THE WIPP WATER QUALITY SAMPLING PROGRAM

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ABSTRACT

The Waste Isolation Pilot Plant (WIPP), a Department of Energy facility, will be used for the underground disposal of wastes. The Water Quality Sampling Program (WQSP) is designed to obtain representative and reproducible water samples to depict accurate water composition data for characterization and monitoring programs in the vicinity of the WIPP. The WQSP is designed to input data into four major programs for the WIPP project: Geochemical Site Characterization, Radiological Baseline, Environmental Baseline, and Performance Assessment. The water-bearing units of interest are the Culebra and Magenta Dolomite Members of the Rustler Formation, units in the Dewey Lake Redbeds, and the Bell Canyon Formation.

At least two chemically distinct types of water occur in the Culebra, one being a sodium/potassium chloride water and the other being a calcium/magnesium sulfate water. Water from the Culebra wells to the south of the WIPP site is distinctly fresher and tends to be of the calcium/magnesium sulfate type. Water in the Culebra in the north and around the WIPP site is of the sodium/potassium chloride type and is much higher in total dissolved solids. The program, which is currently 1 year old, will continue throughout the life of the facility as part of the Environmental Monitoring Program. Results presented here are preliminary in nature and will be updated as the program continues.

INTRODUCTION

The Water Quality Sampling Program (WQSP)[1] is designed to determine the baseline water quality of water-bearing zones in the vicinity of the Waste Isolation Pilot Plant (WIPP) site. This long-term program, which includes a pre-operational and operational phase, incorporates rigorous quality control requirements for the collection of representative and reproducible water samples. The pre-operational phase of the WIPP will be continuing until 1988 when the operational activities will begin. The data collected during the operational phase will help document the water chemistry during this period. The number and frequency of wells to be sampled during the pre-operational and operational phases are outlined in the Water Quality Sampling Plan.[1] The WQSP provides input to four major programs for the WIPP project: Geochemical Site Characterization, Radiological Baseline,[2] Environmental Baseline,[3] and Performance Assessment.

The most important water-bearing zones sampled as part of the WQSP include the Culebra and Magenta Dolomite Members of the Rustler Formation. Samples are collected from water-bearing zones in the Dewey Lake Redbeds on a scheduled basis. During 1985, one sample was collected from the Hays Sandstone Member of the Bell Canyon Formation during hydraulic testing, but repeat sampling is not scheduled for this lone sample as part of the WQSP.

The WIPP site repository is located in the Salado Formation, 2,150 feet below ground surface. Stratigraphically, the Dewey Lake Redbeds, the Magenta Dolomite, and the Culebra Dolomite overlie the Salado Formation. The Bell Canyon lies stratigraphically below the Salado Formation.

The Dewey Lake Redbeds are the youngest water-bearing zones of those discussed above. In general, the Dewey Lake is not found to yield water in the area of the WIPP site.[4] Lying stratigraphically below the Dewey Lake Redbeds are the Magenta and Culebra Dolomites. The Culebra, which underlies the Magenta and is closest to the repository horizon, is considered the most likely conduit for fluid flow to the accessible environment in the event of a breach of the repository. The Culebra is, in general, more transmissive than the Magenta.[4] Further information on the geology of the WIPP site can be found in Powers et al.[5]

Eighteen wells are scheduled to be sampled from the Culebra once each year for the pre-operational period. Two wells in the Dewey Lake Redbeds and four Magenta wells are currently scheduled for sampling once per year during pre-operations under the WQSP.

FIELD PROGRAM

Pumping Scheme

The pumping scheme has been developmental in the first year of the program. Both electric submersible and air-driven positive displacement piston pumps have been incorporated. When feasible, the zone of interest is isolated from other water-bearing units by use of an air-inflatable packer. Some wells were purged by either an electric submersible or the air-driven piston pump before chemical sampling was to begin. At the beginning of chemical sampling the well is continuously pumped until sampling is completed. Rigorous steps have been taken to prevent cross-contamination between wells by thorough rinsing of all mechanical equipment and replacement of sampling lines.

Serial Sampling

Serial sampling is here defined as incremental chemical water field testing while the well is pumped continuously. As the well is pumped, daily serial

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samples are collected and analyzed for nine water quality parameters. Water is pumped directly into a mobile field chemistry trailer, which is outfitted with a constant temperature bath, in-line filter, and several chemistry work stations. The daily serial sample analyses include nine parameters: temperature, pH, Eh, specific conductance, specific gravity, total hardness, alkalinity, chloride, and ferrous and ferric iron. In general, iron and alkalinity are the most sensitive parameters for the serial sampling analyses and are the last parameters to stabilize during continuous pumping. Three consecutive serial sample analysis values within the error limits are considered to indicate stability; and generally, concentrations of the chemical parameters decline as continuous pumping of the well proceeds. After the water is considered to be stable, final samples are collected and shipped to various laboratories for analyses. This daily serial sampling provides a characterization of the formation water in the immediate vicinity of the well and is intended to produce a working knowledge of the formation water chemistry so that reproducible samples can be collected on a continuing basis.

Final Samples

After a well has been deemed stable from serial sampling analyses, final samples are collected from the well and shipped to laboratories for analysis. Analyses are conducted for general chemistry, major cations and anions, selected isotopic data, organics, metals and trace elements, redox couples and gases, and radionuclides. Table I is a listing of the analytes that are tested for the WQSP. For the Geochemical Site Characterization Program, major cations and anions, general chemistry, and isotopic data comprise the most essential analysis. The Radiological Baseline Program requires analyses of 26 radionuclides for the determination of baseline values in the aquifers prior to receipt of waste. The Environmental Baseline Program is most concerned with organics and trace metals as well as major solutes. Performance Assessment is concerned with the WIPP site compliance with EPA 40-CFR-191. As such, much of the water quality data will be used for input into geochemical models; gases and redox couples analyses are uniquely important to Performance Assessment for analysis of the solubility and mobility of radionuclides in the water-bearing zones.

RESULTS AND DISCUSSION

At this writing, thirteen Culebra wells, one Magenta well, and one Bell Canyon well have been sampled. Table II shows the ranges of values found around the WIPP site for the various serial sampling parameters. The values range from fresh water found at Engle well to nearly saturated brine water found at WIPP-29. Table II also shows the total dissolved solids, sodium adsorption ratio, and error in cation/anion balance for the five wells depicted in Fig. 1, 2, and 3.

Figure 4a shows a graph of iron values as a function of serial sampling for five wells. The severe jump in iron concentration at H11b3 was caused by the pumping system being removed from the well and replaced due to mechanical failure. Figure 4b shows alkalinity, as bicarbonate, for the same wells and the same testing period as Fig. 4a. Notice that alkalinity is not as sensitive as iron to the pump removal and replacement as seen for well H11b3. These two figures show the stability trends as serial sampling progresses.

Figure 1 is a stiff graph of the water quality from five wells sampled. The stiff graph plots cations on the left side and anions on the right, which graphically presents the difference in water quality observed in the vicinity of the WIPP site. The general trend seems to show that the wells nearest to the WIPP site and to the north have largely sodium/potassium chloride waters. The freshwater wells to the south show a larger percentage of calcium/magnesium sulfate waters. Notice that the scale for the stiff graph is in equivalents per million. The results show that Engle well, a Culebra well, has relatively fresh water. Engle well is located approximately 10 miles southeast of the WIPP site and is used for stock watering.

Figure 2 shows piper trilinear plots of the same five wells as Fig. 4a. The piper trilinear diagram graphically displays the major cation and anion results from these five wells. The small triangle on the left depicts cations with calcium, magnesium, sodium, and potassium plotted on its three sides. One can see that four wells have as their major components sodium and potassium, with less than 10% calcium or magnesium. Engle well, well number 3 in this figure, has more calcium/magnesium content than sodium/potassium. The small triangle to the right shows the major anions. The triangle's three sides are chloride, sulfate, and alkalinity, respectively. Engle well again proves to be the exception, with sulfate as the dominate anion. The large four-sided rectangle at the top of the figure uses circle size to show the total dissolved solids (TDS) found in each well. Engle well, number 3 in the figure, has no circle, indicating its small TDS relative to the other wells in the figure. The scale at the bottom right corner shows the circle diameter scaling in parts per million TDS.

Figure 3 is a pie diagram of the five wells shown in Fig. 1, and 2, with the circle size representing the total dissolved solids. Each wedge of the pie represents an analyte with its relative percentage to the total being depicted. The scale of radii in the bottom left corner shows the circle size in equivalents per million. Table III lists the data for these five wells, including the conversion from parts per million to equivalents per million.

CONCLUSIONS

The Water Quality Sampling Program is an ongoing and long-term program at the WIPP site to determine the water quality of water-bearing zones around the site. The WQSP provides input to four major programs for the WIPP project that are both pre-operational and operational in nature. Changes will be made in both the scope and direction of the WQSP as more is learned regarding the water quality and as the program develops. We have found a minimum of two distinct types of water chemistry within the Culebra, one a sodium/potassium chloride water and the other a calcium/magnesium sulfate water. Culebra water to the south of the WIPP site is distinctly fresher and tends to be of the calcium/magnesium sulfate type. Northern Culebra water is the sodium/potassium chloride type and has higher

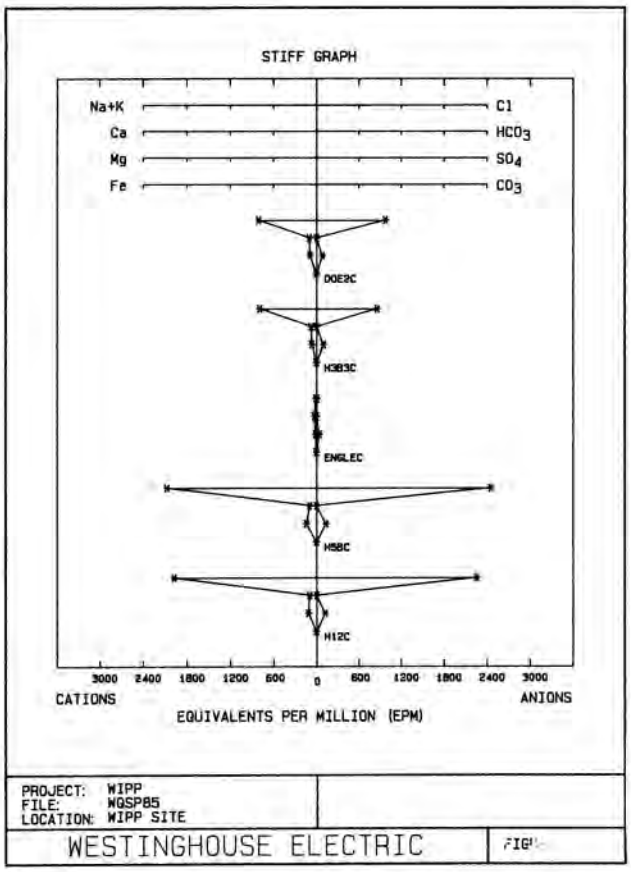

Fig. 1. Stiff Graph of Water Quality.

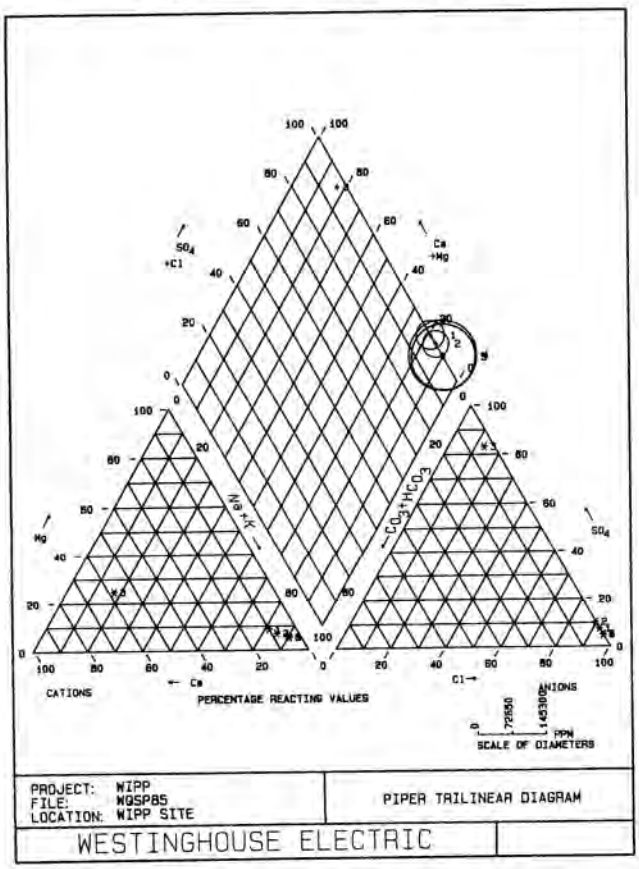

Fig. 2. Piper Trilinear Diagram.

TDS values. Serial sampling has been utilized to determine the stability of the formation water for the representative collection of samples.

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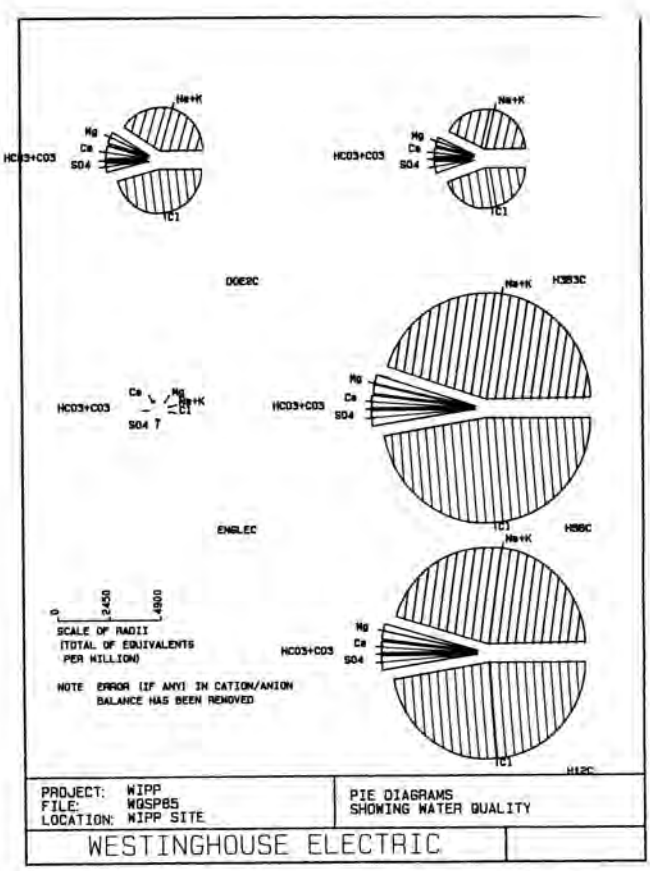

Fig. 3. Pie Diagrams Showing Water Quality.

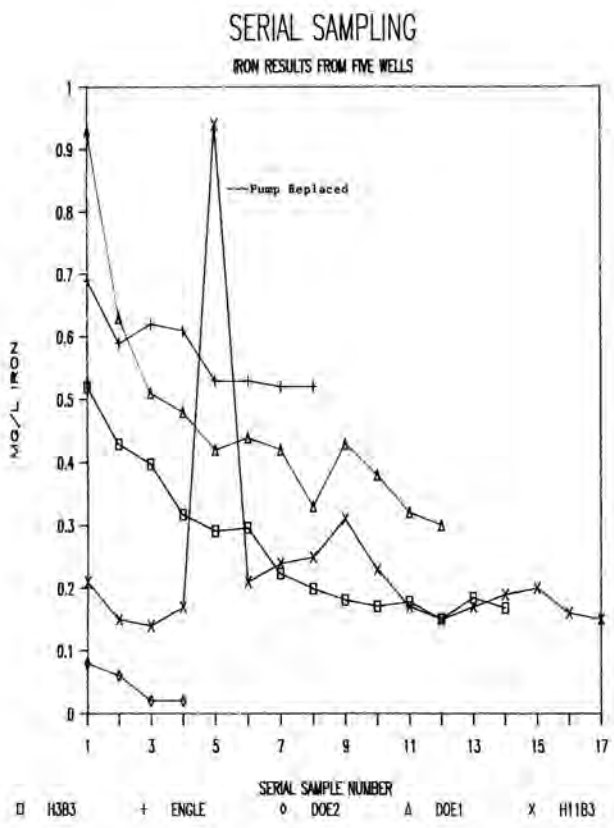

Fig. 4a. Iron Results From Five Wells.

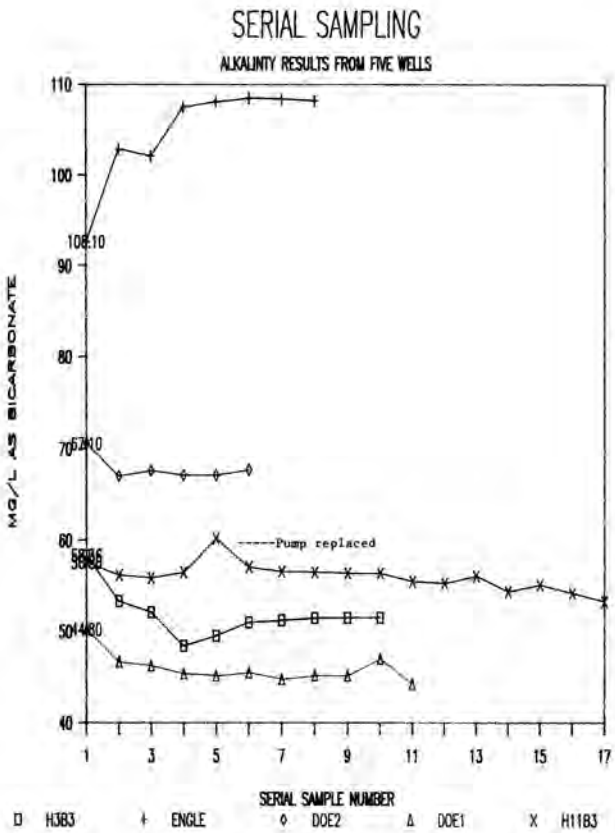

Fig. 4b. Well Alkalinity.

TABLE I

Laboratory Analytes From Final Sampling

MAJOR CATIONS/ANIONS	GENERAL CHEMISTRY	RADIONUCLIDES	MINOR AND TRACE ELEMENTS	ORGANICS	STABLE ISOTOPES	GASES	UNSTABLE ISOTOPES	REDOX COUPLES
CALCIUM	DISSOLVED SOLIDS	PLUTONIUM-238	ALUMINUM	TOC	DEUTERIUM	NITROGEN	U-238/U-234	Fe^{+3}/Fe^{+2}
MAGNESIUM	SUSPENDED SOLIDS	PLUTONIUM-239,240	ANTIMONY	TOX	OXYGEN-18	METHANE	CARBON-14	$NO3^-/NH4^+$
POTASSIUM	pH	PLUTONIUM-241	ARSENIC	PHENOL	SULFUR-34	ETHANE	Sr-87/Sr-86	$H2S/SO4^{-2}$
SODIUM	CONDUCTIVITY	PLUTONIUM-242	BARIUM	VOLATILES	CHLORINE-37	CARBON MONOXIDE		$CH4/CO3^{-2}$
BICARBONATE	CYANIDE	URANIUM-233	BERYLLIUM	BASE/NEUTRALS		CARBON DIOXIDE		$I2^-/IO3^-$
CARBONATE		URANIUM-238	BORON	ACID EXTRACT.		OXYGEN		As^{+5}/As^{+3}
SULFATE		URANIUM-235	BROMIDE			ARGON		
CHLORIDE		AMERICIUM-241	CADMIUM			RADON		
		AMERICIUM-243	CESIUM					
		NEPTUNIUM-237	CHROMIUM					
		CURIUM-244	COBALT					
		RADIUM-226	COPPER					
		RADIUM-228	FLUORIDE					
		CESIUM-137	IODIDE					
		COBALT-60	IRON					
		STRONTIUM-90	LEAD					
		TRITIUM	LITHIUM					
		LEAD-210	MANGANESE					
		POLONIUM-210	MERCURY					
		THORIUM-230	MOLYBDENUM					
		THORIUM-232	NICKEL					
		GROSS ALPHA	NITRATE					
		GROSS BETA	PHOSPHATE					
			SELENIUM					
			SILICA					
			SILVER					
			STRONTIUM					
			THALLIUM					
			TITANIUM					
			ZINC					

TABLE II

Field Analytes Test Ranges By Well

SAMPLING DATES	WELL NAME	ALKALINITY MG/L	CHLORIDE MG/L	DICATIONS MeQ/L	IRON MG/L
1/29-1/24	H3B3	58-48	29300-27500	8400-7900	.55-.15
2/26-3/5	ENGLE	105-91	290-220	42-41	.75-.50
2/20-3/5	DOE-2	70-66	48000-32000	187-173	.09-.02
4/12-4/25	DOE-1	51-44	48000-30000	215-202	.92-.25
5/14-6/4	H11B3	61-53	76000-67000	189-181	.94-.14
6/22-7/2	H3B1	48.1-41.2	3410-3250	75-72.4	.75-.19
7/9-7/25	H4B	79-68.1	7490-7450	71.5-70.8	8.5-1.0
8/3-8/9	H12	65.2-52.5	80500-79200	244-242	2.1-1.1
8/22-8/27	H5b	60.5-48.9	85500-83100	257-250	4.1-2.8
9/7-9/16	H6B	95-92	35000-31000	185-175	.80-.15
10/31-11/14	H9B	120.6-112.8	195.9-176.0	41.9-41.1	.15-.06
11/20-11/25	WIPP26	121.2-118.0	8600-8445	102.2-99.9	.30-.10
12/06-12/13	WIPP29	163.1-158.0	177926-173071	780.1-602.6	1.37-1.06
1/14-1/23	H8B	96.7-95.3	43.4-32.8	42.1-41.6	1.5-0.06

Final Samples

WELL NAME	SAR SODIUM ADSORPTION RATIO	TDS TOTAL DISSOLVED SOLIDS	ERROR CATION/ANION RATIO
DOE2	83.11	60676	3.05%
H3B3	94.23	55999	1.29%
ENGLE	1.90	3297	1.05%
H5B	188.76	142500	5.57%
H12	190.07	142500	4.34%

TABLE III

Chemistry Analysis

WELL NO.: DOE2C

CATIONS	PPM	EPM	% EPM
Ca	1970.00	98.30	9.87
Mg	1060.00	87.17	8.75
Na+K	18810.00	810.89	81.38

ANIONS	PPM	EPM	% EPM
HCO3+CO3	68.00	1.11	0.11
SO4	3950.00	82.24	7.77
Cl	34600.00	975.72	92.13

TOTAL DISSOLVED SOLIDS: 60676
ERROR IN CATION/ANION BALANCE: 3.05 %
SODIUM ABSORPITON RATION (S.A.R.): 83.11

WELL NO.: H5BC

CATIONS	PPM	EPM	% EPM
Ca	1900.00	94.81	4.10
Mg	1700.00	139.81	6.05
Na+K	48300.00	2077.75	89.85

ANIONS	PPM	EPM	% EPM
HCO3+CO3	47.00	0.77	0.03
SO4	6300.00	131.17	5.07
Cl	87000.00	2453.40	94.90

TOTAL DISSOLVED SOLIDS: 142500
ERROR IN CATION/ANION BALANCE: 5.57 %
SODIUM ABSORPITON RATION (S.A.R.): 188.76

WELL NO.: H3B3C

CATIONS	PPM	EPM	% EPM
Ca	1470.00	73.35	7.88
Mg	780.00	64.15	6.89
Na+K	18425.00	793.87	85.24

ANIONS	PPM	EPM	% EPM
HCO3+CO3	52.00	0.85	0.09
SO4	4823.00	100.41	10.51
Cl	30300.00	854.46	89.40

TOTAL DISSOLVED SOLIDS: 55999
ERROR IN CATION/ANION BALANCE: 1.29 %
SODIUM ABSORPITON RATION (S.A.R.): 94.43

WELL NO.: H12C

CATIONS	PPM	EPM	% EPM
Ca	1850.00	92.31	4.23
Mg	1400.00	115.14	5.28
Na+K	46000.00	1974.12	90.49

ANIONS	PPM	EPM	% EPM
HCO3+CO3	56.00	0.92	0.04
SO4	5900.00	122.84	5.16
Cl	80000.00	2256.00	94.80

TOTAL DISSOLVED SOLIDS: 142500
ERROR IN CATION/ANION BALANCE: 4.34 %
SODIUM ABSORPITON RATION (S.A.R.): 190.07

WELL NO.: ENGLEC

CATIONS	PPM	EPM	% EPM
Ca	588.00	29.34	57.89
Mg	152.00	12.50	24.66
Na+K	205.60	8.84	17.45

ANIONS	PPM	EPM	% EPM
HCO3+CO3	108.00	1.77	3.56
SO4	1987.00	41.37	83.32
Cl	231.00	6.51	13.12

TOTAL DISSOLVED SOLIDS: 3297
ERROR IN CATION/ANION BALANCE: 1.05 %
SODIUM ABSORPITON RATION (S.A.R.): 1.90