20 2340	Calcium Hardness	227	mg/L		2.5		
2007013622	3/9/2007 12:55:00	Brine	EPA 200.7	Calcium Total	91	mg/L	15	15	D2	
2007013622	3/9/2007 12:55:00	Brine	SM20 2340	Hardness - Total	429	mg/L		6.6		
2007013652	3/9/2007 13:40:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013652	3/9/2007 13:40:00	Distillate	EPA 300.0	Chloride	7.3	mg/L	1	1.0		
2007013652	3/9/2007 13:40:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013652	3/9/2007 13:40:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007013652	3/9/2007 13:40:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007013652	3/9/2007 13:40:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013652	3/9/2007 13:40:00	Distillate	EPA 180.1	Turbidity	0.70	NTU	1			
2007013652	3/9/2007 13:40:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007013653	3/9/2007 13:45:00	Feed	EPA 200.7	Calcium Total	127	mg/L	4	4.0	D2	
2007013653	3/9/2007 13:45:00	Feed	EPA 200.7	Sodium - Total	398	mg/L	5	50.0	D2	
2007013653	3/9/2007 13:45:00	Feed	SM20 2340	Calcium Hardness	317	mg/L		2.5		
2007013653	3/9/2007 13:45:00	Feed	SM20 2540 C	Total Dissolved Solids	1800	mg/L	1	10		
2007013653	3/9/2007 13:45:00	Feed	SM20 2340	Hardness - Total	515	mg/L		6.6		
2007013653	3/9/2007 13:45:00	Feed	EPA 300.0	Chloride	522	mg/L	5	5.0	D2	
2007013653	3/9/2007 13:45:00	Feed	EPA 200.7	Magnesium - Total	48	mg/L	4	4.0	D1	
2007013654	3/9/2007 13:55:00	Brine	EPA 300.0	Chloride	2060	mg/L	10	10	D2	
2007013654	3/9/2007 13:55:00	Brine	SM20 2540 C	Total Dissolved Solids	2910	mg/L	2	20	N1	Filtered 25 mL of sample.
2007013654	3/9/2007 13:55:00	Brine	SM20 2340	Calcium Hardness	240	mg/L		2.5		
2007013654	3/9/2007 13:55:00	Brine	EPA 200.7	Sodium - Total	755	mg/L	10	100	D2	
2007013654	3/9/2007 13:55:00	Brine	SM20 2340	Hardness - Total	458	mg/L		6.6		
2007013654	3/9/2007 13:55:00	Brine	EPA 200.7	Magnesium - Total	53	mg/L	10	10	D1	
2007013654	3/9/2007 13:55:00	Brine	EPA 200.7	Calcium Total	96	mg/L	10	10	D2	
2007013655	3/9/2007 14:45:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013655	3/9/2007 14:45:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007013655	3/9/2007 14:45:00	Distillate	SM20 2540 C	Total Dissolved Solids	34	mg/L	1	10		
2007013655	3/9/2007 14:45:00	Distillate	EPA 300.0	Chloride	7.2	mg/L	1	1.0		
2007013655	3/9/2007 14:45:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013655	3/9/2007 14:45:00	Distillate	EPA 180.1	Turbidity	0.70	NTU	1			
2007013655	3/9/2007 14:45:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007013655	3/9/2007 14:45:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007013656	3/9/2007 14:50:00	Feed	SM20 2540 C	Total Dissolved Solids	1840	mg/L	1	10		
2007013656	3/9/2007 14:50:00	Feed	SM20 2340	Hardness - Total	560	mg/L		6.6		
2007013656	3/9/2007 14:50:00	Feed	SM20 2340	Calcium Hardness	342	mg/L		2.5		
2007013656	3/9/2007 14:50:00	Feed	EPA 300.0	Chloride	537	mg/L	5	5.0	D2	
2007013656	3/9/2007 14:50:00	Feed	EPA 200.7	Magnesium - Total	53	mg/L	4	4.0	D1	
2007013656	3/9/2007 14:50:00	Feed	EPA 200.7	Calcium Total	137	mg/L	4	4.0	D2	
2007013656	3/9/2007 14:50:00	Feed	EPA 200.7	Sodium - Total	394	mg/L	6	60.0	D2	
2007013657	3/9/2007 14:55:00	Brine	SM20 2540 C	Total Dissolved Solids	3490	mg/L	2	20		Filtered 25 mls of sample.
2007013657	3/9/2007 14:55:00	Brine	SM20 2340	Hardness - Total	537	mg/L		6.6		
2007013657	3/9/2007 14:55:00	Brine	SM20 2340	Calcium Hardness	277	mg/L		2.5		
2007013657	3/9/2007 14:55:00	Brine	EPA 300.0	Chloride	1270	mg/L	10	10	D2	
2007013657	3/9/2007 14:55:00	Brine	EPA 200.7	Sodium - Total	942	mg/L	12	120	D2	
2007013657	3/9/2007 14:55:00	Brine	EPA 200.7	Calcium Total	111	mg/L	12	12	D2	
2007013657	3/9/2007 14:55:00	Brine	EPA 200.7	Magnesium - Total	63	mg/L	12	12	D1	
2007013876	3/12/2007 08:55:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013876	3/12/2007 08:55:00	Distillate	SM20 2340	Calcium Hardness	<2.5	mg/L		2.5		
2007013876	3/12/2007 08:55:00	Distillate	EPA 200.7	Calcium Total	<2.0	mg/L	2	2.0	D1	
2007013876	3/12/2007 08:55:00	Distillate	EPA 200.7	Sodium - Total	<20.0	mg/L	2	20.0	D1	
2007013876	3/12/2007 08:55:00	Distillate	EPA 180.1	Turbidity	0.90	NTU	1			
2007013876	3/12/2007 08:55:00	Distillate	EPA 200.7	Magnesium - Total	<2.0	mg/L	2	2.0	D1	
2007013877	3/12/2007 08:55:00	Distillate	SM20 2540 C	Total Dissolved Solids	40	mg/L	1	10		
2007013878	3/12/2007 08:55:00	Distillate	EPA 300.0	Chloride	7.5	mg/L	1	1.0		
2007013879	3/12/2007 08:50:00	Feed	SM20 2340	Calcium Hardness	320	mg/L		2.5		
2007013879	3/12/2007 08:50:00	Feed	EPA 200.7	Sodium - Total	357	mg/L	5	50.0	D2	
2007013879	3/12/2007 08:50:00	Feed	EPA 200.7	Calcium Total	128	mg/L	4	4.0	D2	
2007013879	3/12/2007 08:50:00	Feed	SM20 2340	Hardness - Total	521	mg/L		6.6		
2007013879	3/12/2007 08:50:00	Feed	EPA 200.7	Magnesium - Total	49	mg/L	4	4.0	D1	
2007013880	3/12/2007 08:50:00	Feed	SM20 2540 C	Total Dissolved Solids	1680	mg/L	1	10		
2007013881	3/12/2007 08:50:00	Feed	EPA 300.0	Chloride	494	mg/L	5	5.0	D2	
2007013978	3/12/2007 11:25:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007013978	3/12/2007 11:25:00	Distillate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		
2007013978	3/12/2007 11:25:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007013978	3/12/2007 11:25:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007013978	3/12/2007 11:25:00	Distillate	EPA 180.1	Turbidity	0.70	NTU	1			
2007013978	3/12/2007 11:25:00	Distillate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		
2007013979	3/12/2007 11:25:00	Distillate	SM20 2540 C	Total Dissolved Solids	42	mg/L	1	10		
2007013980	3/12/2007 11:25:00	Distillate	EPA 300.0	Chloride	9.8	mg/L	1	1.0		
2007013981	3/12/2007 11:20:00	Feed	SM20 2340	Hardness - Total	491	mg/L		6.6		
2007013981	3/12/2007 11:20:00	Feed	SM20 2340	Calcium Hardness	297	mg/L		2.5		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007013981	3/12/2007 11:20:00	Feed	EPA 200.7	Magnesium - Total	47	mg/L	4	4.0	D1	
2007013981	3/12/2007 11:20:00	Feed	EPA 200.7	Sodium - Total	334	mg/L	5	50.0	D2	
2007013981	3/12/2007 11:20:00	Feed	EPA 200.7	Calcium Total	119	mg/L	4	4.0	D2	
2007013982	3/12/2007 11:20:00	Feed	SM20 2540 C	Total Dissolved Solids	1570	mg/L	1	10		
2007013983	3/12/2007 11:20:00	Feed	EPA 300.0	Chloride	514	mg/L	5	5.0	D2	
2007013984	3/12/2007 11:15:00	Brine	SM20 2340	Hardness - Total	532	mg/L		6.6		
2007013984	3/12/2007 11:15:00	Brine	SM20 2340	Calcium Hardness	252	mg/L		2.5		
2007013984	3/12/2007 11:15:00	Brine	EPA 200.7	Sodium - Total	745	mg/L	12	120	D2	
2007013984	3/12/2007 11:15:00	Brine	EPA 200.7	Magnesium - Total	68	mg/L	12	12	D1	
2007013984	3/12/2007 11:15:00	Brine	EPA 200.7	Calcium Total	101	mg/L	12	12	D2	
2007013985	3/12/2007 11:15:00	Brine	SM20 2540 C	Total Dissolved Solids	2940	mg/L	2	20	N1	Filtered 25 mls.
2007013986	3/12/2007 11:15:00	Brine	EPA 300.0	Chloride	1020	mg/L	10	10	D2	
2007014071	3/12/2007 12:10:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014071	3/12/2007 12:10:00	Distillate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		
2007014071	3/12/2007 12:10:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014071	3/12/2007 12:10:00	Distillate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		
2007014071	3/12/2007 12:10:00	Distillate	EPA 180.1	Turbidity	0.70	NTU	1			
2007014071	3/12/2007 12:10:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014072	3/12/2007 12:10:00	Distillate	SM20 2540 C	Total Dissolved Solids	44	mg/L	1	10		
2007014073	3/12/2007 12:10:00	Distillate	EPA 300.0	Chloride	9.5	mg/L	1	1.0		
2007014074	3/12/2007 12:20:00	Feed	SM20 2340	Hardness - Total	544	mg/L		6.6		
2007014074	3/12/2007 12:20:00	Feed	SM20 2340	Calcium Hardness	330	mg/L		2.5		
2007014074	3/12/2007 12:20:00	Feed	EPA 200.7	Magnesium - Total	52	mg/L	4	4.0	D1	
2007014074	3/12/2007 12:20:00	Feed	EPA 200.7	Sodium - Total	386	mg/L	5	50.0	D2	
2007014074	3/12/2007 12:20:00	Feed	EPA 200.7	Calcium Total	132	mg/L	4	4.0	D2	
2007014075	3/12/2007 12:20:00	Feed	SM20 2540 C	Total Dissolved Solids	3520	mg/L	2	20	N1	Filtered 25 mls.
2007014076	3/12/2007 12:20:00	Feed	EPA 300.0	Chloride	488	mg/L	5	5.0	D2	
2007014077	3/12/2007 12:15:00	Brine	SM20 2340	Calcium Hardness	250	mg/L		2.5		
2007014077	3/12/2007 12:15:00	Brine	SM20 2340	Hardness - Total	509	mg/L		6.6		
2007014077	3/12/2007 12:15:00	Brine	EPA 200.7	Calcium Total	100	mg/L	14	14	D2	
2007014077	3/12/2007 12:15:00	Brine	EPA 200.7	Magnesium - Total	63	mg/L	14	14	D1	
2007014077	3/12/2007 12:15:00	Brine	EPA 200.7	Sodium - Total	671	mg/L	14	140	D2	
2007014078	3/12/2007 12:15:00	Brine	SM20 2540 C	Total Dissolved Solids	1340	mg/L	1	10		
2007014079	3/12/2007 12:15:00	Brine	EPA 300.0	Chloride	934	mg/L	10	10	D2	
2007014127	3/12/2007 13:50:00	Distillate	SM20 2340	Hardness - Total	9.1	mg/L		6.6		
2007014127	3/12/2007 13:50:00	Distillate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		
2007014127	3/12/2007 13:50:00	Distillate	EPA 180.1	Turbidity	0.55	NTU	1			
2007014127	3/12/2007 13:50:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014127	3/12/2007 13:50:00	Distillate	EPA 200.7	Magnesium - Total	1	mg/L	1	1.0		
2007014127	3/12/2007 13:50:00	Distillate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014128	3/12/2007 13:50:00	Distillate	SM20 2540 C	Total Dissolved Solids	48	mg/L	1	10		
2007014129	3/12/2007 13:50:00	Distillate	EPA 300.0	Chloride	11.4	mg/L	1	1.0		
2007014130	3/12/2007 13:45:00	Feed	SM20 2340	Calcium Hardness	350	mg/L		2.5		
2007014130	3/12/2007 13:45:00	Feed	EPA 200.7	Sodium - Total	389	mg/L	6	60.0	D2	
2007014130	3/12/2007 13:45:00	Feed	EPA 200.7	Magnesium - Total	54	mg/L	6	6.0	D1	
2007014130	3/12/2007 13:45:00	Feed	EPA 200.7	Calcium Total	140	mg/L	6	6.0	D2	
2007014130	3/12/2007 13:45:00	Feed	SM20 2340	Hardness - Total	572	mg/L		6.6		
2007014131	3/12/2007 13:45:00	Feed	SM20 2540 C	Total Dissolved Solids	1840	mg/L	1	10		
2007014132	3/12/2007 13:45:00	Feed	EPA 300.0	Chloride	528	mg/L	5	5.0	D2	
2007014133	3/12/2007 13:40:00	Brine	SM20 2340	Hardness - Total	504	mg/L		6.6		
2007014133	3/12/2007 13:40:00	Brine	SM20 2340	Calcium Hardness	245	mg/L		2.5		
2007014133	3/12/2007 13:40:00	Brine	EPA 200.7	Sodium - Total	650	mg/L	14	140	D2	
2007014133	3/12/2007 13:40:00	Brine	EPA 200.7	Calcium Total	98	mg/L	14	14	D2	
2007014133	3/12/2007 13:40:00	Brine	EPA 200.7	Magnesium - Total	63	mg/L	14	14	D1	
2007014134	3/12/2007 13:40:00	Brine	SM20 2540 C	Total Dissolved Solids	2680	mg/L	2	20	N1	Filtered 25 mls.
2007014135	3/12/2007 13:40:00	Brine	EPA 300.0	Chloride	900	mg/L	10	10	D2	
2007014150	3/12/2007 15:20:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014150	3/12/2007 15:20:00	Distillate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		
2007014150	3/12/2007 15:20:00	Distillate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		
2007014150	3/12/2007 15:20:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014150	3/12/2007 15:20:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014150	3/12/2007 15:20:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014151	3/12/2007 15:20:00	Distillate	SM20 2540 C	Total Dissolved Solids	40	mg/L	1	10		
2007014152	3/12/2007 15:20:00	Distillate	EPA 300.0	Chloride	9.8	mg/L	1	1.0		
2007014153	3/12/2007 15:25:00	Feed	SM20 2340	Calcium Hardness	352	mg/L		2.5		
2007014153	3/12/2007 15:25:00	Feed	SM20 2340	Hardness - Total	570	mg/L		6.6		
2007014153	3/12/2007 15:25:00	Feed	EPA 200.7	Magnesium - Total	53	mg/L	6	6.0	D1	
2007014153	3/12/2007 15:25:00	Feed	EPA 200.7	Sodium - Total	415	mg/L	6	60.0	D2	
2007014153	3/12/2007 15:25:00	Feed	EPA 200.7	Calcium Total	141	mg/L	6	6.0	D2	
2007014154	3/12/2007 15:25:00	Feed	SM20 2540 C	Total Dissolved Solids	1890	mg/L	1	10		
2007014155	3/12/2007 15:25:00	Feed	EPA 300.0	Chloride	547	mg/L	5	5.0	D2	
2007014156	3/12/2007 15:30:00	Brine	SM20 2340	Calcium Hardness	250	mg/L		2.5		
2007014156	3/12/2007 15:30:00	Brine	EPA 200.7	Sodium - Total	676	mg/L	14	140	D2	
2007014156	3/12/2007 15:30:00	Brine	SM20 2340	Hardness - Total	513	mg/L		6.6		
2007014156	3/12/2007 15:30:00	Brine	EPA 200.7	Calcium Total	100	mg/L	14	14	D2	
2007014156	3/12/2007 15:30:00	Brine	EPA 200.7	Magnesium - Total	64	mg/L	14	14	D1	
2007014157	3/12/2007 15:30:00	Brine	SM20 2540 C	Total Dissolved Solids	2740	mg/L	2	20	N1	filtered 25mls.
2007014158	3/12/2007 15:30:00	Brine	EPA 300.0	Chloride	920	mg/L	10	10	D2	
2007014213	3/13/2007 07:25:00	Distallate	SM20 2340	Hardness - Total	9.1	mg/L		6.6		
2007014213	3/13/2007 07:25:00	Distallate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014213	3/13/2007 07:25:00	Distallate	EPA 200.7	Magnesium - Total	1	mg/L	1	1.0		
2007014213	3/13/2007 07:25:00	Distallate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014213	3/13/2007 07:25:00	Distallate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014213	3/13/2007 07:25:00	Distallate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		
2007014214	3/13/2007 07:25:00	Distallate	SM20 2540 C	Total Dissolved Solids	44	mg/L	1	10		
2007014215	3/13/2007 07:25:00	Distallate	EPA 300.0	Chloride	10.7	mg/L	1	1.0		
2007014216	3/13/2007 07:30:00	Feed	SM20 2340	Hardness - Total	560	mg/L		6.6		
2007014216	3/13/2007 07:30:00	Feed	EPA 200.7	Sodium - Total	397	mg/L	6	60.0	D2	
2007014216	3/13/2007 07:30:00	Feed	EPA 200.7	Magnesium - Total	53	mg/L	6	6.0	D1	
2007014216	3/13/2007 07:30:00	Feed	SM20 2340	Calcium Hardness	342	mg/L		2.5		
2007014216	3/13/2007 07:30:00	Feed	EPA 200.7	Calcium Total	137	mg/L	6	6.0	D2	
2007014217	3/13/2007 07:30:00	Feed	SM20 2540 C	Total Dissolved Solids	1850	mg/L	1	10		
2007014218	3/13/2007 07:30:00	Feed	EPA 300.0	Chloride	539	mg/L	5	5.0	D2	
2007014219	3/13/2007 07:35:00	Brine	SM20 2340	Hardness - Total	515	mg/L		6.6		
2007014219	3/13/2007 07:35:00	Brine	SM20 2340	Calcium Hardness	247	mg/L		2.5		
2007014219	3/13/2007 07:35:00	Brine	EPA 200.7	Sodium - Total	646	mg/L	14	140	D2	
2007014219	3/13/2007 07:35:00	Brine	EPA 200.7	Magnesium - Total	65	mg/L	14	14	D1	
2007014219	3/13/2007 07:35:00	Brine	EPA 200.7	Calcium Total	99	mg/L	14	14	D2	
2007014220	3/13/2007 07:35:00	Brine	SM20 2540 C	Total Dissolved Solids	2640	mg/L	2	20	N1	filtered 25mls.
2007014221	3/13/2007 07:35:00	Brine	EPA 300.0	Chloride	1820	mg/L	10	10	D2	
2007014253	3/13/2007 08:50:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014253	3/13/2007 08:50:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014253	3/13/2007 08:50:00	Distillate	EPA 200.7	Calcium Total	2	mg/L	1	1.0		
2007014253	3/13/2007 08:50:00	Distillate	SM20 2340	Calcium Hardness	5.0	mg/L		2.5		
2007014253	3/13/2007 08:50:00	Distillate	EPA 180.1	Turbidity	0.55	NTU	1			
2007014253	3/13/2007 08:50:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014254	3/13/2007 08:50:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007014255	3/13/2007 08:50:00	Distillate	EPA 300.0	Chloride	9.7	mg/L	1	1.0		
2007014256	3/13/2007 09:00:00	Feed	SM20 2340	Hardness - Total	551	mg/L		6.6		
2007014256	3/13/2007 09:00:00	Feed	SM20 2340	Calcium Hardness	337	mg/L		2.5		
2007014256	3/13/2007 09:00:00	Feed	EPA 200.7	Magnesium - Total	52	mg/L	6	6.0	D1	
2007014256	3/13/2007 09:00:00	Feed	EPA 200.7	Sodium - Total	414	mg/L	6	60.0	D2	
2007014256	3/13/2007 09:00:00	Feed	EPA 200.7	Calcium Total	135	mg/L	6	6.0	D2	
2007014257	3/13/2007 09:00:00	Feed	SM20 2540 C	Total Dissolved Solids	1850	mg/L	1	10		
2007014258	3/13/2007 09:00:00	Feed	EPA 300.0	Chloride	537	mg/L	5	5.0	D2	
2007014259	3/13/2007 08:55:00	Brine	SM20 2340	Hardness - Total	545	mg/L		6.6		
2007014259	3/13/2007 08:55:00	Brine	SM20 2340	Calcium Hardness	257	mg/L		2.5		
2007014259	3/13/2007 08:55:00	Brine	EPA 200.7	Sodium - Total	730	mg/L	14	140	D2	
2007014259	3/13/2007 08:55:00	Brine	EPA 200.7	Calcium Total	103	mg/L	14	14	D2	
2007014259	3/13/2007 08:55:00	Brine	EPA 200.7	Magnesium - Total	70	mg/L	14	14	D1	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014260	3/13/2007 08:55:00	Brine	SM20 2540 C	Total Dissolved Solids	2950	mg/L	2	20	N1	filtered 25mls.
2007014261	3/13/2007 08:55:00	Brine	EPA 300.0	Chloride	1010	mg/L	10	10	D2	
2007014378	3/13/2007 10:15:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014378	3/13/2007 10:15:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014378	3/13/2007 10:15:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014378	3/13/2007 10:15:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014378	3/13/2007 10:15:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014378	3/13/2007 10:15:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014379	3/13/2007 10:15:00	Distillate	SM20 2540 C	Total Dissolved Solids	34	mg/L	1	10		
2007014380	3/13/2007 10:15:00	Distillate	EPA 300.0	Chloride	9.0	mg/L	1	1.0		
2007014381	3/13/2007 10:20:00	Feed	SM20 2340	Hardness - Total	551	mg/L		6.6		
2007014381	3/13/2007 10:20:00	Feed	SM20 2340	Calcium Hardness	337	mg/L		2.5		
2007014381	3/13/2007 10:20:00	Feed	EPA 200.7	Magnesium - Total	52	mg/L	6	6.0	D1	
2007014381	3/13/2007 10:20:00	Feed	EPA 200.7	Calcium Total	135	mg/L	6	6.0	D2	
2007014381	3/13/2007 10:20:00	Feed	EPA 200.7	Sodium - Total	404	mg/L	6	60.0	D2	
2007014382	3/13/2007 10:20:00	Feed	SM20 2540 C	Total Dissolved Solids	1850	mg/L	1	10		
2007014383	3/13/2007 10:20:00	Feed	EPA 300.0	Chloride	519	mg/L	5	5.0	D2	
2007014384	3/13/2007 10:25:00	Brine	SM20 2340	Calcium Hardness	260	mg/L		2.5		
2007014384	3/13/2007 10:25:00	Brine	EPA 200.7	Sodium - Total	817	mg/L	14	140	D2	
2007014384	3/13/2007 10:25:00	Brine	EPA 200.7	Magnesium - Total	71	mg/L	14	14	D1	
2007014384	3/13/2007 10:25:00	Brine	SM20 2340	Hardness - Total	552	mg/L		6.6		
2007014384	3/13/2007 10:25:00	Brine	EPA 200.7	Calcium Total	104	mg/L	14	14	D2	
2007014385	3/13/2007 10:25:00	Brine	SM20 2540 C	Total Dissolved Solids	3260	mg/L	2	20	N1	filtered 25mls.
2007014386	3/13/2007 10:25:00	Brine	EPA 300.0	Chloride	1120	mg/L	10	10	D2	
2007014465	3/13/2007 13:45:00	Distillate	SM20 2540 C	Total Dissolved Solids	32	mg/L	1	10		
2007014465	3/13/2007 13:45:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014465	3/13/2007 13:45:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014465	3/13/2007 13:45:00	Distillate	EPA 300.0	Chloride	9.2	mg/L	1	1.0		
2007014465	3/13/2007 13:45:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014465	3/13/2007 13:45:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014465	3/13/2007 13:45:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014465	3/13/2007 13:45:00	Distillate	EPA 180.1	Turbidity	0.55	NTU	1			
2007014466	3/13/2007 13:55:00	Feed	SM20 2540 C	Total Dissolved Solids	1870	mg/L	1	10		
2007014466	3/13/2007 13:55:00	Feed	EPA 300.0	Chloride	444	mg/L	5	5.0	D2	
2007014466	3/13/2007 13:55:00	Feed	EPA 200.7	Sodium - Total	395	mg/L	6	60.0	D2	
2007014466	3/13/2007 13:55:00	Feed	EPA 200.7	Magnesium - Total	56	mg/L	1	1.0		
2007014466	3/13/2007 13:55:00	Feed	EPA 200.7	Calcium Total	143	mg/L	6	6.0	D2	
2007014466	3/13/2007 13:55:00	Feed	SM20 2340	Calcium Hardness	357	mg/L		2.5		
2007014466	3/13/2007 13:55:00	Feed	SM20 2340	Hardness - Total	588	mg/L		6.6		
2007014467	3/13/2007 14:00:00	Brine	SM20 2540 C	Total Dissolved Solids	3120	mg/L	2	20	N1	filtered 25mls.

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014467	3/13/2007 14:00:00	Brine	SM20 2340	Hardness - Total	564	mg/L		6.6		
2007014467	3/13/2007 14:00:00	Brine	SM20 2340	Calcium Hardness	260	mg/L		2.5		
2007014467	3/13/2007 14:00:00	Brine	EPA 300.0	Chloride	1090	mg/L	10	10	D2	
2007014467	3/13/2007 14:00:00	Brine	EPA 200.7	Sodium - Total	790	mg/L	14	140	D2	
2007014467	3/13/2007 14:00:00	Brine	EPA 200.7	Magnesium - Total	74	mg/L	14	14	D1	
2007014467	3/13/2007 14:00:00	Brine	EPA 200.7	Calcium Total	104	mg/L	14	14	D2	
2007014475	3/13/2007 15:05:00	Distillate	SM20 2540 C	Total Dissolved Solids	32	mg/L	1	10		
2007014475	3/13/2007 15:05:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014475	3/13/2007 15:05:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014475	3/13/2007 15:05:00	Distillate	EPA 300.0	Chloride	8.4	mg/L	1	1.0		
2007014475	3/13/2007 15:05:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014475	3/13/2007 15:05:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014475	3/13/2007 15:05:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014475	3/13/2007 15:05:00	Distillate	EPA 180.1	Turbidity	0.55	NTU	1			
2007014476	3/13/2007 15:10:00	Feed	SM20 2540 C	Total Dissolved Solids	1880	mg/L	1	10		
2007014476	3/13/2007 15:10:00	Feed	SM20 2340	Hardness - Total	576	mg/L		6.6		
2007014476	3/13/2007 15:10:00	Feed	SM20 2340	Calcium Hardness	350	mg/L		2.5		
2007014476	3/13/2007 15:10:00	Feed	EPA 300.0	Chloride	554	mg/L	5	5.0	D2	
2007014476	3/13/2007 15:10:00	Feed	EPA 200.7	Sodium - Total	389	mg/L	6	60.0	D2	
2007014476	3/13/2007 15:10:00	Feed	EPA 200.7	Magnesium - Total	55	mg/L	1	1.0		
2007014476	3/13/2007 15:10:00	Feed	EPA 200.7	Calcium Total	140	mg/L	6	6.0	D2	
2007014477	3/13/2007 15:15:00	Brine	SM20 2540 C	Total Dissolved Solids	3020	mg/L	2	20	N1	filtered 25mls.
2007014477	3/13/2007 15:15:00	Brine	SM20 2340	Hardness - Total	546	mg/L		6.6		
2007014477	3/13/2007 15:15:00	Brine	SM20 2340	Calcium Hardness	250	mg/L		2.5		
2007014477	3/13/2007 15:15:00	Brine	EPA 200.7	Sodium - Total	752	mg/L	14	140	D2	
2007014477	3/13/2007 15:15:00	Brine	EPA 200.7	Magnesium - Total	72	mg/L	14	14	D1	
2007014477	3/13/2007 15:15:00	Brine	EPA 200.7	Calcium Total	100	mg/L	14	14	D2	
2007014477	3/13/2007 15:15:00	Brine	EPA 300.0	Chloride	1060	mg/L	10	10	D2	
2007014505	3/14/2007 07:00:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007014505	3/14/2007 07:00:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014505	3/14/2007 07:00:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014505	3/14/2007 07:00:00	Distillate	EPA 300.0	Chloride	8.7	mg/L	1	1.0		
2007014505	3/14/2007 07:00:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014505	3/14/2007 07:00:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014505	3/14/2007 07:00:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014505	3/14/2007 07:00:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014506	3/14/2007 07:05:00	Feed	SM20 2540 C	Total Dissolved Solids	1870	mg/L	1	10		
2007014506	3/14/2007 07:05:00	Feed	SM20 2340	Hardness - Total	572	mg/L		6.6		
2007014506	3/14/2007 07:05:00	Feed	SM20 2340	Calcium Hardness	350	mg/L		2.5		
2007014506	3/14/2007 07:05:00	Feed	EPA 300.0	Chloride	539	mg/L	5	5.0	D2	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014506	3/14/2007 07:05:00	Feed	EPA 200.7	Sodium - Total	387	mg/L	6	60.0	D2	
2007014506	3/14/2007 07:05:00	Feed	EPA 200.7	Magnesium - Total	54	mg/L	1	1.0		
2007014506	3/14/2007 07:05:00	Feed	EPA 200.7	Calcium Total	140	mg/L	6	6.0	D2	
2007014507	3/14/2007 07:10:00	Brine	SM20 2540 C	Total Dissolved Solids	2860	mg/L	1	10		
2007014507	3/14/2007 07:10:00	Brine	SM20 2340	Hardness - Total	530	mg/L		6.6		
2007014507	3/14/2007 07:10:00	Brine	SM20 2340	Calcium Hardness	250	mg/L		2.5		
2007014507	3/14/2007 07:10:00	Brine	EPA 300.0	Chloride	1010	mg/L	10	10	D2	
2007014507	3/14/2007 07:10:00	Brine	EPA 200.7	Sodium - Total	704	mg/L	14	140	D2	
2007014507	3/14/2007 07:10:00	Brine	EPA 200.7	Magnesium - Total	68	mg/L	14	14	D1	
2007014507	3/14/2007 07:10:00	Brine	EPA 200.7	Calcium Total	100	mg/L	14	14	D2	
2007014610	3/14/2007 09:00:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007014610	3/14/2007 09:00:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014610	3/14/2007 09:00:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014610	3/14/2007 09:00:00	Distillate	EPA 300.0	Chloride	8.7	mg/L	1	1.0		
2007014610	3/14/2007 09:00:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014610	3/14/2007 09:00:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014610	3/14/2007 09:00:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014610	3/14/2007 09:00:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014611	3/14/2007 09:05:00	Feed	SM20 2540 C	Total Dissolved Solids	1830	mg/L	1	10		
2007014611	3/14/2007 09:05:00	Feed	SM20 2340	Hardness - Total	576	mg/L		6.6		
2007014611	3/14/2007 09:05:00	Feed	SM20 2340	Calcium Hardness	350	mg/L		2.5		
2007014611	3/14/2007 09:05:00	Feed	EPA 300.0	Chloride	534	mg/L	5	5.0	D2	
2007014611	3/14/2007 09:05:00	Feed	EPA 200.7	Sodium - Total	384	mg/L	6	60.0	D2	
2007014611	3/14/2007 09:05:00	Feed	EPA 200.7	Magnesium - Total	55	mg/L	1	1.0		
2007014611	3/14/2007 09:05:00	Feed	EPA 200.7	Calcium Total	140	mg/L	6	6.0	D2	
2007014612	3/14/2007 09:10:00	Brine	SM20 2540 C	Total Dissolved Solids	2830	mg/L	1	10		
2007014612	3/14/2007 09:10:00	Brine	SM20 2340	Hardness - Total	525	mg/L		6.6		
2007014612	3/14/2007 09:10:00	Brine	SM20 2340	Calcium Hardness	245	mg/L		2.5		
2007014612	3/14/2007 09:10:00	Brine	EPA 300.0	Chloride	995	mg/L	10	10	D2	
2007014612	3/14/2007 09:10:00	Brine	EPA 200.7	Sodium - Total	690	mg/L	14	140	D2	
2007014612	3/14/2007 09:10:00	Brine	EPA 200.7	Magnesium - Total	68	mg/L	14	14	D1	
2007014612	3/14/2007 09:10:00	Brine	EPA 200.7	Calcium Total	98	mg/L	14	14	D2	
2007014640	3/14/2007 10:25:00	Distillate	SM20 2540 C	Total Dissolved Solids	40	mg/L	1	10		
2007014640	3/14/2007 10:25:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014640	3/14/2007 10:25:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014640	3/14/2007 10:25:00	Distillate	EPA 300.0	Chloride	8.7	mg/L	1	1.0		
2007014640	3/14/2007 10:25:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014640	3/14/2007 10:25:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014640	3/14/2007 10:25:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014640	3/14/2007 10:25:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014641	3/14/2007 10:30:00	Feed	SM20 2540 C	Total Dissolved Solids	1860	mg/L	1	10		
2007014641	3/14/2007 10:30:00	Feed	SM20 2340	Hardness - Total	556	mg/L		6.6		
2007014641	3/14/2007 10:30:00	Feed	SM20 2340	Calcium Hardness	342	mg/L		2.5		
2007014641	3/14/2007 10:30:00	Feed	EPA 300.0	Chloride	532	mg/L	5	5.0	D2	
2007014641	3/14/2007 10:30:00	Feed	EPA 200.7	Sodium - Total	381	mg/L	6	60.0	D2	
2007014641	3/14/2007 10:30:00	Feed	EPA 200.7	Magnesium - Total	52	mg/L	6	6.0	D1	
2007014641	3/14/2007 10:30:00	Feed	EPA 200.7	Calcium Total	137	mg/L	6	6.0	D2	
2007014642	3/14/2007 10:35:00	Brine	SM20 2540 C	Total Dissolved Solids	2850	mg/L	1	10		
2007014642	3/14/2007 10:35:00	Brine	SM20 2340	Hardness - Total	518	mg/L		6.6		
2007014642	3/14/2007 10:35:00	Brine	SM20 2340	Calcium Hardness	242	mg/L		2.5		
2007014642	3/14/2007 10:35:00	Brine	EPA 300.0	Chloride	993	mg/L	10	10	D2	
2007014642	3/14/2007 10:35:00	Brine	EPA 200.7	Sodium - Total	687	mg/L	14	140	D2	
2007014642	3/14/2007 10:35:00	Brine	EPA 200.7	Magnesium - Total	67	mg/L	14	14	D1	
2007014642	3/14/2007 10:35:00	Brine	EPA 200.7	Calcium Total	97	mg/L	14	14	D2	
2007014704	3/14/2007 11:35:00	Distillate	SM20 2540 C	Total Dissolved Solids	34	mg/L	1	10		
2007014704	3/14/2007 11:35:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014704	3/14/2007 11:35:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014704	3/14/2007 11:35:00	Distillate	EPA 300.0	Chloride	8.8	mg/L	1	1.0		
2007014704	3/14/2007 11:35:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014704	3/14/2007 11:35:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014704	3/14/2007 11:35:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014704	3/14/2007 11:35:00	Distillate	EPA 180.1	Turbidity	0.45	NTU	1			
2007014705	3/14/2007 11:40:00	Feed	SM20 2540 C	Total Dissolved Solids	1870	mg/L	1	10		
2007014705	3/14/2007 11:40:00	Feed	SM20 2340	Hardness - Total	552	mg/L		6.6		
2007014705	3/14/2007 11:40:00	Feed	EPA 200.7	Magnesium - Total	51	mg/L	6	6.0	D1	
2007014705	3/14/2007 11:40:00	Feed	EPA 200.7	Calcium Total	137	mg/L	6	6.0	D2	
2007014705	3/14/2007 11:40:00	Feed	EPA 300.0	Chloride	536	mg/L	5	5.0	D2	
2007014705	3/14/2007 11:40:00	Feed	EPA 200.7	Sodium - Total	382	mg/L	6	60.0	D2	
2007014705	3/14/2007 11:40:00	Feed	SM20 2340	Calcium Hardness	342	mg/L		2.5		
2007014706	3/14/2007 11:45:00	Brine	SM20 2540 C	Total Dissolved Solids	2910	mg/L	1	10		
2007014706	3/14/2007 11:45:00	Brine	SM20 2340	Hardness - Total	518	mg/L		6.6		
2007014706	3/14/2007 11:45:00	Brine	SM20 2340	Calcium Hardness	242	mg/L		2.5		
2007014706	3/14/2007 11:45:00	Brine	EPA 300.0	Chloride	1030	mg/L	10	10	D2	
2007014706	3/14/2007 11:45:00	Brine	EPA 200.7	Sodium - Total	715	mg/L	14	140	D2	
2007014706	3/14/2007 11:45:00	Brine	EPA 200.7	Magnesium - Total	67	mg/L	14	14	D1	
2007014706	3/14/2007 11:45:00	Brine	EPA 200.7	Calcium Total	97	mg/L	14	14	D2	
2007014782	3/15/2007 09:00:00	Distillate	SM20 2540 C	Total Dissolved Solids	42	mg/L	1	10		
2007014782	3/15/2007 09:00:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014782	3/15/2007 09:00:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014782	3/15/2007 09:00:00	Distillate	EPA 300.0	Chloride	5.8	mg/L	1	1.0		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014782	3/15/2007 09:00:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014782	3/15/2007 09:00:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014782	3/15/2007 09:00:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014782	3/15/2007 09:00:00	Distillate	EPA 180.1	Turbidity	0.40	NTU	1			
2007014783	3/15/2007 08:55:00	Feed	SM20 2540 C	Total Dissolved Solids	1880	mg/L	1	10		
2007014783	3/15/2007 08:55:00	Feed	SM20 2340	Hardness - Total	586	mg/L		6.6		
2007014783	3/15/2007 08:55:00	Feed	SM20 2340	Calcium Hardness	360	mg/L		2.5		
2007014783	3/15/2007 08:55:00	Feed	EPA 300.0	Chloride	533	mg/L	5	5.0	D2	
2007014783	3/15/2007 08:55:00	Feed	EPA 200.7	Sodium - Total	396	mg/L	6	60.0	D2	
2007014783	3/15/2007 08:55:00	Feed	EPA 200.7	Magnesium - Total	55	mg/L	6	6.0	D1	
2007014783	3/15/2007 08:55:00	Feed	EPA 200.7	Calcium Total	144	mg/L	6	6.0	D2	
2007014784	3/15/2007 08:50:00	Brine	SM20 2540 C	Total Dissolved Solids	2210	mg/L	1	10		
2007014784	3/15/2007 08:50:00	Brine	SM20 2340	Hardness - Total	479	mg/L		6.6		
2007014784	3/15/2007 08:50:00	Brine	SM20 2340	Calcium Hardness	240	mg/L		2.5		
2007014784	3/15/2007 08:50:00	Brine	EPA 300.0	Chloride	736	mg/L	10	10	D2	
2007014784	3/15/2007 08:50:00	Brine	EPA 200.7	Sodium - Total	525	mg/L	14	140	D2	
2007014784	3/15/2007 08:50:00	Brine	EPA 200.7	Magnesium - Total	58	mg/L	14	14	D1	
2007014784	3/15/2007 08:50:00	Brine	EPA 200.7	Calcium Total	96	mg/L	14	14	D2	
2007014829	3/15/2007 11:25:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007014829	3/15/2007 11:25:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014829	3/15/2007 11:25:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014829	3/15/2007 11:25:00	Distillate	EPA 300.0	Chloride	6.3	mg/L	1	1.0		
2007014829	3/15/2007 11:25:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014829	3/15/2007 11:25:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014829	3/15/2007 11:25:00	Distillate	EPA 180.1	Turbidity	0.60	NTU	1			
2007014829	3/15/2007 11:25:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014830	3/15/2007 11:20:00	Feed	SM20 2540 C	Total Dissolved Solids	1850	mg/L	1	10		
2007014830	3/15/2007 11:20:00	Feed	SM20 2340	Hardness - Total	582	mg/L		6.6		
2007014830	3/15/2007 11:20:00	Feed	SM20 2340	Calcium Hardness	360	mg/L		2.5		
2007014830	3/15/2007 11:20:00	Feed	EPA 300.0	Chloride	534	mg/L	5	5.0	D2	
2007014830	3/15/2007 11:20:00	Feed	EPA 200.7	Sodium - Total	382	mg/L	6	60.0	D2	
2007014830	3/15/2007 11:20:00	Feed	EPA 200.7	Magnesium - Total	54	mg/L	6	6.0	D1	
2007014830	3/15/2007 11:20:00	Feed	EPA 200.7	Calcium Total	144	mg/L	6	6.0	D2	
2007014831	3/15/2007 11:15:00	Brine	SM20 2540 C	Total Dissolved Solids	2820	mg/L	1	10		
2007014831	3/15/2007 11:15:00	Brine	SM20 2340	Hardness - Total	540	mg/L		6.6		
2007014831	3/15/2007 11:15:00	Brine	SM20 2340	Calcium Hardness	272	mg/L		2.5		
2007014831	3/15/2007 11:15:00	Brine	EPA 300.0	Chloride	948	mg/L	10	10	D2	
2007014831	3/15/2007 11:15:00	Brine	EPA 200.7	Sodium - Total	682	mg/L	14	140	D2	
2007014831	3/15/2007 11:15:00	Brine	EPA 200.7	Magnesium - Total	65	mg/L	14	14	D1	
2007014831	3/15/2007 11:15:00	Brine	EPA 200.7	Calcium Total	109	mg/L	14	14	D2	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007014991	3/16/2007 08:25:00	Distillate	SM20 2540 C	Total Dissolved Solids	50	mg/L	1	10		
2007014991	3/16/2007 08:25:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007014991	3/16/2007 08:25:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007014991	3/16/2007 08:25:00	Distillate	EPA 300.0	Chloride	6.8	mg/L	1	1.0		
2007014991	3/16/2007 08:25:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007014991	3/16/2007 08:25:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007014991	3/16/2007 08:25:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007014991	3/16/2007 08:25:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007014992	3/16/2007 08:30:00	Feed	SM20 2540 C	Total Dissolved Solids	1810	mg/L	1	10		
2007014992	3/16/2007 08:30:00	Feed	SM20 2340	Hardness - Total	585	mg/L		6.6		
2007014992	3/16/2007 08:30:00	Feed	SM20 2340	Calcium Hardness	367	mg/L		2.5		
2007014992	3/16/2007 08:30:00	Feed	EPA 300.0	Chloride	529	mg/L	5	5.0	D2	
2007014992	3/16/2007 08:30:00	Feed	EPA 200.7	Calcium Total	147	mg/L	6	6.0	D2	
2007014992	3/16/2007 08:30:00	Feed	EPA 200.7	Magnesium - Total	53	mg/L	6	6.0	D1	
2007014992	3/16/2007 08:30:00	Feed	EPA 200.7	Sodium - Total	360	mg/L	1	10.0	D2	
2007014993	3/16/2007 08:35:00	Brine	SM20 2540 C	Total Dissolved Solids	2700	mg/L	1	10		
2007014993	3/16/2007 08:35:00	Brine	SM20 2340	Hardness - Total	576	mg/L		6.6		
2007014993	3/16/2007 08:35:00	Brine	SM20 2340	Calcium Hardness	292	mg/L		2.5		
2007014993	3/16/2007 08:35:00	Brine	EPA 300.0	Chloride	908	mg/L	10	10	D2	
2007014993	3/16/2007 08:35:00	Brine	EPA 200.7	Sodium - Total	704	mg/L	14	140	D2	
2007014993	3/16/2007 08:35:00	Brine	EPA 200.7	Magnesium - Total	69	mg/L	14	14	D1	
2007014993	3/16/2007 08:35:00	Brine	EPA 200.7	Calcium Total	117	mg/L	14	14	D2	
2007015008	3/16/2007 10:35:00	Distillate	SM20 2540 C	Total Dissolved Solids	38	mg/L	1	10		
2007015008	3/16/2007 10:35:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007015008	3/16/2007 10:35:00	Distillate	SM20 2340	Calcium Hardness	2.5	mg/L		2.5		
2007015008	3/16/2007 10:35:00	Distillate	EPA 300.0	Chloride	5.9	mg/L	1	1.0		
2007015008	3/16/2007 10:35:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007015008	3/16/2007 10:35:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007015008	3/16/2007 10:35:00	Distillate	EPA 200.7	Calcium Total	1	mg/L	1	1.0		
2007015008	3/16/2007 10:35:00	Distillate	EPA 180.1	Turbidity	0.45	NTU	1			
2007015009	3/16/2007 10:30:00	Feed	SM20 2540 C	Total Dissolved Solids	1880	mg/L	1	10		
2007015009	3/16/2007 10:30:00	Feed	SM20 2340	Hardness - Total	573	mg/L		6.6		
2007015009	3/16/2007 10:30:00	Feed	SM20 2340	Calcium Hardness	355	mg/L		2.5		
2007015009	3/16/2007 10:30:00	Feed	EPA 300.0	Chloride	529	mg/L	5	5.0	D2	
2007015009	3/16/2007 10:30:00	Feed	EPA 200.7	Sodium - Total	379	mg/L	6	60.0	D2	
2007015009	3/16/2007 10:30:00	Feed	EPA 200.7	Magnesium - Total	53	mg/L	6	6.0	D1	
2007015009	3/16/2007 10:30:00	Feed	EPA 200.7	Calcium Total	142	mg/L	6	6.0	D2	
2007015010	3/16/2007 10:25:00	Brine	SM20 2540 C	Total Dissolved Solids	2920	mg/L	1	10		
2007015010	3/16/2007 10:25:00	Brine	SM20 2340	Hardness - Total	532	mg/L		6.6		
2007015010	3/16/2007 10:25:00	Brine	SM20 2340	Calcium Hardness	272	mg/L		2.5		

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007015010	3/16/2007 10:25:00	Brine	EPA 300.0	Chloride	1000	mg/L	10	10	D2	
2007015010	3/16/2007 10:25:00	Brine	EPA 200.7	Sodium - Total	701	mg/L	14	140	D2	
2007015010	3/16/2007 10:25:00	Brine	EPA 200.7	Magnesium - Total	63	mg/L	14	14	D1	
2007015010	3/16/2007 10:25:00	Brine	EPA 200.7	Calcium Total	109	mg/L	14	14	D2	
2007015094	3/16/2007 11:55:00	Distillate	Production	Total Organic Carbon	4.49	mg/L	1			
2007015095	3/16/2007 11:50:00	Feed	Production	Total Organic Carbon	15.2	mg/L	2			DF = 2 due to high concentration, matrix
2007015096	3/16/2007 11:45:00	Brine	Production	Total Organic Carbon	30.6	mg/L	4			DF = 4 due to high concentration, matrix
2007015097	3/16/2007 12:25:00	Distillate	Production	Total Organic Carbon	4.68	mg/L	1			
2007015098	3/16/2007 12:35:00	Feed	Production	Total Organic Carbon	15.3	mg/L	2			DF = 2 due to high concentration, matrix
2007015099	3/16/2007 12:30:00	Brine	Production	Total Organic Carbon	33.2	mg/L	4			DF = 4 due to high concentration, matrix
2007018695	4/4/2007 14:45:00	Distillate	Production	Total Organic Carbon	8.52	mg/L	1			
2007018696	4/4/2007 14:50:00	Feed	Production	Total Organic Carbon	46.1	mg/L	1		N1	Diluted 1:10 due to high analyte concentration.
2007018697	4/4/2007 14:55:00	Brine	Production	Total Organic Carbon	66.2	mg/L	1		N1	Diluted 1:10 due to high analyte concentration.
2007018698	4/4/2007 14:45:00	Distillate	SM20 2540 C	Total Dissolved Solids	24	mg/L	1	10		
2007018698	4/4/2007 14:45:00	Distillate	SM20 2340	Hardness - Total	<6.6	mg/L		6.6		
2007018698	4/4/2007 14:45:00	Distillate	SM20 2340	Calcium Hardness	<2.5	mg/L		2.5		
2007018698	4/4/2007 14:45:00	Distillate	EPA 300.0	Chloride	3.6	mg/L	1	1.0		
2007018698	4/4/2007 14:45:00	Distillate	EPA 200.7	Sodium - Total	<10.0	mg/L	1	10.0		
2007018698	4/4/2007 14:45:00	Distillate	EPA 200.7	Magnesium - Total	<1.0	mg/L	1	1.0		
2007018698	4/4/2007 14:45:00	Distillate	EPA 200.7	Calcium Total	<1.0	mg/L	1	1.0		
2007018698	4/4/2007 14:45:00	Distillate	EPA 180.1	Turbidity	0.50	NTU	1			
2007018699	4/4/2007 14:50:00	Feed	SM20 2540 C	Total Dissolved Solids	4870	mg/L	2	20	N1	filtered 25mls.
2007018699	4/4/2007 14:50:00	Feed	SM20 2340	Hardness - Total	817	mg/L		6.6		
2007018699	4/4/2007 14:50:00	Feed	SM20 2340	Calcium Hardness	429	mg/L		2.5		
2007018699	4/4/2007 14:50:00	Feed	EPA 300.0	Chloride	1390	mg/L	5	5.0	D2	
2007018699	4/4/2007 14:50:00	Feed	EPA 200.7	Sodium - Total	1240	mg/L	20	200	D2	
2007018699	4/4/2007 14:50:00	Feed	EPA 200.7	Magnesium - Total	94	mg/L	6	6.0	D2	
2007018699	4/4/2007 14:50:00	Feed	EPA 200.7	Calcium Total	172	mg/L	6	6.0	D2	
2007018700	4/4/2007 14:55:00	Brine	SM20 2540 C	Total Dissolved Solids	6710	mg/L	2	20	N1	Filtered 25mls
2007018700	4/4/2007 14:55:00	Brine	SM20 2340	Hardness - Total	1050	mg/L		6.6		
2007018700	4/4/2007 14:55:00	Brine	SM20 2340	Calcium Hardness	557	mg/L		2.5		
2007018700	4/4/2007 14:55:00	Brine	EPA 300.0	Chloride	1980	mg/L	10	10	D2	
2007018700	4/4/2007 14:55:00	Brine	EPA 200.7	Sodium - Total	1710	mg/L	25	250	D2	
2007018700	4/4/2007 14:55:00	Brine	EPA 200.7	Magnesium - Total	120	mg/L	14	14	D2	

LIMS Number	Sample Date/Time	Sample ID	Method	Parameter	Result	Units	Dilution	RL	Data Qualifier	Notes
2007018700	4/4/2007 14:55:00	Brine	EPA 200.7	Calcium Total	223	mg/L	14	14	D2	

Appendix C

Metric Conversions

Metric Conversions

From	To	Multiply
inch	cm	2.54
inch	mm	25.4
ft	m	0.3048
ft^2	m^2	0.0929
^oF	^oC	$^oC = (^oF-32)/1.8$
psia	bar	0.06895
lbmole/sec	gmole/sec	453.59
BTU/lbmole ^oF	J/gmole K	4.184
BTU/lbmole	J/gmole	2.326
BTU/hr ft^2 ^oF	W/m^2 K	5.6783
BTU/hr ft ^oF	W/m K	1.73073
BTU/hr	W	0.29307
BTU/hr ft^2	W/m^2	3.1546
lb	kg	0.45359
lb	g	453.59
lb/hr	g/hr	453.59
lb/hr ft	kg/hr m	1.488
lb/hr ft^2	kg/hr m^2	4.8826
lb/ft^3	g/mL	0.016
gal	m^3	0.003785