EVALUATION OF SALINE GROUNDWATER EXTRACTED FROM THE LAKE TOOLIBIN LAKE DISTRICT FOR USE IN COMMERCIAL SOLAR SALT PRODUCTION

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1.0 Summary

Groundwater pumping has been developed in the Toolibin Lake Recovery Plan to protect the lake and its environs from further salinisation. The groundwater pumped is high in salinity and a cost efficient means of disposal is being sought.

The purpose of this study was to ascertain whether the saline water pumped by the scheme was suitable for commercial salt production.

The study indicated the following:

A high quality salt (sodium chloride) could be produced from the groundwater.

Evaporation data indicates that a well designed evaporative system would require 0.126 hectares of evaporative ponds for disposal of each megalitre of water pumped per annum.

2.0 INTRODUCTION

2.1 Salt Production

Normal solar salt production is the controlled evaporation and fractional crystallisation of sea water to recover salt (sodium chloride) with a minimum of impurities.

The operation of a solar salt production system is basically a simple combination of introducing sea water into the evaporation ponds, allowing it to concentrate to the point of salt saturation, transferring it into salt crystallisation ponds and then disposing of the liquor as bitterns prior to the deposition of excessive amounts of contaminating salts.

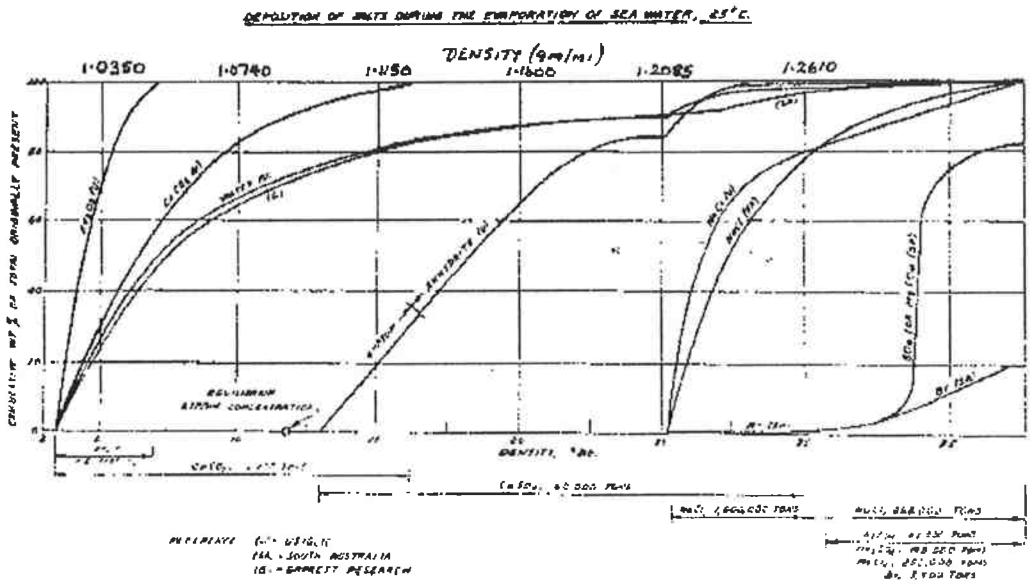


Figure 2.1

The sequence of salt deposition through the evaporative sequence is depicted in figure 2.1 above and is well documented by Dr. Donald E. Garrett of the Garrett Research and Development Company, La Verne, California. Quote "Figure 2.1 shows the path of crystallisation for the various constituents of sea water upon evaporation. Two of the minor components, iron and carbonate, crystallise very early in the evaporation sequence as perhaps iron, calcium and magnesium carbonates. They start crystallising immediately and iron is essentially removed by the time the brine reaches a density of 1.0500 (gm/ml) and the carbonate by the density of 1.1150 (gm/ml). Gypsum (CaSO4.2H2O) starts crystallising about 1.0995 (gm/ml) and continues throughout the remaining course of evaporation. However, at a density of about 1.1275 (gm/ml) it should change its crystallisation form to anhydrite (CaSO4) and by density 1.2300 (gm/ml) most of it has been crystallised.

Salt becomes saturated at about density 1.2130 (gm/ml) and as with each of the remaining components continues crystallising throughout the course of evaporation. At a density of 1.2500 (gm/ml), about 72% of the salt has been crystallised and at a density of 1.2600 (gm/ml) 79%."

At this point the remaining brine is discharged as bitterns due to the contamination of the salt through precipitation of magnesium and sulphate salts.

It is impossible to produce 100% pure sodium chloride in a solar evaporation facility. End-users of salt consider Calcium (0.05% max), Magnesium (0.03% max), Sulphate 0.15% max) and Insoluble Material (0.02% max) as the major contaminants in the end product.

In the case of evaluating the saline water from the Toolibin Lake District for the production of solar salt, it is useful to compare its chemical composition and evaporative sequence to that of sea water.

3.0 TEST PROCEDURES

3.1 Sampling

Department of Conservation and Land Management carried out the sampling of the water to be tested and the following sampling procedure was established to obtain a representative sample of the Lake Toolibin water.

Sampling Procedure

If possible the water sample should be drawn from the pump discharge pipe (ex Lake Toolibin groundwater pump) which discharges into Lake Taarblin. The pump should have been running for at least 24 hours. It will be preferable if the water salt concentration is close to the previously reported 42,900 mg/l average.

Ten new 20 litre plastic bottles will be used. When sampling, the bottles should be rinsed three times with the water being sampled.

The bottles should be filled to overflowing and the lid placed on. (Ensure there is no air pocket in the bottle).

These samples were then transported by road to Saltfield Technology's testing facility in Kerang, Northern Victoria. There phase chemistry and evaporation trials were conducted.

3.2 Test Procedure

Two standard A class pans were plastic lined and set up in a manner in which both received the same amount of sunshine and wind.

One pan was filled with fresh water and the other pan was filled with saline water collected from the 200 litre sample drawn from Lake Toolibin.

Evaporation measurements were taken during the test period on both pans. The fresh water pan was adjusted to volume to keep it at the same depth as the pan containing the saline water.

During the evaporation, samples were drawn from the saline water pan at various intervals along the density gradient and tested for density, Sodium Chloride, Calcium, Magnesium, Sulphate, Silicon, Iron, Bromine and Potassium.

When the Sodium Chloride had become totally saturated and precipitation was observed, water from the saline water pan was decanted off and samples of the resultant precipitated salts collected. These samples were both weighed and submitted for analysis.

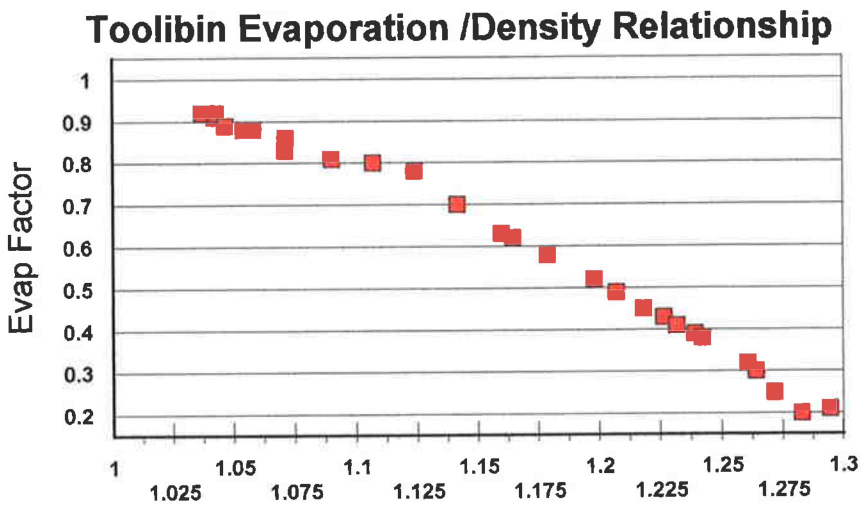
Further washing tests were carried out on the precipitated salt collected. The samples were subject to a quick spray wash in fresh water over a 200 micron screen and allowed to drain. These samples were also submitted for analysis.

4.0 TEST RESULTS AND OBSERVATIONS

4.1 Evaporation Data

There are various factors which affect the evaporation observed in a body of water of varying salt concentrations to that observed in a Class A pan with fresh water. Usually a large body of water is deeper than an A class pan and has a lower surface temperature thus reducing the rate at which water vapour is formed. Although the initial saline water evaporation rate may be close to that of fresh water, because of the decreasing vapour pressure of the high viscosity stronger brines, it decreases along a density gradient. It is normal practice to assign an evaporation factor to brines, this factor is arrived at by dividing the observed evaporation of brine in a pan by the observed evaporation in a class A pan.

Figure 4.1(a) below shows the evaporation factor fresh water pan/Toolibin saline water observed over a range of brine densities for the test period.

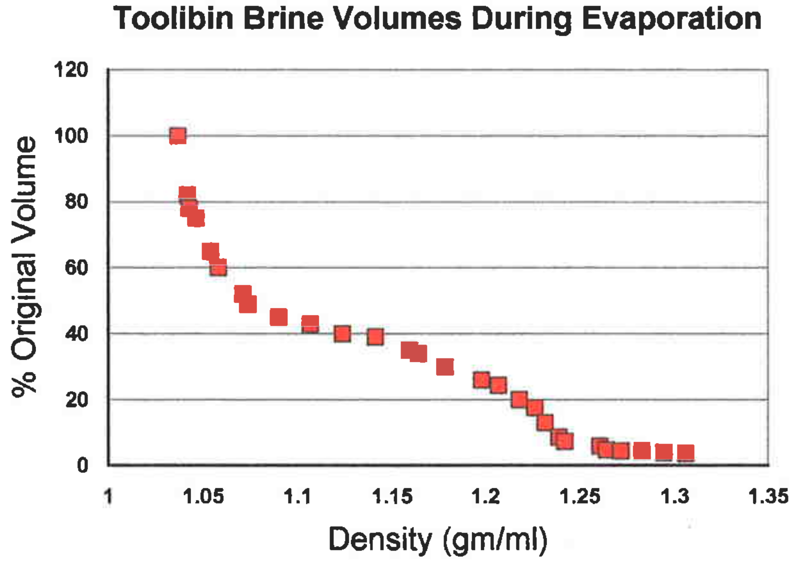


(Figure 4.1 (a))

In summary, the fresh water pan/Toolibin saline water pan evaporation factors for densities were as follows:-

Density Range (gm/ml)	Pan/Evaporation Factor
1.0250 - 1.0500	0.92
1.0500 - 1.0750	0.89
1.0750 - 1.1000	0.82
1.1000 - 1.1250	0.79
1.1250 - 1.1500	0.74
1.1500 - 1.1750	0.62
1.1750 - 1.2000	0.56
1.2000 - 1.2250	0.48
1.2250 - 1.2500	0.39

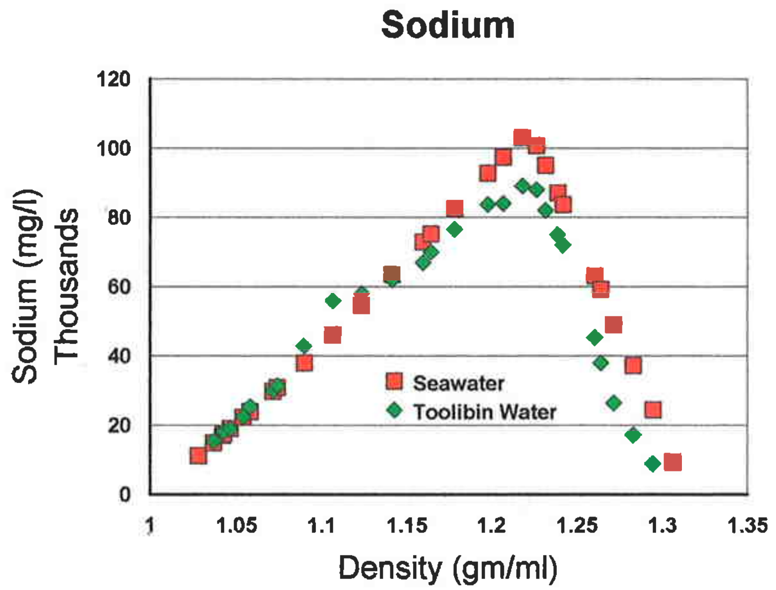
Figure 4.1(b) shows the volume change of the Toolibin brine along the density gradient produced during the tests.



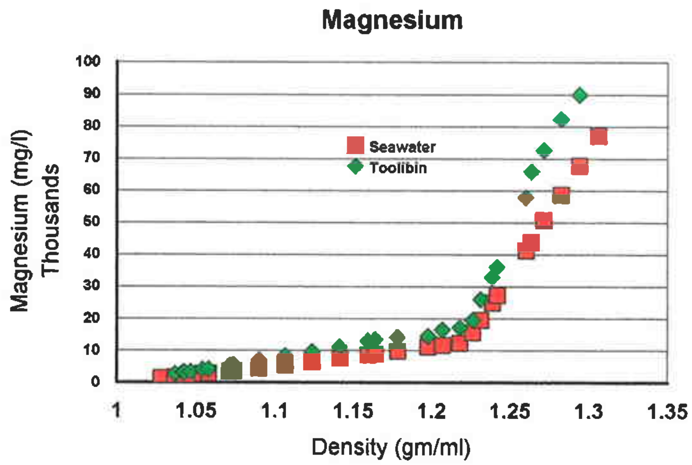
(Figure 4.1b)

4.2 Brine Chemistry

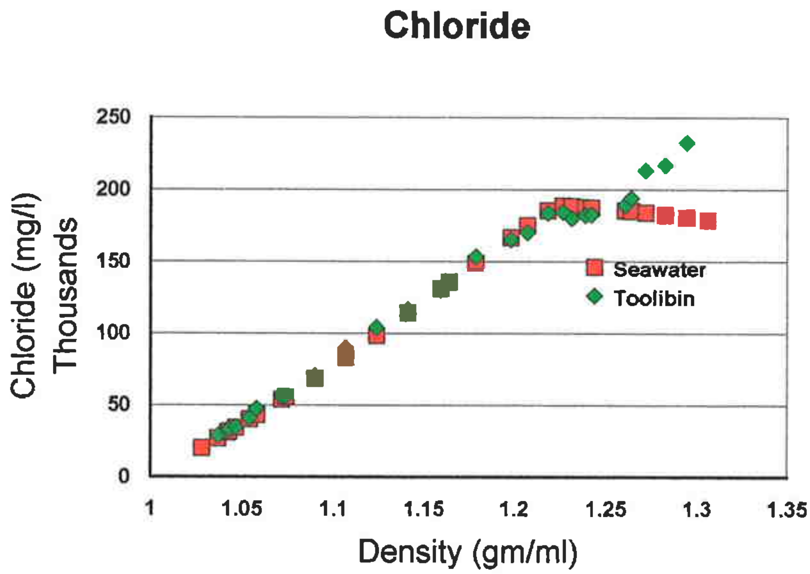
The analysis results of samples drawn along a density gradient are tabulated in Appendix.1
As sea water is primarily used as a source of brine in most commercial solar salt production facilities around the world it is worthwhile, when evaluating a particular supply of saline water for use in solar salt production, to compare the phase chemistry along a density gradient of the water to that of sea water.
Appendix 2 shows the analysis for major elements along the evaporative sequence in Toolibin brine compared to levels for these elements in sea water.



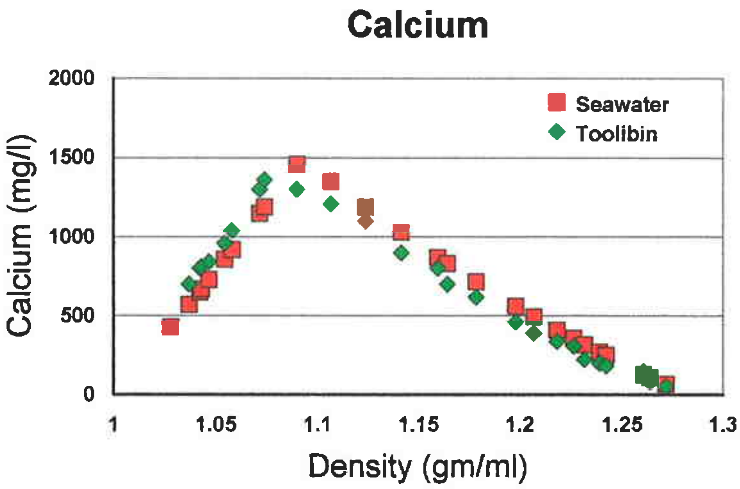
As can be seen from the previous plot sodium levels in Toolibin water start to drop at around density 1.2155 (gm/ml). This indicates that sodium chloride is precipitating and this point of precipitation is consistent with sea water.



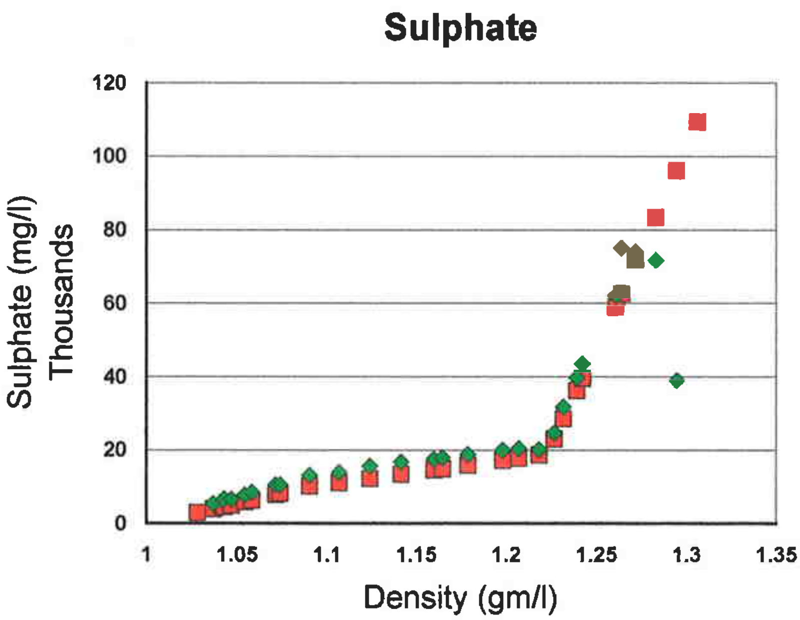
Above magnesium in Toolibin water concentrates along the gradient in a similar manner to sea water. Again the rise in magnesium levels at density around 1.2200 (gm/ml) indicates the start of sodium chloride precipitation.



It is interesting to note that chloride concentration in the Toolibin brine is consistent with that of sea water until a density of 1.2500 (gm/ml). At this point normally chloride in the form of sodium chloride and magnesium chloride tend to co-precipitate in sea water. In the case of Toolibin it appears that magnesium sulphate is precipitating and magnesium chloride is concentrating in the brine.



Above shows calcium levels in Toolibin brines behave in a similar manner to the levels in sea water. Precipitation of gypsum (calcium sulphate) starts a little earlier in the Toolibin brine.



Above shows sulphate ion in the Toolibin brine along the density gradient. The levels are consistent with those of sea water except at density 1.2510 (gm/l) where the Toolibin brine sulphate levels drop dramatically indicating magnesium sulphate precipitation.

4.3 Salt Growth

Sodium chloride salt produced during the test was white in colour and the crystal structure was classical cubic without inclusions.

Salt precipitated over various density ranges during the test was collected and samples prepared and submitted for analysis. The results are tabulated below:

Raw salt unwashed

DENSITY RANGE

	1.2185 to 1.2267 (gm/l)	1.2267 to 1.2320 (gm/l)	1.2320 to 1.2425 (gm/l)	1.2425 to 1.2642 (gm/l)	1.2642 to 1.2946 (gm/l)
Element	%	%	%	%	%
Sodium (Na)	35.00	39.00	37.00	34.00	13.50
Magnesium (Mg)	0.360	0.400	0.640	1.450	7.000
Silicon (Si)	0.010	<0.010	<0.010	<0.010	<0.010
Sulphate (SO4)	2.52	0.57	1.26	2.34	20.40
Chloride (Cl)	52.20	58.00	56.90	52.60	22.90
Potassium (K)	0.026	0.030	0.041	0.074	0.100
Calcium (Ca)	0.880	0.035	0.190	0.072	0.011
Iron (Fe)	<0.001	<0.001	<0.001	<0.001	<0.001
Bromine (Br)	0.019	0.021	0.028	0.052	0.068

Washing Trial

A bulk sample was prepared from salt precipitated in a density range from 1.2185 (gm/l) to 1.2642 (gm/l) The sample was subjected to washing on a 200 screen, firstly washing with a high density brine prepared with clean salt then followed by a quick washing with fresh water. The analysis of the washed salt, compared to industry specifications, is tabulated below.

ELEMENT	WASHED SALT	INDUSTRY SPECIFICATION
Calcium	0.042%	<0.050%
Magnesium	0.025%	<0.030%
Sulphate	0.113%	<0.150%

Amount of Salt Produced From Test

The salt precipitated in the density range from 1.2185 (gm/l) to 1.2642 (gm/l) was weighed. The measurements observed indicated that one megalitre of Toolibin bore water containing 39.42 tonne of sodium chloride, would yield 32.325 tonne of sodium chloride, that could be washed to commercial specifications.

5.0 CONCLUSIONS

Saline water with the same chemical composition as the sample collected from the Lake Toolibin pump discharge would be an excellent supply of brine for a solar salt harvesting project.

There is a definite zone during the evaporative sequence, where sodium chloride fractionally precipitates with a minimum amount of impurities. The impurities are mainly associated with retained high viscosity brine coating the salt crystal and are readily washed off.

In field conditions operating procedures would be critical in the movement of brines, both at the stage of calcium depletion and at the point of co-precipitation of magnesium salts.

The tests indicate that 82% of the sodium chloride pumped in solution would be recovered before the brine would have to be moved to the bitterns pond. This is a fairly low recovery and when designing an evaporative disposal system, consideration should be given to establishing a bitterns system that allows further recovery of sodium chloride. The resultant bitterns are high in magnesium salts and there could be possibility for commercial extraction of these salts.

When evaporation systems are man made and are less than fifty hectares in size it is possible to build in engineering which will maximise the amount of evaporation that can be achieved. Such methods include: layout of ponds to maximise wave action (surface area) by wind direction, allowance for seasonal pond levels, allowance for deep storage of saturated brines, decanting of fresh and diluted brines and biological systems to enhance solar energy absorption. Experience has shown that A class pan evaporation for a given area adjusted for brine evaporation factor can be achieved. The tests indicate that a weighted average evaporation factor of 0.7 can be used for Toolibin water. The Toolibin area with a mean evaporation of 1645 mm, rainfall of 509 mm and net evaporation of 1137 mm could achieve an effective evaporation of 1137 X 0.7 = 796 mm. This indicates that for every megalitre of saline water pumped per annum, an area of 0.126Ha would be required to allow disposal by evaporation.

6.0 APPENDIX 1

Density	Na Sea	Toolibin	Mg Sea	Toolibin	Cl Sea	Toolibin	Ca Sea	Toolibin	SO4 Sea	Toolibin
1.0284	11280		1360		20290		430		2970	
1.0372	15000	15500	1810	2800	26990	28600	570	700	3950	5400
1.0424	17222	18000	2070	3200	30990	32300	650	800	4530	6300
1.0432	17540	18300	2110	3210	31560	33140	670	810	4610	6700
1.0469	19150	19000	2310	3400	34460	34500	730	840	5040	6600
1.0545	22430	22500	2700	4000	40360	41100	860	960	5900	7800
1.0584	24100	25400	2900	4260	43360	47700	920	1040	6340	8430
1.0717	29930	30000	3600	5400	53830	55800	1150	1300	7870	10500
1.0741	30980	31500	3730	5560	55720	56280	1190	1360	8140	10510
1.0902	38150	43000	4600	7040	68640	70700	1460	1300	100300	13140
1.1069	46230	56000	5570	8320	83170	89820	1350	1210	11150	13940
1.1240	54760	58000	6600	9700	98510	104000	1190	1100	12230	15650
1.1417	63670	62000	7670	11200	114540	116830	1030	900	13370	16850
1.1600	72980	67000	8790	13010	131280	129970	870	800	14580	17500
1.1647	75370	70000	9080	13500	135580	135500	830	700	14890	18000
1.1789	82620	76500	9960	14240	148740	153200	718	620	15860	18870
1.1983	92770	83800	11170	14520	166840	165170	562	460	17220	19980
1.2073	97440	84000	11740	16500	175280	170200	495	390	17850	20400
1.2185	103100	89200	12420	17230	185470	183620	410	340	18630	20120
1.2267	100840	88000	15650	19500	188880	184600	360	310	23070	24600
1.2319	95230	82000	19520	26000	188460	180000	320	225	28480	31800
1.2393	87200	75000	25030	32790	187800	182170	270	200	36180	39800
1.2425	83700	72000	27420	36000	187500	182800	250	185	39530	43500
1.2609	63120	45446	41390	57900	185520	189230	130	150	59090	62040
1.2642	59360	38000	43930	66000	185120	194000	110	84	62650	75000
1.2719	49130	26500	50800	72650	183980	213420	70	53	71870	74026
1.2830	37260	17300	58730	82220	182560	217250			83420	71740
1.2946	24600	9000	67790	90000	180810	232800			96140	39000
1.3063	9450		77130		178860				109270	

APPENDIX 2

Density	Na	Mg	Cl	Ca	SO4	K	Br	Si	Fe
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1.0372	15500	2800	28600	700	5400	150	94	17	<1.0
1.0424	18000	3200	32300	800	6300	170	106	19	<1.0
1.0432	18300	3210	33140	810	6700	169	105	19	<1.0
1.0469	19000	3400	34500	840	6600	170	112	20	<1.0
1.0545	22500	4000	41100	960	7800	200	140	23	<1.0
1.0584	25400	4260	47700	1040	8430	235	160	25	<1.0
1.0717	30000	5400	55800	1300	10500	270	185	30	<1.0
1.0741	31500	5560	56280	1360	10510	390	210	32	<1.0
1.0902	43000	7040	70700	1300	13140	460	260	31	<1.0
1.1069	56000	8320	89820	1210	13940	520	290	35	<1.0
1.1240	58000	9700	104000	1100	15650	590	310	38	<1.0
1.1417	62000	11200	116830	900	16850	610	320	36	<1.0
1.1600	67000	13010	129970	800	17500	680	390	40	<1.0
1.1647	70000	13500	135500	700	18000	700	410	40	<1.0
1.1789	76500	14240	153200	620	18870	750	470	35	<1.0
1.1983	83800	14520	165170	460	19980	800	500	30	<1.0
1.2073	84000	16500	170200	390	20400	840	520	30	<1.0
1.2185	89200	17230	183620	340	20120	920	580	35	<1.0
1.2267	88000	19500	184600	310	24600	1020	620	40	<1.0
1.2319	82000	26000	180000	225	31800	1350	780	40	<1.0
1.2393	75000	32790	182170	200	39800	1500	920	48	<1.0
1.2425	72000	36000	182800	185	43500	1750	1300	60	<1.0
1.2609	45446	57900	189230	150	62040	2750	1820	70	<1.0
1.2642	38000	66000	194000	84	75000	3200	2500	90	<1.0
1.2719	26500	72650	213420	53	74026	4000	2850	110	<1.0
1.2830	17300	82220	217250		71740	4650	3000	115	<1.0
1.2946	9000	90000	232800		39000	5600	3300	120	<1.0