Lake Meredith Salinity Control Project

Project Alternatives Summary

January, 2006

OPTION		Extraction / Injection Rate	Expected Life (yrs)	Groundwater Savings AF/Yr	Capital Cost	Amortized Capital + O&M	* Current O&M	** LONG TERM ANNUAL COST	*** Estimated Annual Benefit (range)
1	Operate Well (as-is)	150 gpm	???	1,500 - 6,000	$ -	$ -	$375,000	$ 375,000	$ 375,000 - $ 2,300,000
2	Operate Well (workover)	150 gpm	3-15	1,500 - 6,000	$ 1,800,000	$ 175,000	$375,000	$ 550,000	$ 375,000 - $ 2,300,000
3	Cheapest Alternative - Solar Ponds	250 gpm	50 +	1,500 - 9,500	$ 8,250,000	$ 750,000	$310,000	$ 1,060,000	$ 600,000 - $ 3,500,000
4	Cheapest Alternative - Solar Ponds	500 gpm	50 +	1,500 - 18,000	$ 15,400,000	$ 1,300,000	$310,000	$ 1,610,000	$ 1,000,000 - $ 6,000,000

* Does not include money set aside for replacement fund ($155,000 for 05/06).

** Does not include current debt service of $280,000. Current pay-off is approximately $1 million with 4 years left to pay.

** Basis for Estimated Annual Benefit (combination of direct and indirect savings to Cities):

- 150 gpm extraction/injection yields about 8% reduction in chloride loading
- 250 gpm yields 12% reduction
- 500 gpm yields 20% reduction

Note: *Based on our current TDS levels, overall demand (90K AF), and current level of chloride reduction (12%), we show to have a savings of about $600,000 which is primarily PEC and groundwater savings (direct budget savings). Groundwater savings are estimated at 8,500 AF.*

RATING SCALE

- Best ● (red)
- Good ◒ (half red)
- Average ○
- Bad ◒ (half dark)
- Worst ●

Lake Meredith Salinity Control Project

Brine Disposal Alternatives

January, 2006

500 GPM Disposal Options

Option	Description	Reliability	Longevity	Ease of Operation / Manpower	Injection Well Workover	New Injection Well(s)	Solar Ponds	Water Sales	Sell Salt ● / Store Salt ○	Capital Cost Range (millions)		Amortized Capital + O&M Cost (millions)	
S1	Solar Pond (pickle)	Best	Best	Best	78 gpm		184 acres			$ 13.9	$ 16.9		$ 1.4
S2	Solar Pond	Best	Good	Best	20 gpm		220 acres		○	$ 16.1	$ 19.6	$ 1.3	$ 1.5
FS2	RO + Solar	Good	Good	Average	20 gpm		138 acres	0.29 MGD		$ 16.5	$ 20.1	$ 2.8	$ 3.0
IW	Injection Wells (3 wells)	Good	Bad	Best		500 gpm				$ 13.4	$ 16.3	$ 1.8	$ 2.1
F1	RO + Well (2 wells)	Good	Bad	Good		300 gpm		0.29 MGD		$ 16.8	$ 19.9	$ 3.3	$ 3.7
FS1	RO + Solar (pickle)	Good	Average	Average	78 gpm		102 acres	0.29 MGD		$ 14.2	$ 17.3	$ 2.6	$ 2.9
F2	River RO + Well (2 wells)	Good	Bad	Good		304 gpm		0.66 MGD		$ 18.5	$ 22.5	$ 3.2	$ 3.6
FS3	RO + Solar	Average	Average	Bad	20 gpm		139 acres	0.29 MGD	●	$ 18.8	$ 22.9	$ 3.3	$ 3.6
S3	Solar Pond	Average	Average	Bad	20 gpm		221 acres		●	$ 18.4	$ 22.4	$ 1.8	$ 2.1
SV	Solar + Crystallizer (bittern)	Bad	Average	Bad	20 gpm		184 acres		●	$ 23.0	$ 28.0	$ 3.0	$ 3.3
FV1	RO + Crystallizer (pickle)	Bad	Bad	Bad	78 gpm			0.29 MGD		$ 20.9	$ 25.4	$ 6.2	$ 6.6
FSV	RO + Solar + Crystallizer (bittern)	Bad	Bad	Worst	20 gpm		102 acres	0.29 MGD	●	$ 23.6	$ 28.7	$ 4.3	$ 4.8
FV2	RO + Crystallizer (bittern)	Worst	Bad	Worst	20 gpm			0.29 MGD	●	$ 30.0	$ 36.5	$ 7.8	$ 8.4

Notes:

1. Other disposal options were researched; however, they were not further evaluated because they were unproven technologies or had history of problems.
2. Amortized Costs shown do not include *current* debt service or O&M expenses such as personnel costs, costs associated w/ production wells, etc.
3. Capital and Amortized Cost range is based on estimate without and with 25% contingencies.
3. Solar Ponds - evaporation ponds used to reduce brine volume for injection. Climate will not support total evaporation. Longest project life.
4. RO (Reverse Osmossis) - water treatment process where solids are filtered through a membrane. Not typcially used for TDS levels of this magnitude.
5. River RO - this entails withdrawing water directly from Canadian river flow and removing salt through RO process. Production wells would not be needed.
6. Crystallizer - process by which energy is applied to brine to evaporate/seperate water from solids.
7. Pickle - brine concentrated to point just before salt will precipitate out of solution.
8. Bittern - waste stream after precipitation of salt.

RATING SCALE

- Best ●
- Good ◒
- Average ○
- Bad ◓
- Worst ●

Lake Meredith Salinity Control Project

Brine Disposal Alternatives

January, 2006

250 GPM Disposal Options

Option	Description	Reliability	Longevity	Ease of Operation / Manpower	Injection Well Workover	New Injection Well(s)	Solar Ponds	Water Sales	Sell Salt ● / Store Salt ○	Capital Cost Range (millions)		Amortized Capital + O&M Cost (millions)	
S1	Solar Pond (pickle)	Best	Best	Best	39 gpm		92 acres			$ 7.32	$ 8.92	$ 0.68	$ 0.80
S2	Solar Pond	Best	Good	Best	10 gpm		110 acres		⊙	$ 8.48	$ 10.33	$ 0.74	$ 0.88
FS2	RO + Solar	Good	Good	Average	10 gpm		69 acres	0.14 MGD		$ 8.78	$ 10.69	$ 1.55	$ 1.70
IW	Injection Wells (2 wells)	Good	Bad	Best		250 gpm				$ 9.66	$ 11.76	$ 1.26	$ 1.49
F1	RO + Well (1 wells)	Good	Bad	Good		150 gpm		0.14 MGD		$ 10.02	$ 12.20	$ 1.87	$ 2.07
FS1	RO + Solar (pickle)	Good	Average	Average	39 gpm		51 acres	0.14 MGD		$ 7.67	$ 9.34	$ 1.49	$ 1.62
F2	River RO + Well (1 wells)	Good	Bad	Good		180 gpm		0.39 MGD		$ 12.37	$ 15.06	$ 2.56	$ 2.80
FS3	RO + Solar	Average	Average	Bad	10 gpm		70 acres	0.14 MGD	●	$ 11.02	$ 13.42	$ 1.92	$ 2.11
S3	Solar Pond	Average	Average	Bad	10 gpm		110 acres		●	$ 10.73	$ 13.06	$ 1.06	$ 1.24
SV	Solar + Crystallizer (bittern)	Bad	Average	Bad	10 gpm		92 acres		●	$ 13.85	$ 16.86	$ 1.86	$ 2.10
FV1	RO + Crystallizer (pickle)	Bad	Bad	Bad	39 gpm			0.14 MGD		$ 13.00	$ 15.83	$ 3.57	$ 3.82
FSV	RO + Solar + Crystallizer (bittern)	Bad	Bad	Worst	10 gpm		51 acres	0.14 MGD	●	$ 14.38	$ 17.51	$ 2.57	$ 2.83
FV2	RO + Crystallizer (bittern)	Worst	Bad	Worst	10 gpm			0.14 MGD	●	$ 19.15	$ 23.31	$ 4.64	$ 4.90

Notes:

1. Other disposal options were researched; however, they were not further evaluated because they were unproven technologies or had history of problems.
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LMSCP ALTERNATIVES ANALYSIS

1.0 GOAL

Our goal is to find a technology or combination of technologies that will allow us to continue to operate this salinity removal system on an economical basis. A series of alternatives will be established and evaluated to accomplish this end. A common set of assumptions and evaluation criteria will be established so the various alternatives can be accurately compared and evaluated.

2.0 ALTERNATIVES

2.1 BASIC ALTERNATIVES

The basic alternatives available to accomplish the goal are:

1. Solar evaporation of the discharge from the production wells.
2. Some form of micro filtration to remove TDS (such as nanofiltration or low pressure reverse osmosis).
3. Enhanced evaporation by mechanical or other means. (Turbomister, etc.)
4. Zero liquid discharge through use of vacuum evaporators or similar technology.
5. Direct disposal to surface water of discharge from the production wells, or concentrate from another alternative.
6. Disposal to a municipal sewer of the discharge from the production wells, or concentrate from another alternative.
7. Deep well injection of the discharge from the production wells, or concentrate from another alternative.
8. Dilute the TDS with water from a well field.

Items 2 through 5 are volume reduction methods and involve a waste stream that is smaller than the discharge from the production wells. Items 5 through 8 are disposal methods for the TDS contained in the discharge from the production wells. These basic alternatives can be assembled in various combinations to expand the total alternatives in the search for a workable solution. A matrix will be established of these various alternatives.

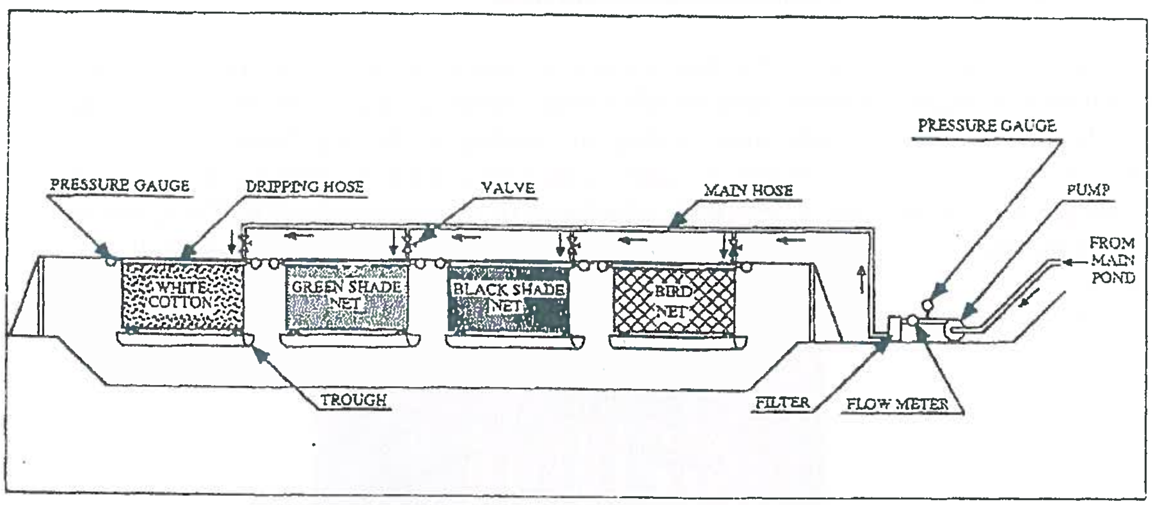
2.2 ALTERNATIVES MATRIX

Items 2 through 5 above are the basic methods that can be used to reduce the volume of brine coming from the production wells. They can each be used, singly, to reduce the volume. They can all, theoretically, be used together for a combined reduction. For example, the production well brine could first be fed to a filtration system to remove an initial amount of TDS. The liquid effluent from filtration could be then fed into a solar evaporation system also using enhanced evaporation equipment. The now very concentrated brine could be fed to vacuum evaporators for further reduction in volume.

Turbomister

Netting

The idea here is to suspend netting vertically over an evaporation pond. Pond water would be pumped to drip lines placed over the top edge of the netting. The water would trickle across the netting, offering more surfaces for evaporation.



Pond Circulator

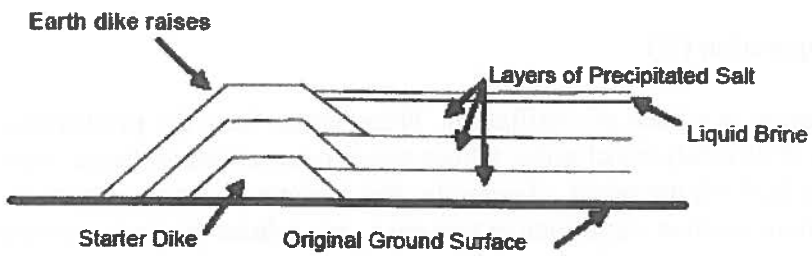
This apparatus is called a SolarBee and is manufactured by Pump Systems Inc. The machine was developed to clean up and maintain wastewater and freshwater reservoirs. It works by drawing water from the pond bottom and spreading it along the surface in a laminar fashion. The units are placed in the middle of ponds. Power for these units is provided by solar cells.

3. Solar evaporation (S).

This alternative was partially evaluated in an earlier report. It involves routing the production pump effluent to a series of evaporation ponds. The ponds would be operated as typical salt production ponds and would reduce the volume from the production pumps by at least 84%. There are three variations in this alternative.

The first is to evaporate the effluent to a point just before solid phase salt (NaCl) will begin to form in the ponds. At this point, the remaining brine would be routed to disposal. In this case, the volume of effluent water will be reduced 84%.

The second variation is to continue the evaporation and make salt, reducing the volume by 96%. The remaining brine would be routed to disposal. The salt would NOT be harvested and would remain in place. The salt would be stored as shown below:



Each year the new salt crop would be placed on top of the previous years salt. Periodically, the levee or dike would have to be raised. Eventually, the stack would have to be capped and a new area developed.

The third variation is to continue the evaporation and make salt. The volume of effluent water would be reduced by 96%. The remaining brine would be routed to disposal. The salt would be harvested (removed from the ponds) and sold.

Lee Wilson has looked at the seepage issues associated with solar evaporation ponds. He feels strongly that the State of New Mexico would require double pond liners. At a minimum, he feels liners would be needed to increase efficiency in removing salinity from the river by eliminating seepage recycling.

6. Enhanced evaporation plus solar evaporation (ES).

Here the turbomister units would be used along with solar evaporation to reduce the total area needed.

7. Enhanced evaporation plus vacuum evaporation (EV).

Boiling water is expensive. The evaporation load on a vacuum evaporator could be reduced by removing some of the water prior to feeding the evaporator. This could be accomplished by using enhanced evaporation as a step preceding vacuum evaporation.

8. Filtration plus solar evaporation (FS).

The area needed for solar evaporation could be reduced by decreasing the volume of feed. This could be accomplished by first running the production well effluent through an RO unit. RO units work best with dilute feeds.

9. Filtration plus vacuum evaporation (FV).

This alternative is similar to #8 above, but uses RO to reduce the volume going to the vacuum evaporator.

10. Solar evaporation plus vacuum evaporation (SV).

This alternative is similar to #8 above, but uses solar evaporation to reduce the volume going to the vacuum evaporator.

11. Enhanced evaporation plus filtration plus solar evaporation (EFS).

Here, enhanced evaporation and RO is used to reduce the area needed for solar evaporation.

12. Enhanced evaporation plus filtration plus vacuum evaporation (EFV)

Enhanced evaporation and filtration are used to reduce the volume being fed to vacuum evaporation.

13. Enhanced evaporation plus solar evaporation plus vacuum evaporation (ESV).

Like #13 above, enhanced evaporation in conjunction with solar evaporation are used to reduce the volume fed to vacuum evaporation.

14. Filtration plus solar evaporation plus vacuum evaporation (FSV).

Like #13 above, RO in conjunction with solar evaporation are used to reduce the volume fed to vacuum evaporation.

Given the distance (at least 25 miles), the size of the nearby town facilities that could accept the waste, and low likelihood that the municipalities would accept the waste into their system, this alternative will not be further explored.

3.2.3 Dilute the TDS with water from a new well field.

This would be a waste of good water. It is also doubtful that the State of New Mexico would allow this use of water. This alternative will not be pursued further.

3.2.4 Deep well injection of the discharge from the production wells, or concentrate from another alternative.

This is the only viable alternative for disposal.

3.3 MATCHING VOLUME REDUCTION ALTERNATIVES WITH DEEP WELL ALTERNATIVES

The table below shows the amount of brine exiting the volume reduction alternatives. These are the amounts that would have to be disposed by deep well injection.

Alternatives	Injection Amount 250 gpm Cases (gpm)	Injection Amount 500 gpm Cases (gpm)
F1	150	300
F2	180	304
S1	39	78
S2	10	20
S3	10	20
FS1	39	78
FS2	10	20
FS3	10	20
FV1	39	78
FV2	10	20
SV	10	20
FSV	10	20

Obviously, the various alternatives would impose different loads on the injection well. Given the condition of the existing well, it is prudent to judge that any injection amount of 150gpm or above would require a separate new injection well. Further, given input from Sandia, a new well would probably be located near Tucumcari. The existing well would have to be reworked before it could be reliably used continuously for injection.

500 gpm Case Capital and Operating Cost Estimates

Alternative	Description	Capital Cost Range ($mil)		Amortized Capital plus O&M Costs ($mil)	
		Low	High	Low	High
F1	RO + 1 Well	16.3	19.9	3.3	3.7
F2	River RO + 1 Well	18.5	22.5	3.2	3.6
S1	Solar Pond (Pickle)	14.1	17.2	1.2	1.4
S2	Solar Pond	16.3	19.9	1.3	1.6
S3	Solar Pond w/ Salt	18.6	22.7	1.8	2.1
FS1	RO + S1	14.4	17.6	2.6	2.9
FS2	RO + S2	16.7	20.4	2.8	3.1
FS3	RO + S3	19.0	23.2	3.3	3.7
FV1	RO + cryst (pickle)	21.1	25.7	6.3	6.7
FV2	RO + cryst (bittern)	30.2	36.8	7.8	8.4
SV	Solar + cryst	23.2	28.2	3.0	3.4
FSV	RO + Solar + Cryst	23.8	28.9	4.4	4.8
IW	2 New Wells	13.4	16.3	1.8	2.1

Note that a new alternative (IW) has been added. In this alternative, enough new deep wells are added such that no volume reduction is needed. The production well brine is routed directly to the injection wells with no volume reduction treatment.

Amortized costs were calculated assuming various equipment lives and an interest rate of 5.5%. Operating and maintenance costs for each alternative were added to the amortized capital cost to obtain a yearly lifetime cost estimate.

The S1 alternative has the lowest lifetime cost at both pumping rates.

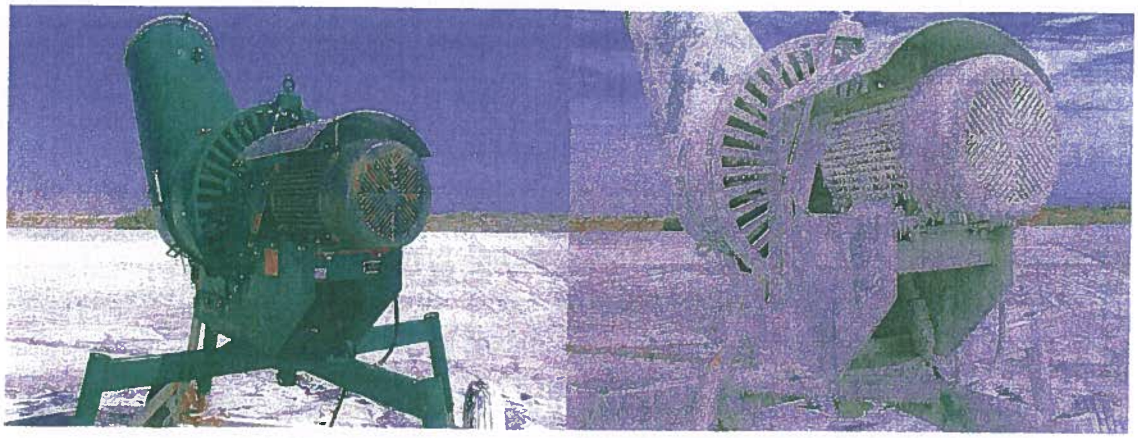
3.5 EXPLANATION OF ALTERNATIVES ELIMINATED

- Enhanced evaporation (E).

Mechanical Spray Evaporators

The only known use of enhanced evaporation using these units with salt brine took place at the Salton Sea in Southern California. The US Bureau of Reclamation (USBR) set up test ponds containing two of these units to define the cost, benefits, and problem areas associated with their use in this application. The brine at the Salton Sea is similar to the LMSCP brine, thus the USBR data is directly applicable to the current investigation.

The USBR tested units from two manufacturers. The two units were a Snow Machines Super Polecat, and a Slimline Mobile S30P Turbomister, and they were tested for 5 months in 2002. The two units were mounted in a 5 acre pond. The



Clean unit Fouling due to mist ingestion

Note that robotically rotating the units to keep them aligned with the wind direction has not been tried. As above, this is a critical problem that would also occur at the LMSCP site and would have to be resolved for the application to be viable.

- "The air quality permit to operate the evaporators required that the devices be shut down any time the wind speeds reached 15-minute average wind speeds of 21 miles per hour (mph) or greater; however, it was found to be more beneficial to the operation if the equipment was shut down when 15-minute average wind speeds reached 10 mph or greater." This was due to the drift of salt beyond the pond boundaries. This salt drift issue may be alleviated by the use of drift fences as shown below.

A discussion with the Slimline representative indicated that 90% of the drift fell within 500ft in 10mph wind. Therefore, the fences could be located close to the

Other than this one limited test, netting is an experimental alternative at best. The amount of evaporation enhancement is not well known. It cannot be said that this is currently viable technology. Therefore it cannot be considered further.

Pond Circulator

The SolarBee unit pictured previously was tested by USBR at the Salton Sea in 2004 in a short term test. The report has not been funded by the government for over a year. Thus no report is available. Other sources of information on this test indicate: 1) evaporation was not enhanced by the SolarBee during the daytime, in fact it was reduced 14%, 2) evaporation at night was increased 1.5 times by the SolarBee.

Given that there is so little reliable information on this equipment and no usable design information, this alternative will not be considered further. However, it should be said that if solar evaporation ponds are shown to be viable elsewhere in this report, equipment such as this could be further evaluated to reduce the size of the ponds needed.

Harry Remmers with the USBR indicates that none of the above technologies are being used by USBR for any of their solar evaporation projects.

- Vacuum Evaporation (V).

This alternative basically calls for boiling away almost all the water from the production wells. This is a very expensive and unfeasible option. The equipment supplier declined to give an estimate for this alternative stating that it was unreasonable to consider. Therefore, this alternative is eliminated. However, unlike the "E" options, vacuum evaporation in conjunction with other technologies was investigated.

3.6 DISCUSSION OF OTHER EVALUATION CRITERIA

Each alternative is rated on the accompanying spreadsheet based on these criteria.

3.6.1 Reliability

Reliability here encompasses several considerations. One is simply the number of moving parts. Generally, the more moving parts in an operation, the more potential for breakdowns. Also, some alternatives such as RO have well known track records in the area of low salinity brines. They have a less well known history in more concentrated brines such as we are dealing with. This impacts reliability.

Another large impact on reliability is in the area of salt sales. Certain of the alternatives produce salt to be sold. These sales are usually made under contract should operate for a reasonable sustained period, but the degree of corrosion and ultimate life of the wellbore remains unknown without further operations and detailed evaluation and assessment."

5. The injection of concentrated brines "may offer some additional boost to injectivity due to density addition". However, they caution that "filtration and fluid compatibility remain other potential difficulties if salinity or fluid weight remain too high." Here they are concerned with pore plugging due to mineral precipitation.

4.1 STRATEGIES TO PROLONG THE LIFE OF THE EXISTING WELL

4.1.1 The volume reduction alternatives discussed above offer an opportunity to reduce the injection rate and extend the well life as it concerns reservoir issues.

The deep well injection rates for alternatives F1, F2, S1, and S2 for both the 250gpm and 500gpm cases are shown below. A dilution rate of 10% is assumed.

Alternative	250 gpm Case	500 gpm Case
F1	165 gpm	330gpm
F2	198	335
S1	43	86
S2	11	22

The injection rates for F1 and F2 in the 500gpm case are well above the 250gpm injection rate that has historically been a problem. Therefore, those alternatives should not be considered if the existing well is to be used. In addition, they are probably inappropriate for any single new well. Based on Sandia's projection of wellhead pressure vs injection rate, F1 for the 250 gpm case would extend the reservoir life of the well from ~30,000 hours to ~450,000 hours or about 48 years. F2 for the 250 gpm case would extend the life to about 140,000 hours or 12 years. S1 or S2 for either the 250 or 500 gpm cases would extend the reservoir life indefinitely.

4.1.2 Deaeration of the brine before injection has potential for reducing ongoing corrosion. Rusting corrosion requires an oxidant. Oxygen in air is the usual culprit. Removing dissolved air from the brine would remove the oxygen oxidant. Deaeration equipment should be considered for any alternative.

4.1.3 Dilution and filtration of the brine before injection has potential for eliminating pore plugging due to mineral precipitation. It is possible that the existing production well brine will precipitate minerals as it is currently injected. Injection brine from F1 or F2 may also precipitate minerals downhole. Brines from S1 or S2 will definitely precipitate minerals downhole. In all cases, the precipitation would occur due to