

# Characteristics of the Near-surface Brine Resources in the Newfoundland Basin, Tooele and Box Elder Counties, Utah

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## Introduction

The Great Salt Lake Desert of western Utah, also known as the West Desert, is underlain by a shallow aquifer system that contains brine from which potentially economic quantities of sodium, potassium, and magnesium salts can be produced. This brine is probably a remnant of freshwater Lake Bonneville, which occupied the basin from about 32,000 to 14,000 years ago. A similar origin is suggested for the Great Salt Lake. Comparisons of Great Salt Lake brine and West Desert brine indicate that they differ chemically.

In the 1980s, in response to flooding caused by the rising Great Salt Lake, the State of Utah installed pumps to move Great Salt Lake brine into a portion of the West Desert where some of the water could evaporate. The concentrated brines were expected to flow back into the Great Salt Lake. This project was called the West Desert Pumping Project (WDPP) and it operated from April 10, 1987 through June 30, 1989. During this period, the U.S. Geological Survey (USGS) estimated that brine containing 695 million tons of salt was pumped into the West Desert (Wold and Waddell, 1993). When pumping ceased, USGS estimated that 123 million tons of salt had been discharged from the evaporation pond back towards the Great Salt Lake. Of the salt not returned to the lake, the USGS estimated that 315 million tons remained in a pond in the West Desert, 10 million tons were contained in a salt crust on the floor of the pond, 71 million tons infiltrated the subsurface of the inundated area, and 88 million tons were withdrawn by a mineral extraction operation. The USGS was unable to account for about 88 million tons of the 695 million tons that they estimated had been removed from the Great Salt Lake.

Studies indicate that the Great Salt Lake brine pumped into the West Desert mixed with the West Desert subsurface brine creating brine that is chemically different from both original brines (Kohler, 2002). The purpose of this report is to characterize the West Desert brine in the area flooded by Great Salt Lake brine before, during, and after the pumping project. TEQUIL, a geochemical model developed by the University of California at San Diego, was used to characterize the various brines by comparing the minerals expected to precipitate as the brine evaporates and the concentration of key ions that remain in solution.

## Geologic Setting

The Great Salt Lake Desert is a broad valley in the Great Basin portion of the Basin and Range physiographic province west of the Great Salt Lake. The Great Salt Lake Desert is a closed basin with all drainage towards the center of the basin. This broad basin consists of a number of smaller sub-basins that are separated by very low topographic divides. The principal sub-basins within the Great Salt Lake Desert are the Bonneville Salt Flats and Pilot Valley. This report focuses on the basin immediately west of the Newfoundland Mountains that was filled with Great Salt Lake brine during the duration of the state's pumping project. This basin has not been formally named, but it will be referred to in this report as the Newfoundland basin. Recent maps of this area refer to an area called the Newfoundland Evaporation Basin that is a man-made feature that was part of the West Desert Pumping Project and is bounded on the south and west by an artificial dike. In this report, the more restrictive Newfoundland basin refers to the topographic depression west of the Newfoundland Mountains (fig. 1). The West Pond refers to the brine pond that was in the Newfoundland basin as a result of the pumping project.

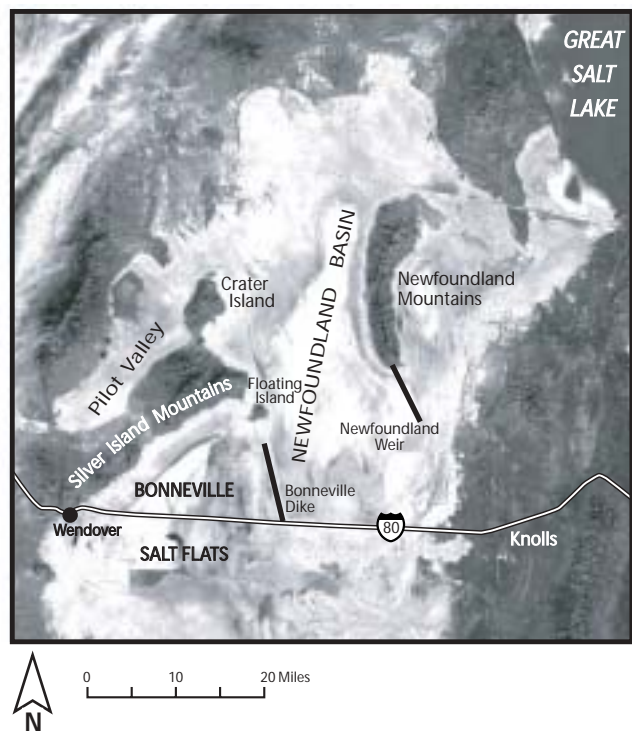


Figure 1. Great Salt Lake Desert showing sub-basins.

The sediments comprising the Great Salt Lake Desert mudflats consist primarily of carbonate muds, clay, gypsum, and salt. Minor occurrences of oolitic sand and thin carbonate layers of probable algal origin are also present in the surface sediments within the Great Salt Lake Desert. An ephemeral salt crust covers the playa surface in Pilot Valley, and the Bonneville Salt Flats has a permanent salt crust. Since cessation of the West Desert Pumping Project in 1989, a salt crust has also been deposited on the playa in the lower part of the Newfoundland basin. The area of the mud flats exhibits very low relief with elevations generally ranging from about 4,210 to 4,225 feet above sea level. Locally, small dunes of wind-blown gypsum sand provide a slight amount of relief to the otherwise flat surface. Extensive dunes of gypsum sand are present along the eastern edge of the playa.

The hydrologic system within the Great Salt Lake Desert generally consists of three types of aquifers: an alluvial fan aquifer adjacent to the mountain ranges around the perimeter of the playas, a shallow brine aquifer that occurs in the upper 20 feet of the playas, and a deep basin fill aquifer (Lines, 1979). Limited brine chemistry from the shallow brine aquifer suggest that it is the only part of the groundwater system that was affected by the West Desert Pumping Project.

## Previous Work

The first assessment of the Great Salt Lake Desert brine resource was conducted by Thomas Nolan of the USGS in the 1920s (Nolan, 1927). Nolan completed 405 shallow test holes distributed over the entire Great Salt Lake Desert. Brine samples were collected and analyzed from these drill holes, but complete analyses were not included in Nolan's published report. However, the report does include a composite analysis of 126 samples taken during his field investigation. Nolan does not identify which of his 405 test holes were included in the composite sample. The results of Nolan's investigation were used by the USGS to classify much of the Great Salt Lake Desert as a known potassium resource area.

In the early 1960s, George J. Lindenburg, a graduate student at the University of Utah, conducted an investigation of the shallow brines in part of the Great Salt Lake Desert and compared them with brines of the Great Salt Lake (Lindenburg, 1974). As part of this investigation, brine samples were collected from the shallow brine aquifer at 65 different locations. Fourteen of these sites were within the area inundated by the pumping project, but none were within the Newfoundland basin. Lindenburg concluded that the shallow brines from the Great Salt Lake have a higher sulfate content than the shallow subsurface brines of the Great Salt Lake Desert. He attributed this difference to the addition of sulfate to the Great Salt Lake from the Jordan River and other tributaries that feed the lake. He concluded that higher sulfate values are not found in the shallow subsurface brines of the Great Salt Lake Desert because they represent a closed system that does not receive similar recharge.

In the mid-1960s, much of the area of the West Pond was explored for potassium by Reynolds Metals Company under a prospecting permit from the Federal government. During this exploration program, 92 shallow drill holes were completed within the area flooded by the pumping project, 72 of which were in the Newfoundland basin. Brine samples from these drill holes were analyzed for potassium, magnesium, chloride and sulfate, and the data are discussed below.

As part of the feasibility study for the West Desert Pumping Project, Dames and Moore (1983) completed a report that addressed the shallow brine aquifer within West Pond. As part of their field investigation, Dames and Moore drilled a number of wells along the alignment of the dike along the south and southwest boundary of the proposed West Pond. The Utah Geological Survey (UGS) analyzed water samples taken from these wells, and major ions were reported on a weight-percent basis. The sum of the weight-percent values for the individual ions was reported as percent total dissolved solids (TDS).

## Data Compilation

The Reynolds data obtained from the Newfoundland basin are key to this study because they provide a good summary of the shallow brine composition before the area was inundated by Great Salt Lake brine. In order to model the Reynolds data, the missing sodium and calcium values had to be estimated. A strong linear relationship was found when the sodium content of other West Desert brine samples is plotted against the chloride content. By fitting a linear regression line to the plot of sodium against chloride, the following relationship is shown:

$$\text{Na (mmoles)} = (0.9349 \times \text{Cl (mmoles)}) - 42.19$$

Using this relationship, the missing sodium values were estimated. Calcium ions were estimated by determining the amount of  $\text{Ca}^{++}$  necessary to achieve charge balance for the solution. To convert the Dames and Moore data from weight-percent to grams per liter, it was necessary to calculate the density of the solution. This was accomplished by plotting density vs. TDS for West Desert samples with known values. The linear regression curve fit to these data provided the following relationship:

$$\text{Density} = 7.305 \times \text{TDS} - 1.009$$

These procedures are described in more detail in Kohler (2002).

The average pre-WDPP brine chemistry for the adjusted data from the various sources is listed in table 1. The Reynolds data are separated into two groups, Reynolds N from the Newfoundland basin, and Reynolds S from a small topographic depression southeast of the Newfoundland basin.

None of these studies developed quantitative information on the hydrologic characteristics of the shallow brine aquifer in the West Pond, but some qualitative

**Table 1. Summary of pre-WDPP shallow brine samples from the West Pond (Newfoundland basin) area. Ion concentrations reported in moles per liter.**

Data Source	Number of Samples	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>--</sup>
Nolan	126	2.492	0.075	0.038	0.079	2.712	0.042
Lindenburg	13	1.875	0.072	0.045	0.060	2.057	0.071
Reynolds N	72	3.128	0.099	0.045	0.129	3.354	0.061
Reynolds S	20	2.537	0.148	0.048	0.107	2.728	0.060

observations were made. Nolan noted that the brine was found in thin horizontal zones in the sediments rather than being uniformly distributed throughout them. He also observed that in the areas away from the edge of the flat, the brine flow, if plentiful, was under a small hydrostatic pressure and would raise a few inches in the borehole (Nolan, 1927). Nolan also noted that brine flow was scanty in some areas but did not identify exactly where these areas were located. With regards to the characteristics of the shallow brine aquifer, Reynolds Metals Company (1966) offered the following: "A few holes filled very quickly, others very slowly. In many we could see liquid trickling down the walls from just below the collar, but we could not often distinguish successive lower points of influx that certainly contributed to the flow. In a few cases it seemed as if the liquid welled up from the bottom faster than it oozed in from the sides."

### Great Salt Lake Brine Pumped into the West Pond

From April 10, 1987, to June 30, 1989, an estimated 2.7 million acre-feet of water was pumped into the West Pond (Wold and Waddell, 1993). The USGS periodically collected 13 samples at the outlet of the pump and analyzed them for the major ions (Kidd Waddell, USGS, personal commun., 1999). Of the 13 brine samples, only one sample had a mole balance of  $\pm 5\%$  and was deemed reliable enough to be used in this study. However, the Utah Geological Survey (UGS) also collected samples from the Great Salt Lake during the period that the pumping project was operating. The UGS samples should be representative of the brine that was pumped into the West Pond. Analyses from these samples were obtained from the UGS (J.W. Gwynn, UGS, personal commun., 1999). In addition to sampling the brine at the pump, the USGS collected 24 samples from points scattered throughout the West Pond in June 1989 to estimate the amount of salt contained in solution in the pond at the end of pumping

(Wold and Waddell, 1993). The average composition of the brine from these sources is summarized in table 2.

Great Salt Lake brine generally contains higher concentrations of magnesium and sulfate than brine in the shallow brine aquifer underlying the Newfoundland basin prior to pumping. This difference is emphasized when a comparison is made of the ratios of potassium to magnesium and calcium to sulfate for the two different brines. The pre-pumping project shallow groundwater brine represented by the Reynolds North data (table 1) has a K/Mg ratio of 0.77 and a Ca/SO<sub>4</sub> ratio of 0.74. In contrast, analyses of the Great Salt Lake brine using the average values from April 1987 to June 1989 (table 2) show a K/Mg ratio of 0.35 and a Ca/SO<sub>4</sub> ratio of 0.06.

When pumping stopped in June 1989, water remaining in the West Pond continued to evaporate, and the pond decreased in size and retreated to the lowest part of the basin and eventually dried up. Satellite imagery of the West Pond suggests that it disappeared by July 22, 1991, leaving behind an extensive salt crust in excess of 3 feet thick in the center of the basin. Since 1991, satellite imagery shows that a surface pond forms in the Newfoundland basin during periods of low evaporation in the winter and following heavy precipitation.

### Present Shallow Brine Aquifer in the Newfoundland Basin

In order to make a preliminary assessment of the brine presently in the shallow brine aquifer in the West Pond, a field investigation was undertaken during the summer of 1999. As part of this investigation, brine samples were recovered from shallow boreholes (6 to 8 feet) drilled in various locations throughout the West Pond area. These boreholes were drilled with a standard 4-inch bucket soil auger and a log was kept of the sediments encountered as well as the brine depth. The brine was then bailed from the borehole with a portable centrifugal pump at a rate of 1 to 2 gallons per minute until approximately 50 gallons of brine had been removed. At this point, samples were collected for analysis. In a typical borehole, the pumping rate of 1 to 2 gallons per minute lowered the water level a few inches, but sustainable flow could be maintained. When pumping stopped, the water level in the borehole returned to the original level. In the boreholes away from the center of the basin, the brine was typically confined and the water level would raise a few inches above its original level. In the center

**Table 2. Summary of brine samples representative of Great Salt Lake brine pumped into the West Pond. Ion concentrations reported in moles per liter.**

Data Source	Number of Samples	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>--</sup>
USGS West Desert Pump	1	2.175	0.066	0.005	0.160	2.454	0.115
UGS Great Salt Lake Average, April 1987 to June 1989	13	2.301	0.075	0.006	0.217	2.591	0.101
USGS West Pond, June 1989	24	4.789	0.153	0.010	0.342	5.308	0.188

of the basin, no confined conditions were observed. Three of the samples collected during this investigation, obtained in the center of the basin, on or near locations sampled by Reynolds Metals in the 1960s, are of particular interest because they provide a basis for identifying changes to the shallow brine aquifer chemistry in the area last occupied by the waters from the WDPP. The analyses from these three samples are summarized in table 3.

**Table 3. Brine samples from the shallow brine aquifer collected in the center of the Newfoundland basin, 1999. Ion concentrations reported in moles per liter.**

Well Designation	Na <sup>+</sup>	K <sup>+</sup>	Ca <sup>++</sup>	Mg <sup>++</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>--</sup>
NB-8	3.454	0.425	0.004	0.823	4.727	0.365
NB-9	3.341	0.527	0.008	0.848	5.012	0.373
NB-10	3.310	0.486	0.008	0.859	5.012	0.318
Average	3.368	0.479	0.007	0.843	4.917	0.352

Not surprisingly, the marked increases in concentrations of potassium and magnesium reflect brine that has been concentrated through evaporation.

### Geochemical Modeling of West Pond Brines

The TEQUIL program was developed by the University of California at San Diego for the geothermal industry to predict the chemical behavior of the natural brines from which the energy is extracted. Although the program was developed for the geothermal industry, it has been found to have wide applications in other industries including solar pond engineering (Møller and others, 1997). The program is based on a model which uses semi-empirical equations of Pitzer (1973) that were used by Harvie and Weare (1980) to show that the free energy calculations on electrolyte solutions could be used to accurately predict complex solubility relationships in the Na-K-Ca-Mg-SO<sub>4</sub> system (Møller and others, 1997). Various versions of this program are available, but for the purposes of this investigation, the 25°C model for the Na-K-Ca-Mg-H-Cl-OH-SO<sub>4</sub>-HCO<sub>3</sub>-CO<sub>3</sub>-CO<sub>2</sub>-H<sub>2</sub>O system (Harvie and others, 1984) was used.

TEQUIL provides a user interface to input the composition (in moles) of the initial solution. The model then reduces water through an iterative process to simulate evaporation. For each iteration, the program calculates the solubility for the various minerals that could be expected to precipitate from the brine. When the solution becomes saturated with a given mineral, the mineral is allowed to precipitate. The precipitated salt remains in contact with and is allowed to react with the brine. The results of the evaporation simulation are saved by the program in a text file that lists the molar composition of the concentrated brine and any minerals that precipitate from the brine.

TEQUIL was used to better understand how the brines introduced to the Newfoundland basin from the Great Salt Lake may have interacted with the subsurface brines contained within the shallow brine aquifer. TEQUIL identified

the minerals that would precipitate from the brine and the sequence of precipitation. The model shows that evaporation of samples of brine from the Great Salt Lake produced a very consistent sequence of minerals even though the brine chemistries appear to be different. The mineral sequence projected by the model for the Great Salt Lake is consistent with actual results reported from the evaporation of Great Salt Lake brine (Butts, 1993, Jones and others, 1997).

The model also shows that when brines from the shallow brine aquifer from the Great Salt Lake Desert (before the West Desert Pumping Project) are evaporated, an equally consistent sequence of minerals results which is significantly different than the minerals which precipitate from the Great Salt Lake. The mineral sequence projected by the model for brine from the shallow brine aquifer in the Great Salt Lake Desert is consistent with the sequence reported for Reilly-Wendover's potash extraction operation near the Bonneville Salt Flats (Bingham, 1980).

The model was applied to subsurface brine from the Newfoundland basin before the area was inundated by the pumping project, brine from Great Salt Lake, and subsurface brine presently found in the center of the basin. The program was run for sufficient iterations to simulate the removal of over 99% of the water through evaporation. The model results were then graphed to show the sequence of minerals that precipitated from the brines. To aid in understanding the graphs, the primary salt minerals that the model showed would precipitate from the brines used in this exercise are shown in table 4.

The results of using the TEQUIL 25°C model to simulate evaporation of a Great Salt Lake brine reported from the North Arm in 1978 are shown in figure 2. The y-axis values on the left side of the graph show the mass of the halite precipitated from the brine. The y-axis values on the right side of the graph show the amount of the various salts precipitated in moles. For Great Salt Lake brine, the model indicates that the order of initial precipitation for the primary salts is as follows: anhydrite-halite-glauberite-polyhalite-leonite-kainite-carnallite-kieserite-bischofite.

**Table 4. Evaporite minerals derived from West Desert brines (adapted from Braitsch, 1971).**

Mineral	Formula	Molecular Weight
Anhydrite	CaSO <sub>4</sub>	136.15
Bischofite	MgCl <sub>2</sub> • 6H <sub>2</sub> O	203.33
Bloedite	Na <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> • 4H <sub>2</sub> O	334.51
Carnallite	KMgCl <sub>2</sub> • 6H <sub>2</sub> O	277.88
Epsomite	MgSO <sub>4</sub> • 7H <sub>2</sub> O	246.50
Gypsum	CaSO <sub>4</sub> • 2H <sub>2</sub> O	172.18
Glauberite	Na <sub>2</sub> Ca(SO <sub>4</sub> ) <sub>2</sub>	278.21
Halite (common salt)	NaCl	58.454
Hexahydrate	MgSO <sub>4</sub> • 6H <sub>2</sub> O	228.49
Kainite	KMgClSO <sub>4</sub> • 3H <sub>2</sub> O	244.48
Kieserite	MgSO <sub>4</sub> • H <sub>2</sub> O	138.41
Leonite	K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> • 4H <sub>2</sub> O	366.71
Mirabilite	Na <sub>2</sub> SO <sub>4</sub> • 10H <sub>2</sub> O	322.22
Polyhalite	Ca <sub>2</sub> K <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>4</sub> • 2H <sub>2</sub> O	602.98
Sylvite	KCl	74.553
Syngenite	K <sub>2</sub> Ca(SO <sub>4</sub> ) <sub>2</sub> • H <sub>2</sub> O	328.43

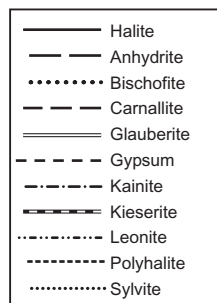
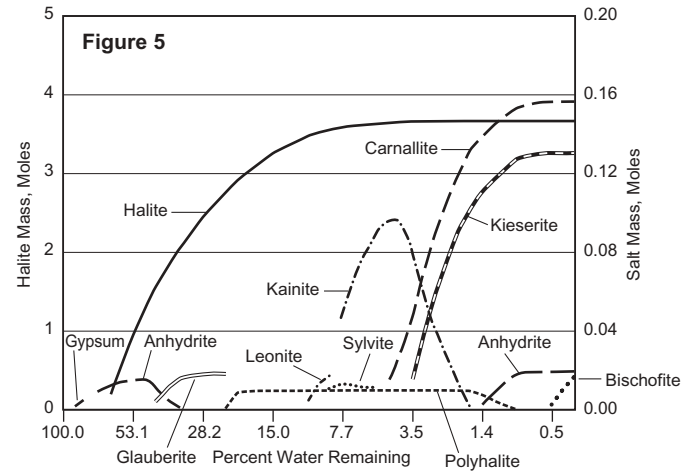
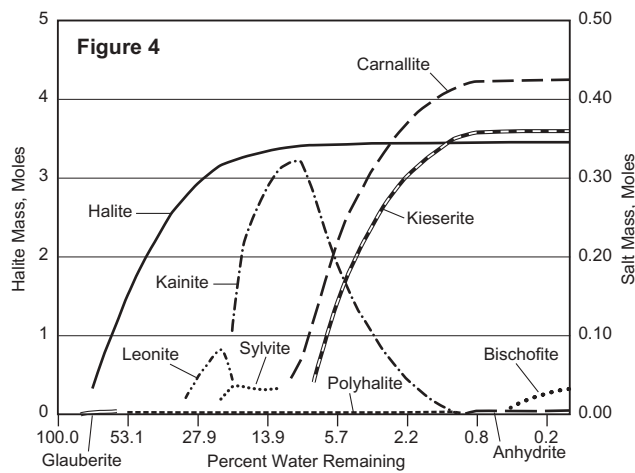
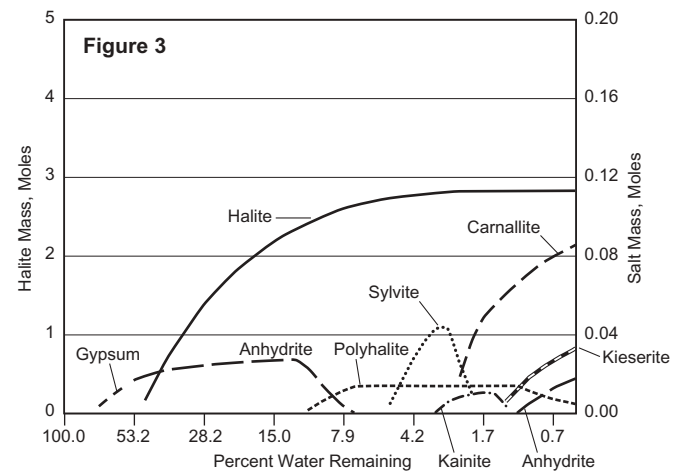
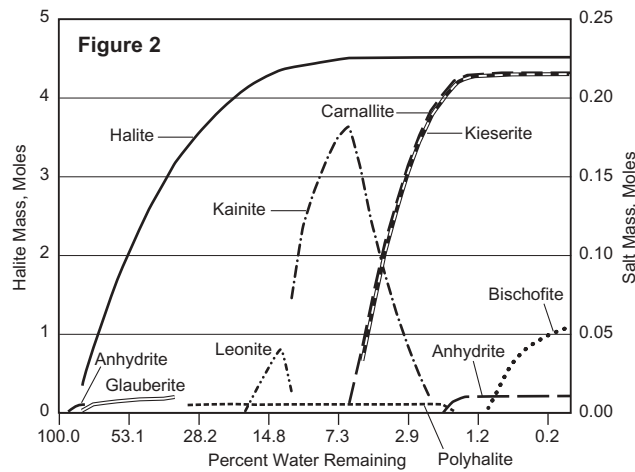
Similar results were obtained from modeling the average Great Salt Lake brine from 1987 to 1989.

The model's prediction of minerals that would precipitate from brine sampled by Reynolds (Auger Hole #60238) before the basin was flooded by Great Salt Lake brine is shown on figure 3. The minerals precipitated from the subsurface West Desert brine, as predicted by the model, are quite different than minerals derived from Great Salt Lake brine. The model shows minerals precipitating as follows: gypsum-anhydrite-halite-polyhalite-sylvite-kainite-carnallite-kieserite.

The TEQUIL model was then applied to the brine collected in the summer of 1999 from an auger hole (NB#8) located near Reynolds Auger Hole #60238. The results, as

shown on figure 4, appear to be significantly different from either Great Salt Lake brine or the original Newfoundland basin brine. First of all, the brine has been significantly concentrated by evaporation. Because of this, the maximum value on the y-axis for the precipitated salts had to be increased to 0.5 moles from the 0.2 and 0.25 moles used on the other graphs to adequately show the distribution of the precipitated minerals. For the present groundwater brine in the center of the basin, the non-halite minerals precipitated out as follows: glauberite-halite-polyhalite-leonite-sylvite-kainite-carnallite-kieserite-bischofite.

The mineral suite projected by the model for the shallow groundwater brine in the center of the Newfoundland basin seems to contain components of both



**Figure 2. Modeled mineral deposition during evaporation, Great Salt Lake-North Arm brine, 27 October 1978 (sample depth = 10 feet).**

**Figure 3. Modeled mineral deposition during evaporation, Deep Basin (NB): Reynolds auger hole #60238 brine (site of NB#8, 1999).**

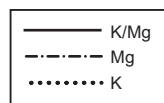
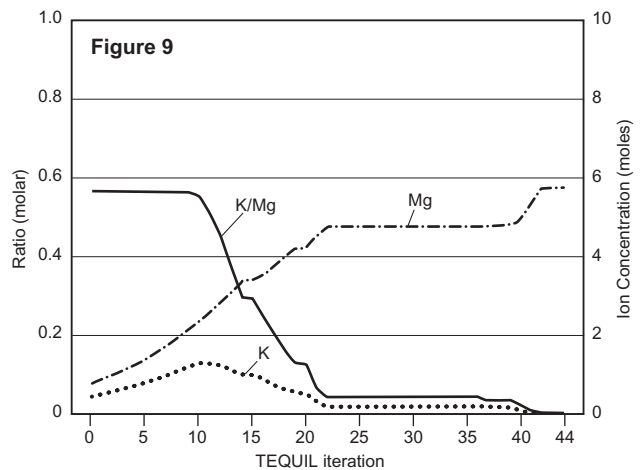
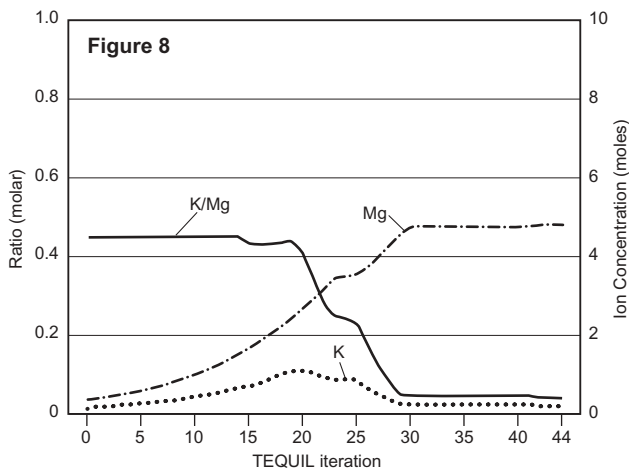
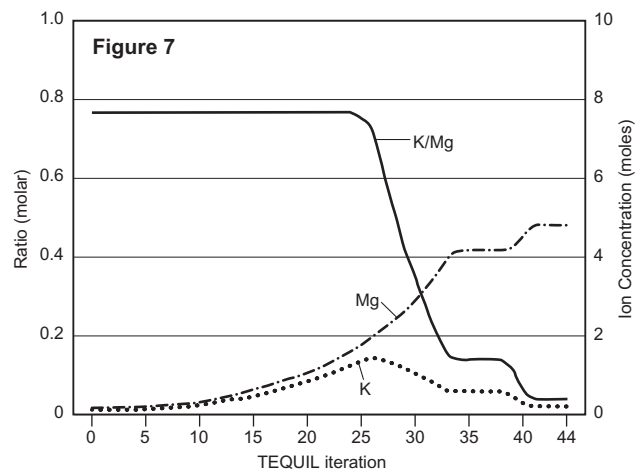
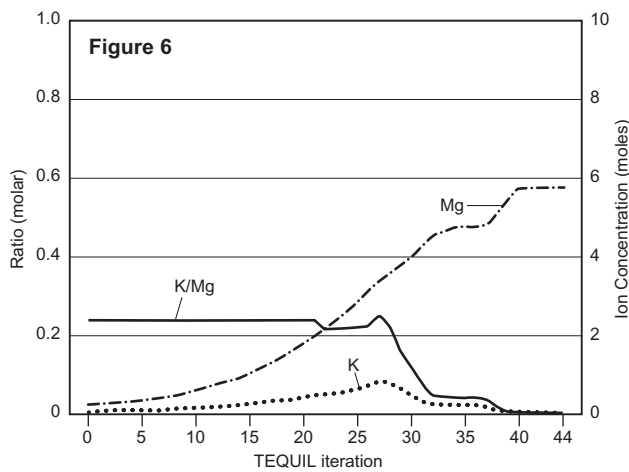
**Figure 4. Modeled mineral deposition during evaporation, BLM auger hole NB#8, sample NBW-9 brine, Newfoundland basin, 27 August 1999.**

**Figure 5. Modeled mineral deposition during evaporation, Reynolds auger hole #60238 + 1978 North-Arm mix (50% + 50%).**

the Great Salt Lake and original groundwater. This suggests that the brine presently contained in the shallow brine aquifer in the center of the basin represents a mixture of the original groundwater brine with brine from the Great Salt Lake. To test this hypothesis, TEQUIL was used to project evaporation of an artificial brine representing a mixture of 50% Great Salt Lake and 50% of the pre-pumping Newfoundland basin brine (Reynolds auger hole #60238). The results are shown on figure 5. The resulting curves are very similar to those for the brine sample collected from auger hole NB#9 in 1999 (table 3).

The TEQUIL Model was also used to further characterize brine from various sources by plotting the ratio of potassium to magnesium as the brine is concentrated through evaporation. The graphed results are shown in

figures 6 through 9. In each graph the molar ratio of potassium to magnesium remains constant until minerals containing potassium and magnesium begin to precipitate. Magnesium stays in solution longer than potassium so the K/Mg ratio decreases as evaporation proceeds. For the K/Mg ratio to increase, it would be necessary to either add additional potassium or reduce the magnesium content of the brine. One way to increase the K/Mg ratio for Great Salt Lake brine would be to mix it with a brine that has a higher K/Mg ratio. The K/Mg ratio for Great Salt Lake brine (fig. 6) is relatively low, starting out at about 0.24. On the other extreme, the pre-pumping brine in the Newfoundland basin (fig. 7) shows a K/Mg ratio of 0.77, showing a clear difference between the two brines. The K/Mg ratio of the brine in the basin from the pumping project from June 1989



**Figure 6. Modeled mineral deposition during evaporation, K/Mg ratio of Great Salt Lake brine (average of North and South arms).**

**Figure 7. Modeled mineral deposition during evaporation, K/Mg ratio during evaporation of West Desert brine (Reynolds North data, 1966).**

**Figure 8. Modeled mineral deposition during evaporation, K/Mg ratio during evaporation of West Pond brine (final brine in pond, 1989).**

**Figure 9. Modeled mineral deposition during evaporation, K/Mg ratio in Newfoundland basin shallow brine aquifer, 1999.**

(fig. 8) starts at 0.45, suggesting the possibility of some mixing with Newfoundland basin groundwater while the pumping project was in operation. The K/Mg ratio of the brine sampled in the Newfoundland basin in 1999 (fig. 9) starts at 0.57, possibly indicating that the brine added to the Newfoundland basin from the Great Salt Lake continued to mix with the original subsurface brine.

## Summary and Conclusion

Subtle differences in brine chemistry are not always readily apparent in brine from the Great Salt Lake and the Great Salt Lake Desert when these brines are compared using analyses of the major ions in the brine. This may be due to dilution of the brine by meteoric water or simply to the fact that the brines are dominated by sodium and chloride, which tend to mask differences in the other ions. By evaporating the brines and identifying the minerals that precipitate out of the solution, these subtle differences become more evident. The TEQUIL model at 25°C seems to produce a reasonable prediction of the simple Na-K-Ca-Mg-Cl-SO<sub>4</sub>-H<sub>2</sub>O system to which these brines belong. Application of the model shows that the mineral suite precipitating from Great Salt Lake brine is very different than the minerals precipitating from groundwater brines in the Great Salt Lake Desert. The model also shows that the brine presently in the shallow brine aquifer in the portion of the Great Salt Lake Desert inundated by pumped Great Salt Lake brine contains components of both brines and may represent a mixture of Great Salt Lake and original West Desert brines. These conclusions are based on a limited field investigation, and more sampling should be undertaken to confirm and refine the interpretations.

Based on USGS estimates, as much as 386 million tons of salt from the Great Salt Lake was added to the brine resource in the area flooded by the pumping project. This is demonstrated by the elevated levels of potassium and magnesium in the Newfoundland basin. However, TEQUIL modeling indicates that brine from the Great Salt Lake mixed with the existing groundwater brine, resulting in a change in the chemical character of the brine. Instead of a simple halite-sylvite-carnallite system, the mixing of Great Salt Lake brine has resulted in a system with a more complex mineralogy.

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