Groundwater Restoration Report
for
RME-Halliburton-Mono Power
Nine Mile Lake R&D
In Situ Uranium Project

FEE EXEMPT

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ENERGY

A Subsidiary of
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Mr. Walt Ackerman, Administrator
Land Quality Division
Department of Environmental Quality
401 West 19th Street
Cheyenne, WY 82002

Mr. Bill Garland, Administrator
Water Quality Division
Department of Environmental Quality
1111 E. Lincolnway
Cheyenne, WY 82002

Mr. Ross Scarano, Chief
Uranium Recovery Licensing Branch
Division of Waste Management
U.S. Nuclear Regulatory Commission
7915 Eastern Avenue
Silver Spring, MD 20910

Dear Sirs:

Re: Nine Mile Lake R&D In Situ Project
Source Material License SUA-1228;
Docket No. 40-8380
DEQ R&D In Situ License TFN 1 5/186
DEQ License to Explore No. LE-4

Attached is Rocky Mountain Energy Company's Groundwater Restoration Report for the Nine Mile Lake R&D in situ uranium mining project. The report describes the operational history and water quality of the acid leach test patterns (Patterns 1,2, and 3) at the Nine Mile Lake site in Natrona County, Wyoming. This report is submitted pursuant to DEQ and NRC requests and in support of RME's position that restoration requirements for the acid patterns have been fulfilled. Restoration of the carbonate leach test (Pattern 4) has been very successful and will be discussed in a separate report.

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10 Longs Peak Drive
Box 2000
Broomfield, Colorado 80020
303 469-8814

As DEQ and NRC personnel know, RME has withdrawn production scale license applications for this project and has no current plans to continue R&D activities. RME has made considerable improvements in developing effective acid restoration techniques as demonstrated by the relative success of Pattern 3 restoration efforts. At this time, RME does not intend to pursue production scale mining, but improvements in current uranium market conditions or further developments in acid restoration technologies could conceivably justify future project development.

Included in the report are: a summary of leaching, restoration and post-restoration activities for each pattern, baseline and post-restoration water quality data for each pattern, evaluations of probable fate of residual groundwater constituents of particular interest, a regional aquifer impact analysis and a discussion of regulatory agency restoration requirements.

RME requests an expedient review of this report by the NRC and Land and Water Quality Divisions of the DEQ in order to implement appropriate management plans for the project. We would encourage a cooperative agency review of the material presented and suggest a joint meeting of Land and Water Quality Divisions to discuss report contents as soon as practical.

We would also welcome phone calls during the initial review period to answer any questions which arise. Because there is a considerable volume of information and data within the report, verbal communications could help focus review efforts.

Sincerely,

Michael R. Neumann

Michael R. Neumann
Licensing Specialist

Attachment
cc: Mr. K. Kalman(NRC)
Mr. F. Ross(NRC)
Ms. K. Ogle(DEQ-LQD)
Mr. R. Chancellor (DEQ-LQD, District 4)
Mr. A. Mancini (DEQ-WQD)
Mr. T. Mueller (DEQ-WQD, District 4)

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EXECUTIVE SUMMARY

Introduction

The Nine Mile Lake Groundwater Restoration report has been prepared pursuant to license or permit requirements of the Wyoming Department of Environmental Quality (DEQ) and the U.S. Nuclear Regulatory Commission (NRC). The report summarizes results of acid leaching and restoration tests conducted over a six year period at the RME-Halliburton-Mono Power joint venture at the Nine Mile Lake site in Natrona County, Wyoming. Information and analyses presented demonstrate that all groundwater restoration requirements have been fully met.

Report Summary

Sections 1.0, 2.0 and 3.0 discuss operational histories of three acid test patterns and present results of groundwater restoration programs. Data sufficient to evaluate groundwater quality before, during and following restoration of each pattern are included. Post restoration groundwater quality has been thoroughly evaluated on the basis of two laboratory analyses of samples collected from 32 pattern injection, production and monitor wells during February, 1982. Data evaluation confirms that affected groundwaters have been restored to a condition and quality of use consistent with pre-mining use suitability.

Section 4.0 summarizes results of two chemical migration modeling studies conducted by RME personnel and a geohydrologic consultant to estimate the magnitude and extent of potential groundwater contaminant movement from the acid patterns. The most probable and worst case assessments predict that residual contaminants of concern will be reduced to site background concentrations within a distance of less than one half mile of the R&D permit area.

Section 5.0 discusses potential aquifer water quality and use impacts. Ambient background water quality is generally poor and suitable only for industrial use. No wells other than those controlled by RME appropriate groundwater from the host aquifer within a 3 mile radius of the test site. It is, therefore, highly improbable that any existing sources of water supply would be adversely affected by post restoration water quality.

Section 6.0 reviews appropriate licenses, permit conditions and regulations applicable to groundwater restoration requirements for Patterns 1,2, and 3. All permit and license obligations regarding restoration have been fully met as have pertinent regulatory agency requirements.

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Discussion

Test work at Nine Mile Lake was initiated in 1976 to evaluate the feasibility of an untried technology to recover uranium in a cost effective, environmentally acceptable manner. In situ mining of uranium by means of an acidic leach solution was an innovative technique so knowledge gained through operations provided the only reliable means of obtaining information. As with any research and development endeavor, not all tests were entirely successful, but a great deal of valuable information was obtained. In keeping with the philosophy of an R&D operation, results obtained from initial test work were used to refine and guide subsequent research efforts.

Results of Pattern 1 leaching and restoration efforts conducted from November 1976 through October 1978, were disappointing. Ineffective well completion techniques, equipment failures and an inadequate understanding of formation geochemical reactions contributed to the build up of gypsum deposits within the formation. These deposits thwarted efforts to restore groundwater quality by sweeping the pattern interior with clean formation water and created a source of high calcium and sodium concentrations.

Subsequent restoration programs resulted in considerable water quality improvement within the pattern, however, water quality deterioration occurs rapidly with the dissolution of residual gypsum ($CaSO_4$). Resulting groundwater contaminants, are composed primarily of soluble salts which pose essentially no environmental or health hazard. Previous experience indicates further restoration efforts would be ineffective in achieving permanent water quality improvement.

Pattern 2 test activities, which began in December 1977 and concluded in September 1979, were successful due to experience gained with Pattern 1 and technological improvements. The amenability of the Nine Mile Lake orebody to solution mining with an acid lixiviant was confirmed. Uranium head grades were more than adequate to justify further project development work. Control of solutions within the test pattern was maintained throughout leaching operations and initial restoration results were encouraging.

Stabilization monitoring revealed some deterioration of water quality so additional restoration programs were subsequently conducted. These efforts successfully retrieved "pods" of affected groundwater and restored outlying portions of the pattern apparently not contacted during the initial restoration program. All major parameters and minor constituents except aluminum, vanadium, and zinc were within pattern baseline ranges when restoration was terminated in February 1982.

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A third pattern was planned to test the feasibility of simultaneous upper and lower ore zone leaching due to the favorable results of the second acid leach test. Problems with unbalanced injection flow rates were encountered soon after leaching began (September, 1979). Upper ore zone injection flow rates were found to be much greater than lower zone rates which resulted in a temporary loss of solution control. Immediate remedial actions effectively restored solution control while corrective measures designed to allow independent control of upper and lower ore zone injection/production rates were implemented. Corrective measures were not as effective as planned and Pattern 3 leaching efforts were terminated prematurely.

Restoration of Pattern 3 was deferred while testing of a sodium bicarbonate lixiviant was conducted in a fourth pattern. A small production rate from Pattern 3 was maintained during this period to prevent uncontrolled solution movement away from the pattern. Restoration using a modified groundwater sweep process began in August 1981 and was completed February 1, 1982. Restoration results were significantly better than had been previously achieved in Patterns 1 and 2. This improvement is largely attributed to restoration flow rates equal to or greater than leaching flow rates, a relatively short leaching period, and an apparent lack of gypsum buildup in the formation.

Post restoration water quality indicated all parameters were restored to background concentrations except radium and vanadium which were moderately higher in some interior wells. Post restoration monitoring over six months has shown essentially no changes in water quality other than radium levels in one well.

Conclusions

Six years of research work at the Nine Mile Lake site has confirmed the feasibility of recovering uranium from the host formation by means of a sulfuric acid leach solution and in situ mining techniques. A considerable amount of time, effort and money have been expended to develop a groundwater restoration process which would be environmentally acceptable and commercially viable. Although initial groundwater attempts were only partially successful, progressive technological advances have occurred, largely through trial and error, which suggest it may be feasible to meet restoration requirements on a commercial scale basis.

Groundwater within the three acid test patterns has been restored "to a condition such that its quality of use is equal to and consistent with the use for which the water was suitable prior to the commencement of the operation" in accordance with Department of Environmental Quality rules and regulations. Thorough evaluation of post restoration water quality, regional background water quality, and existing aquifer use characteristics indicate the potential for adverse environmental impacts due to residual groundwater contamination is negligible. Further

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restoration attempts using best practicable technology would not cause any significant, permanent improvements in water quality. All license or permit requirements pertinent to groundwater restoration have been fulfilled as have all applicable regulatory agency requirements.

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NINE MILE LAKE

GROUNDWATER RESTORATION REPORT

JUNE 21, 1982

Introduction

The purpose of this report is to describe results of the sulfuric acid leach and restoration tests of the Teapot Sandstone at Rocky Mountain Energy's Nine Mile Lake in situ research and development project. The report compares restored groundwater quality in test Patterns 1, 2, and 3 to site and regional background water quality and presents two analyses of the probable fate of key groundwater constituents remaining at levels above background ranges. Also included are a discussion of potential regional aquifer impacts and review of regulatory agency requirements pertinent to groundwater restoration.

This report is intended to demonstrate that RME has fulfilled all appropriate groundwater restoration obligations and that "affected groundwaters have been restored to a condition such that its quality of use is equal to and consistent with the use for which the water was suitable prior to the commencement of the operation," in accordance with Wyoming Department of Environmental Quality Land and Water Quality Division rules and regulations (Land Quality Rules and Regulations, Chapter XXI; Water Quality Rules and Regulations, Chapter VIII).

1.0 Operational History - Pattern 1

Pattern 1 is a seven spot pattern consisting of six

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injection wells equally spaced along a 50-foot radius from a central production well. Figure 1.1 shows the pattern location and approximate well configuration. All wells were completed with screens through the entire upper ore zone (25 feet) of the Teapot Sandstone. Four monitor wells, located at right angles from the pattern interior, were also completed in the upper ore zone.

1.1 Pattern 1 Leaching

Leaching began in November of 1976 using a sulfuric acid (H_2SO_4) leach solution at a strength of 1.5 to 2.0 grams/liter and hydrogen peroxide (H_2O_2) as an oxidant. Leaching continued sporadically at a production rate of about 40 gpm through August of 1977 during which time approximately 8 pore volumes were circulated through the pattern and 200 pounds of yellowcake recovered.

Numerous problems due to well plugging, channeling, and equipment failure plagued leaching operations. Natural geochemical reactions between the leach solution, host formation and ambient groundwater led to build up of gypsum ($CaSO_4$) within the formation.

1.2 Pattern 1 Restoration

Initial Pattern 1 restoration efforts consisted of a groundwater sweep at 30 to 46 gpm which began in September of 1977 and continued intermittently for 13 months until October of 1978. Rotating production from the six injection wells and single production well was necessary to maintain adequate flow rates.

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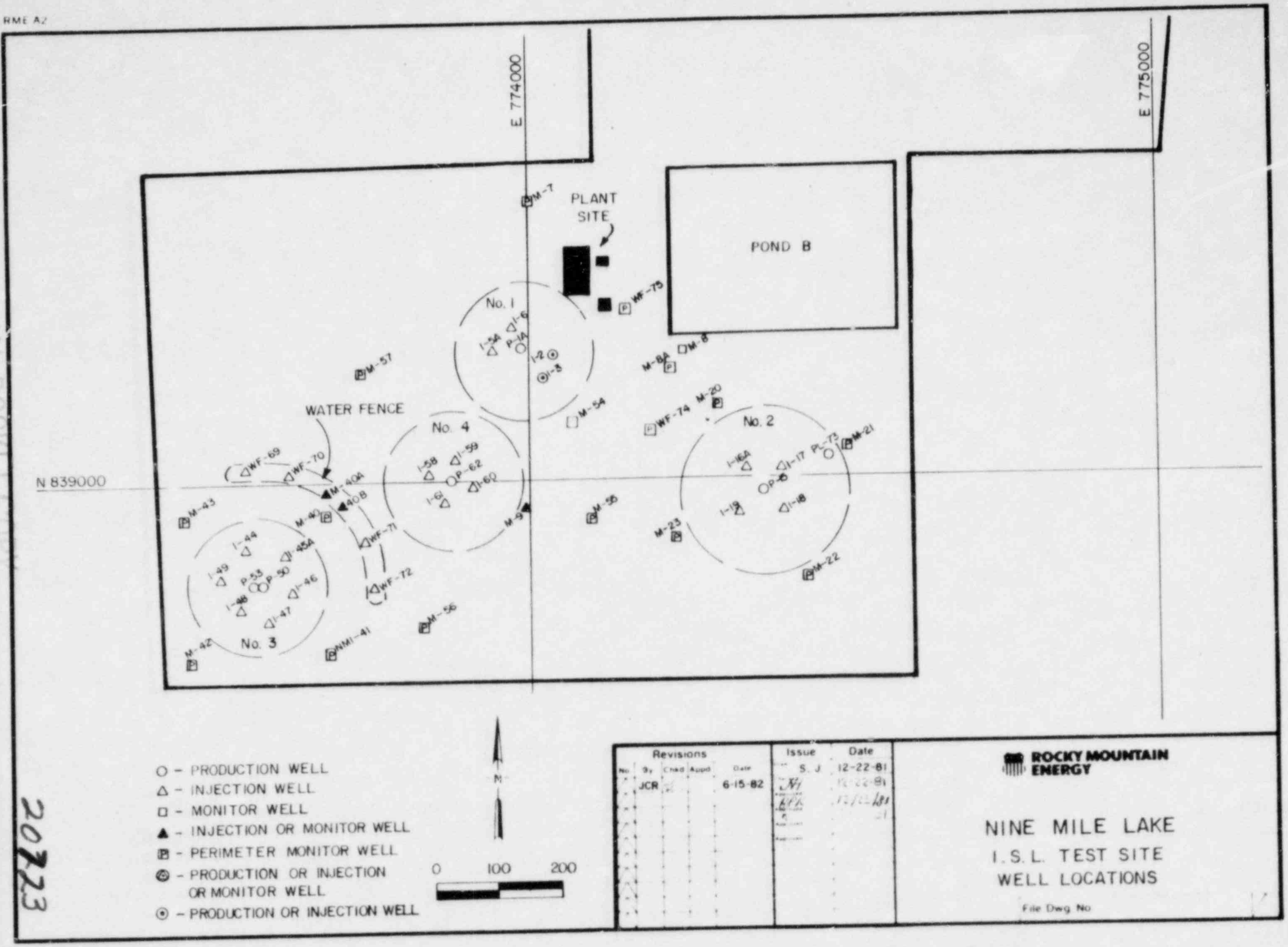

Revisions					Issue	Date
No	By	Chkd	Appd	Date	S. J	12-22-81
	JCR			6-15-82		12-22-81
						12/22/81

ROCKY MOUNTAIN ENERGY

NINE MILE LAKE
I.S.L. TEST SITE
WELL LOCATIONS

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FIGURE 1.1

Approximately 12 pore volumes (1 PV = 925,000 gal) of affected groundwater were removed during this restoration phase. Water quality within the pattern interior had been restored to approximately background range except for pH, calcium, sodium, and TDS. Table 1.1 compares water quality in the production and injection wells at the end of phase 1 restoration with baseline ranges.

Table 1.1

Pattern 1 Water Quality
Post Restoration
October 1978

Parameter	Baseline Range	Well Number P-1A	I-1	I-3	I-5
pH	6.6 - 7.1	5.9	6.6	6.4	6.3
TDS	2225 - 2780	2074	2628	5326	5469
SO_4	1100 - 1450	1850	1410	2400	2250
Ca	71 - 104	66	128	161	140
Cl	1.8 - 4.9	38	-	31	43
Na	560 - 772	494	711	1250	1280
Mg	46 - 63	48	78	102	135
K	7.0 - 16.2	13	11	13	14
U_3O_8	0.002 - 2.00	0.022	0.053	0.155	0.021
V	ND - 0.10	0.03	0.07	0.04	ND

Note: All values reported as mg/l except pH (std. units)

From the fall of 1978 through the spring of 1981, Pattern 1 remained inactive except for periodic pumping for miscellaneous use. Occasional sampling during this period showed substantial water quality deterioration primarily due to dissolution of gypsum within the pattern interior which increased TDS levels. High TDS levels were largely due to sulfate, sodium, magnesium, calcium, chloride, and potassium ions. No significant increases in trace metal concentrations were observed which substantiates the fact that very little mobilization of heavy

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metals, including uranium, occurred during leaching. pH remained fairly constant during this period at about 6.3 to 6.5.

Although not required by license or permit, several restoration attempts were made beginning in April 1981 using a variety of water treatment processes and filtration methods to obtain a product suitable for reinjection. Treatment of affected groundwater by means of a lime and soda ash circuits in various combinations with charcoal and mechanical filtration devices, using different flocculents and sequestering agents for chemical pretreatment, were all unsuccessful.

During May 1981, efforts to restore groundwater with reverse osmosis (RO) treatment were begun. Due to water quality variability within the pattern interior, suitable pretreatment methods to allow reliable RO performance were not developed until the end of May. From May 31 through June 30, satisfactory RO performance was achieved and restoration continued at about 22 gpm with 20 gpm reinjected. Restoration was discontinued and the pattern shut down to evaluate stability as little or no improvement in water quality was occurring and most constituents had been restored to background range. Water quality deterioration began rapidly so RO restoration was started again July 28 and continued through August 17 when all parameters were again within baseline range with no further improvement occurring. Table 1.2 compares production fluid water quality at shutdown with background water quality.

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Monthly stabilization monitoring of the pattern has again shown a gradual deterioration in water quality from September through December 1981, despite having returned all parameters to baseline range during the last restoration phase. A total of 2.6 pore volumes were recovered from the pattern with 2.2 pore volumes of treated water reinjected from May 1981 through August 1981. Table 1.3 summarizes leaching and restoration injection and production volumes. A total of 13.8 pore volumes of affected water were removed during restoration versus 6.9 pore volumes injected during leaching.

Table 1.2

Pattern 1 Water Quality
August 1981

Parameter	Baseline Range	Production Fluid
pH	6.6 - 7.1	6.3
TDS	2225 - 2780	2560
SO_4	1100 - 1450	1429
Ca	71 - 104	80
Cl	1.8 - 4.9	37
Na	560 - 772	664
Mg	46 - 63	46
K	7.0 - 16.2	7.7
U_3O_8	0.002 - 2.00	0.10
V	ND - 0.10	0.09

Note: All values reported as mg/l except pH (std. units)

1.3 Pattern 1 Post Restoration Water Quality

Gradual deterioration of water quality has been observed in the pattern interior since the last restoration effort. Table P1-1 through P1-11 present well sampling results for all pattern production, injection, and monitor wells as of February 23, 1982. Appendix A presents EPA certified laboratory results for the February sampling. Also included in Tables P1-1, P1-2, P1-8,

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TABLE 1.3
PATTERN 1
WATER BALANCE SUMMARY

OPERATIONAL MODE	PRODUCTION (GAL.)	PORE[1] VOLUMES	INJECTION (GAL.)	PORE VOLUMES	NET PRODUCTION (GAL.)
Leaching 11/76 - 8/77	7,327,348	7.9	6,386,881	6.9	940,467
Restoration					
Phase 1 (9/77 - 10/78)	10,345,012	11.2	---	---	10,345,012
Phase 2 (5/81 - 6/81)	1,954,291	2.1	1,598,905	1.7	355,386
Phase 3 (7/81 - 8/81)	464,415	0.5	405,050	---	59,365
TOTAL	12,763,718	13.8	2,003,955	1.7	10,759,763

TOTAL WATER CONSUMPTION = 11,700,290 gallons

[1] One Pore Volume = 925,276 gallons

Total number of restoration pore volumes = 174% of mining pore volumes

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TABLE P1-1

NINE MILE LAKE
PATTERN 1
P-1A

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/24/82	CDM 2/24/82	NML 3/8/82	NML 4/7/82	NML 5/4/82
pH	6.6-7.1	6.9	6.5	6.9	6.4	6.4	6.3
Conductivity	2860-3650	3162	10300	14000	10500	11000	11000
Major Constituents							
Bicarbonate	271-370	316	354	270	360	362	362
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	290	223	295	297	297
Calcium	71-104	87	397	340	422	337	350
Chloride	1.8-4.9	3.3	113	99	101	124	145
Magnesium	46-63	50	179	161	189	146	190
Potassium	7.0-16.2	12.8	16.2	12	19.2	17.0	18.7
Sodium	560-772	620	2459	2300	2674	2474	2268
Sulfate	1100-1450	1240	6184	6190	6208	6589	5771
TDS	2225-2780	2483	10020	9150	10180	10520	10880
Anion/Cation			97	96	105	97	101
Minor Constituents							
Ammonia as N	0.02-0.42	0.22	----	<0.2			
Nitrate as N	0.04-0.48	0.14	----	<0.05			
Nitrite as N	0.01-0.58	0.12	----	<0.05			
Aluminum	<0.1	<0.1	0.09	<0.5			
Arsenic	<0.01	<0.01	----	<0.005			
Cadmium	0.01-0.04	0.02	0.01	0.011			
Chromium	<0.01	<0.01	----	0.02			
Copper	ND-0.03	0.015	0.06	0.116			
Fluoride	0.53-0.61	0.58	0.36	0.1			
Iron	ND-1.42	0.68	1.63	1.3	0.79	1.59	0.78
Lead	ND-0.1	0.1	0.14	<0.005			
Mercury	ND-0.037	0.007	----	<0.0001			
Molybdenum	<0.1	<0.1	<0.06	0.005			
Selenium	ND-0.07	0.022	----	0.013			
Vanadium	ND-0.1	0.1	0.17	0.139	0.16	0.117	0.04
Zinc	0.05-0.56	0.19	0.07	0.054			
Silicon (SiO_2)	7.7-9.6	8.4	8.0	6			
Radiochemistry							
Uranium as U_3O_8	0.002-2.00	0.384	0.695	0.542	0.730	0.664	0.700
Radium-226	0.6-92	37	592	510	580		390
Thorium-230	ND-2.3	0.7	1.5	1.9			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

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TABLE P1-2

NINE MILE LAKE
PATTERN 1
I-2

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/24/82	CDM 2/24/82	NML 3/8/82	NML 4/7/82	NML 5/4/82
pH	6.6-7.1	6.9	6.7	6.7	6.4	6.6	6.3
Conductivity	2860-3650	3162	8500	12000	8500	9000	9600
Major Constituents							
Bicarbonate	271-370	316	203	230	302	309	295
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	166	190	248	253	242
Calcium	71-104	87	232	310	301	325	333
Chloride	1.8-4.9	3.3	99	103	85	111	128
Magnesium	46-63	50	151	154	130	141	160
Potassium	7.0-16.2	12.8	14.4	11	15.2	15.8	17.5
Sodium	560-772	620	1961	2000	2082	3002	1924
Sulfate	1100-1450	1240	4954	5020	5242	6023	5077
TDS	2225-2780	2483	8320	7570	8500	9200	7785
Anion/Cation			100	104	100	104	100
Minor Constituents							
Ammonia as N	0.02-0.42	0.22	----	<0.2			
Nitrate as N	0.04-0.48	0.14	----	<0.05			
Nitrite as N	0.01-0.58	0.12	----	<0.05			
Aluminum	<0.1	<0.1	0.05	<0.5			
Arsenic	<0.01	<0.01	----	<0.005			
Cadmium	0.01-0.04	0.02	0.01	0.010			
Chromium	<0.01	<0.01	----	0.03			
Copper	ND-0.03	0.015	0.05	0.015			
Fluoride	0.53-0.61	0.58	0.30	<0.1			
Iron	ND-1.42	0.68	0.09	0.52	0.40	1.16	1.04
Lead	ND-0.1	0.1	0.13	<0.005			
Mercury	ND-0.037	0.007	----	<0.001			
Molybdenum	<0.1	<0.1	0.11	<0.005			
Selenium	ND-0.07	0.022	----	0.007			
Vanadium	ND-0.1	0.1	0.13	0.104	0.04	0.039	0.01
Zinc	0.05-0.56	0.19	0.04	0.061			
Silicon (SiO_2)	7.7-9.6	8.4	28.9	25			
Radiochemistry							
Uranium as U_3O_8	0.002-2.00	0.384	0.229	0.248	0.136	0.151	0.174
Radium-226	0.6-92	37	183	190	160		75
Thorium-230	ND-2.3	0.7	0.4	0.3	0.0		

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed.
Range represents variability among all wells.

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TABLE P1-3

NINE MILE LAKE
PATTERN 1
I-1

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/23/82	CDM 2/23/82
pH	6.6-7.1	6.9	6.8	7.1
Conductivity	2860-3650	3162	3200	3900
Major Constituents				
Bicarbonate	271-370	316	182	135
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	149	112
Calcium	71-104	87	117	110
Chloride	1.8-4.9	3.3	32	40
Magnesium	46-63	50	62	62
Potassium	7.0-16.2	12.8	7.4	6.0
Sodium	560-772	620	647	630
Sulfate	1100-1450	1240	1703	1700
TDS	2225-2780	2483	2670	2590
Anion/Cation			100	99
Minor Constituents				
Ammonia as N	0.02-0.42	0.22	----	<0.2
Nitrate as N	0.04-0.48	0.14	----	0.07
Nitrite as N	0.01-0.58	0.12	----	<0.05
Aluminum	<0.1	<0.1	0.05	<0.5
Arsenic	<0.01	<0.01	----	<0.005
Cadmium	0.01-0.04	0.02	<0.01	0.006
Chromium	<0.01	<0.01	----	0.03
Copper	ND-0.03	0.015	0.02	0.012
Fluoride	0.53-0.61	0.58	----	<0.1
Iron	ND-1.42	0.68	2.66	2.4
Lead	ND-0.1	0.1	0.07	<0.005
Mercury	ND-0.037	0.007	----	<0.0001
Molybdenum	<0.1	<0.1	<0.05	<0.005
Selenium	ND-0.07	0.022	----	0.013
Vanadium	ND-0.1	0.1	0.09	0.056
Zinc	0.05-0.56	0.19	0.04	0.041
Silicon (SiO_2)	7.7-9.6	8.4	22.3	23
Radiochemistry				
Uranium as U_3O_8	0.002-2.00	0.384	0.063	0.078
Radium-226	0.6-92	37	109	100
Thorium-230	ND-2.3	0.7	0.0	-0.2

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

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TABLE P1-4

NINE MILE LAKE
PATTERN 1
I-3

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/23/82	CDM 2/23/82
pH	6.6-7.1	6.9	6.8	7.2
Conductivity	2860-3650	3162	11200	16000
Major Constituents				
Bicarbonate	271-370	316	485	389
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	398	322
Calcium	71-104	87	412	370
Chloride	1.8-4.9	3.3	117	115
Magnesium	46-63	50	140	182
Potassium	7.0-16.2	12.8	16.1	12
Sodium	560-772	620	2339	2600
Sulfate	1100-1450	1240	5859	6490
TDS	2225-2780	2483	10560	10100
Anion/Cation			99	101
Minor Constituents				
Ammonia as N	0.02-0.42	0.22	----	<0.2
Nitrate as N	0.04-0.48	0.14	----	<0.05
Nitrite as N	0.01-0.58	0.12	----	<0.05
Aluminum	<0.1	<0.1	0.06	<0.5
Arsenic	<0.01	<0.01	----	0.006
Cadmium	0.01-0.04	0.02	0.01	0.014
Chromium	<0.01	<0.01	----	0.03
Copper	ND-0.03	0.015	0.06	0.017
Fluoride	0.53-0.61	0.58	0.28	<0.1
Iron	ND-1.42	0.68	0.99	0.54
Lead	ND-0.1	0.1	0.14	<0.005
Mercury	ND-0.037	0.007	----	0.0005
Molybdenum	<0.1	<0.1	0.02	<0.005
Selenium	ND-0.07	0.022	----	0.02
Vanadium	ND-0.1	0.1	0.22	0.056
Zinc	0.05-0.56	0.19	0.08	0.062
Silicon (SiO_2)	7.7-9.6	8.4	13.2	8
Radiochemistry				
Uranium as U_3O_8	0.002-2.00	0.384	0.255	0.200
Radium-226	0.6-92	37	189	150
Thorium-230	ND-2.3	0.7	0.0	0.4

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

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TABLE P1-5

NINE MILE LAKE
PATTERN 1
I-4

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/23/82	CDM 2/23/82
pH	6.6-7.1	6.9	7.4	7.4
Conductivity	2860-3650	3162	11,300	16000
Major Constituents				
Bicarbonate	271-370	316	628	481
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	515	398
Calcium	71-104	87	367	390
Chloride	1.8-4.9	3.3	107	113
Magnesium	46-63	50	161	167
Potassium	7.0-16.2	12.8	16.1	12
Sodium	560-772	620	2589	2700
Sulfate	1100-1450	1240	6131	6580
TDS	2225-2780	2483	9680	10100
Anion/Cation			97	102
Minor Constituents				
Ammonia as N	0.02-0.42	0.22	----	<0.2
Nitrate as N	0.04-0.48	0.14	----	0.53
Nitrite as N	0.01-0.58	0.12	----	<0.05
Aluminum	<0.1	<0.1	0.08	<0.5
Arsenic	<0.01	<0.01	----	<0.005
Cadmium	0.01-0.04	0.02	0.01	0.012
Chromium	<0.01	<0.01	----	0.02
Copper	ND-0.03	0.015	0.06	0.020
Fluoride	0.53-0.61	0.58	0.24	<0.1
Iron	ND-1.42	0.68	4.39	2.8
Lead	ND-0.1	0.1	0.15	<0.005
Mercury	ND-0.037	0.007	----	<0.0001
Molybdenum	<0.1	<0.1	0.13	0.005
Selenium	ND-0.07	0.022	----	<0.007
Vanadium	ND-0.1	0.1	0.07	0.056
Zinc	0.05-0.56	0.19	0.04	0.040
Silicon (SiO_2)	7.7-9.6	8.4	15.1	15
Radiochemistry				
Uranium as U_3O_8	0.002-2.00	0.384	0.050	0.107
Radium-226	0.6-92	37	105	110
Thorium-230	ND-2.3	0.7	0.3	1.2

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all well.

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TABLE P1-6

NINE MILE LAKE
PATTERN 1
I-5

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/23/82	CDM 2/23/82
pH	6.6-7.1	6.9	6.4	6.7
Conductivity	2860-3650	3162	10,300	15000
Major Constituents				
Bicarbonate	271-370	316	341	261
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	280	216
Calcium	71-104	87	398	370
Chloride	1.8-4.9	3.3	91	99
Magnesium	46-63	50	112	176
Potassium	7.0-16.2	12.8	16.8	13
Sodium	560-772	620	2139	2500
Sulfate	1100-1450	1240	5179	6260
TDS	2225-2780	2483	8300	9200
Anion/Cation			95	103
Minor Constituents				
Ammonia as N	0.02-0.42	0.22	----	<0.2
Nitrate as N	0.04-0.48	0.14	----	<0.05
Nitrite as N	0.01-0.58	0.12	----	<0.05
Aluminum	<0.1	<0.1	0.14	<0.5
Arsenic	<0.01	<0.01	----	<0.005
Cadmium	0.01-0.04	0.02	0.02	0.012
Chromium	<0.01	<0.01	----	0.02
Copper	ND-0.03	0.015	0.06	0.017
Fluoride	0.53-0.61	0.58	0.36	0.1
Iron	ND-1.42	0.68	0.84	0.61
Lead	ND-0.1	0.1	0.14	<0.005
Mercury	ND-0.037	0.007	----	<0.0001
Molybdenum	<0.1	<0.1	----	<0.005
Selenium	ND-0.07	0.022	----	0.011
Vanadium	ND-0.1	0.1	0.10	0.075
Zinc	0.05-0.56	0.19	0.08	0.062
Silicon (SiO_2)	7.7-9.6	8.4	15.4	14
Radiochemistry				
Uranium as U_3O_8	0.002-2.00	0.384	0.643	0.448
Radium-226	0.6-92	37	307	240
Thorium-230	ND-2.3	0.7	1.3	2.0

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

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TABLE P1-7

NINE MILE LAKE
PATTERN 1
I-6

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/23/82	CDM 2/23/82
pH	6.6-7.1	6.9	6.6	6.6
Conductivity	2860-3650	3162	6700	7200
Major Constituents				
Bicarbonate	271-370	316	257	198
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	211	164
Calcium	71-104	87	224	220
Chloride	1.8-4.9	3.3	78	80
Magnesium	46-63	50	93	114
Potassium	7.0-16.2	12.8	12.2	9.2
Sodium	560-772	620	1379	1400
Sulfate	1100-1450	1240	3678	3760
TDS	2225-2780	2483	6200	5580
Anion/Cation			105	97
Minor Constituents				
Ammonia as N	0.02-0.42	0.22	----	<0.2
Nitrate as N	0.04-0.48	0.14	----	<0.05
Nitrite as N	0.01-0.58	0.12	----	<0.05
Aluminum	<0.1	<0.1	0.02	<0.5
Arsenic	<0.01	<0.01	----	<0.005
Cadmium	0.01-0.04	0.02	<0.01	0.010
Chromium	<0.01	<0.01	----	0.02
Copper	ND-0.03	0.015	0.04	0.011
Fluoride	0.53-0.61	0.58	0.21	<0.1
Iron	ND-1.42	0.68	1.12	0.68
Lead	ND-0.1	0.1	0.08	<0.005
Mercury	ND-0.037	0.007	----	<0.0001
Molybdenum	<0.1	<0.1	0.03	<0.005
Selenium	ND-0.07	0.022	----	0.015
Vanadium	ND-0.1	0.1	0.08	0.028
Zinc	0.05-0.56	0.19	0.06	0.050
Silicon (SiO_2)	7.7-9.6	8.4	12.2	12
Radiochemistry				
Uranium as U_3O_8	0.002-2.00	0.384	0.428	0.401
Radium-226	0.6-92	37	88	100
Thorium-230	ND-2.3	0.7	0.7	0.3

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

TABLE P1-8

NINE MILE LAKE
PATTERN 1
M-7

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/25/82	CDM 2/25/82	NML 3/14/82	NML 4/9/82	NML 5/9/82
pH	6.6-7.1	6.9	6.8	7.1	6.7	6.8	6.8
Conductivity	2860-3650	3162	4000	4500	3900	3600	3500
Major Constituents							
Bicarbonate	271-370	316	359	284	360	349	369
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	294	234	295	286	302
Calcium	71-104	87	123	140	143	142	169
Chloride	1.8-4.9	3.3	50	37	35	35	48
Magnesium	46-63	50	68	73	60	62	64
Potassium	7.0-16.2	12.8	10.2	8.1	10.5	10.2	9.6
Sodium	560-772	620	755	830	782	819	672
Sulfate	1100-1450	1240	1873	2000	1935	1878	1491
TDS	2225-2780	2483	3320	3130	3160	3118	3120
Anion/Cation			103	104	99	102	106
Minor Constituents							
Ammonia as N	0.02-0.42	0.22	----	<0.2			
Nitrate as N	0.04-0.48	0.14	----	1.1			
Nitrite as N	0.01-0.58	0.12	----	<0.05			
Aluminum	<0.1	<0.1	0.08	<0.5			
Arsenic	<0.01	<0.01	----	<0.005			
Cadmium	0.01-0.04	0.02	<0.01	<0.005			
Chromium	<0.01	<0.01	----	0.01			
Copper	ND-0.03	0.015	0.02	0.009			
Fluoride	0.53-0.61	0.58	0.42	0.1			
Iron	ND-1.42	0.68	0.09	0.08	0.20	0.06	0.04
Lead	ND-0.1	0.1	0.04	<0.005			
Mercury	ND-0.037	0.007	----	<0.0001			
Molybdenum	<0.1	<0.1	0.02	<0.005			
Selenium	ND-0.07	0.022	----	0.059			
Vanadium	ND-0.1	0.1	0.14	0.029	0.01	0.065	0.01
Zinc	0.05-0.56	0.19	0.03	0.022			
Silicon (SiO_2)	7.7-9.6	8.4	8.4	8			
Radiochemistry							
Uranium as U_3O_8	0.002-2.00	0.384	0.222	0.224	0.133	0.186	0.169
Radium-226	0.6-92	37	-----	8.0			7.9
Thorium-230	ND-2.3	0.7	-----	0.2			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among all wells.

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TABLE P1-9

NINE MILE LAKE
PATTERN 1
M-8A

	BASELINE RANGE	NML 2/25/82	CDM 2/25/82	NML 3/9/82	NML 4/9/82	NML 5/5/82
pH	6.8-7.2	7.2	7.3	7.0	7.1	6.8
Conductivity	2800-3100	3100	3400	3000	2800	2600
Major Constituents						
Bicarbonate	193-309	336	257	343	340	341
Carbonate	0	0	0	0	0	0
Alkalinity as $CaCO_3$	160-253	275	212	281	279	280
Calcium	86-116	126	120	123	109	133
Chloride	26-33	41	31	32	34	44
Magnesium	40-56	48	53	53	49	48
Potassium	6.3-10.0	10.3	8.3	10.3	9.4	9.0
Sodium	504-576	549	530	535	562	507
Sulfate	1210-1395	1341	1440	1320	1386	1221
TDS	1910-2400	2250	2310	2380	2340	2280
Anion/Cation		101	96	100	98	101
Minor Constituents						
Ammonia as N	ND-0.2	----	<0.2			
Nitrate as N	ND-0.05	----	<0.05			
Nitrite as N	ND-0.05	----	<0.05			
Aluminum	0.5-1.1	0.58	0.6			
Arsenic	ND-0.005	----	<0.005			
Barium	ND-0.2	0.19	<0.2			
Boron	0.2-0.3	----	0.4			
Cadmium	ND-0.005	<0.01	0.006			
Chromium	ND-0.01	----	0.01			
Copper	0.03-0.04	0.02	0.008			
Fluoride	ND-0.1	0.50	0.1			
Iron	0.14-1.5	1.33	0.95	0.50	0.62	0.95
Lead	ND-0.005	0.03	<0.005			
Manganese	0.09-0.11	0.12	0.131			
Mercury	0.0001-0.0002	----	<0.0001			
Molybdenum	0.008-0.010	0.02	<0.005			
Nickel	0.03-0.04	0.11	0.03			
Selenium	ND-0.005	----	<0.005			
Vanadium	0.005-0.044	0.09	0.009	0.01	0.052	0.04
Zinc	ND-0.024	0.02	0.017			
Silicon as SiO_2			8			
Radiochemistry						
Uranium as U_3O_8	0.148-0.283	0.263	0.224	0.102	0.101	0.079
Radium-226	20-59		18			17
Thorium-230	ND-1.3		0.8			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm),
pH (standard units) and radionuclides (pCi/l).

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TABLE P1-10

NINE MILE LAKE
PATTERN 1
M-9

	PATTERN* BASELINE RANGE	PATTERN* BASELINE MEAN	NML 2/25/82	CDM 2/25/82	NML 3/9/82	NML 4/7/82	NML 5/4/82
pH	6.6-7.1	6.9	6.7	7.2	6.7	6.7	6.5
Conductivity	2860-3650	3162	2700	3200	2600	2400	2600
Major Constituents							
Bicarbonate	271-370	316	262	210	268	255	241
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	222-303	259	215	171	220	209	198
Calcium	71-104	87	65	73	67	61	74
Chloride	1.8-4.9	3.3	33	31	32	35	43
Magnesium	46-63	50	50	44	38	39	40
Potassium	7.0-16.2	12.8	9.1	7.2	9.4	8.8	8.6
Sodium	560-772	620	516	490	524	547	532
Sulfate	1100-1450	1240	1148	1200	1147	1197	1229
TDS	2225-2780	2483	1960	1970	2040	2080	2050
Anion/Cation			97	98	101	98	99
Minor Constituents							
Ammonia as N	0.02-0.42	0.22	----	<0.2			
Nitrate as N	0.04-0.48	[illegible]	----	<0.05			
Nitrite as N	0.01-0.58	0.12	----	<0.05			
Aluminum	<0.1	<0.1	0.06	<0.5			
Arsenic	<0.01	<0.01	----	<0.005			
Cadmium	0.01-0.04	0.02	<0.01	0.005			
Chromium	<0.01	<0.01	----	0.01			
Copper	ND-0.03	0.015	0.02	0.007			
Fluoride	0.53-0.61	0.58	0.52	0.2			
Iron	ND-1.42	0.65	0.39	2.8	0.03	0.24	0.08
Lead	ND-0.1	0.1	0.03	0.014			
Mercury	ND-0.037	0.007	----	<0.0001			
Molybdenum	<0.1	<0.1	0.01	<0.005			
Selenium	ND-0.07	0.022	----	0.046			
Vanadium	ND-0.1	0.1	0.23	0.085	0.23	0.104	0.18
Zinc	0.05-0.56	0.19	0.02	0.020			
Silicon (SiO_2)	7.7-9.6	8.4	7.6	8			
Radiochemistry							
Uranium as U_3O_8	0.002-2.00	0.384	0.225	0.189	0.284	0.175	0.127
Radium-226	0.6-92	37	-----	58			36
Thorium-230	ND-2.3	0.7	-----	0.6			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

*Pattern Baseline sampling contracted to D'Appolonia; one round of samples bailed. Range represents variability among wells.

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TABLE P1-11

NINE MILE LAKE
PATTERN 4
M-54

		BASELINE RANGE	NML 2/2/82	CDM 2/2/82
pH		6.4-6.8	6.2	----
Conductivity	umhos/cm	5500-7500	7200	----
Major Constituents				
Bicarbonate (HCO_3)	mg/l	254-291	225	181
Carbonate (COH_3)	mg/l	0	0	0
Alkalinity (as $CaCO_3$eq)	mg/l	208-239	184	150
Calcium	mg/l	190-282	191	210
Chloride	mg/l	60-118	68	64
Magnesium	mg/l	100-144	81	130
Potassium	mg/l	10-14	15	11
Sodium	mg/l	1107-1709	----	1300
Sulfate	mg/l	3133-4603	3449	3850
TDS	mg/l	5260-6520	6260	5790
Anion/Cation	mg/l			92
Minor Constituents				
Ammonia as N	mg/l	0.23-0.31	----	< 0.2
Nitrate as N	mg/l	<0.05	----	< 0.05
Nitrite as N	mg/l	<0.05	----	< 0.05
Aluminum	mg/l	0.3-3.6	0.09	< 0.5
Arsenic	mg/l	0.024-0.050	----	0.022
Barium	mg/l	0.10-0.14	----	< 0.2
Boron	mg/l	0.20-0.30	----	0.8
Cadmium	mg/l	0.10-0.20	0.02	0.01
Chromium	mg/l	0.03-0.05	0.05	0.01
Copper	mg/l	0.01-0.02	----	0.01
Fluoride	mg/l	0.5-0.6	0.52	0.10
Iron	mg/l	0.4-2.7	0.73	0.63
Lead	mg/l	0.008-0.170	0.13	0.043
Manganese	mg/l	0.46-0.52	----	0.30
Mercury	mg/l	<0.0001	----	0.0008
Molybdenum	mg/l	0.04-0.09	0.09	<0.005
Nickel	mg/l	0.05-0.09	0.04	0.07
Selenium	mg/l	0.002-0.100	----	<0.005
Vanadium	mg/l	0.02-0.15	0.01	0.043
Zinc	mg/l	0.12-0.22	0.07	0.106
SiO_2	mg/l	13.0-14.4	10.5	----
Radiochemistry				
Uranium as U_3O8	mg/l	0.063-0.165	0.147	0.212
Radium-226	pCi/l	270-520	751	550
Thorium-230	pCi/l	2.4-15.0	0.5	1.1

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Pl-9, and Pl-10 are results of stabilization monitoring of two pattern interior wells (P-1A, I-2) and the perimeter monitor wells for March through May of 1982.

Examination of the data confirms that TDS levels within the pattern interior are fairly high with an average value of 7,960 mg/l in February. Significant variability exists as TDS concentrations range from 2,600 mg/l to about 10,000 mg/l. Dissolved solids consist of soluble salts with sulfate, sodium, calcium, and chloride ions constituting the primary contaminants. Of these ions, all are within baseline values obtained from regional monitor wells completed in the Teapot Sandstone.

Table 1.4 summarizes background water quality for individual test patterns, the R&D project site and the Teapot Sandstone aquifer as characterized by regional monitor wells. Pattern 1 baseline data was not included in the table because baseline was established from one round of bailed samples in 1977 and is of questionable validity. The table shows that baseline water quality within the Teapot Sand exceeds 12,000 mg/l TDS and sulfate, sodium, calcium, and chloride levels respectively exceed 6,000; 2,600; 420 and 390 mg/l. Thus, groundwater in the pattern falls within the prior use suitability (industrial) category.

Other than soluble salts, all parameters have been restored to site baseline ranges (Table 1.4). Potentially toxic elements such as arsenic, selenium, lead, and mercury are within

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TABLE 1.4

NINE MILE LAKE

BASELINE WATER QUALITY

DATA SUMMARY

PARAMETER[1]	Pattern 2 Range			Pattern 3 Range			Pattern 4 Range			Site Range [3]			Regional Monitors		
	Low		High	Low		High	Low		High	Low		High	Low		High
Field Measurements[2]															
pH (std. units)	6.4	-	6.9	6.4	-	7.2	6.3	-	7.1	6.3	-	7.2	5.5	-	8.1
Conductivity (µmhos/cm)	1950	-	4000	1375	-	3500	2400	-	3700	1375	-	4000	1150	-	11600
Bicarbonate	256	-	315	224	-	426	278		333	224	-	426	160	-	492
Carbonate	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0
Alkalinity (as $CaCO_3$)	210	-	258	184	-	349	228	-	273	184	-	349	95	-	403
Major Constituents															
Calcium	50	-	160	41	-	135	57	-	153	41	-	160	24	-	429
Chloride	9	-	80	20	-	55	27	-	65	9	-	80	6	-	390
Magnesium	12	-	129	13	-	71	34	-	96	12	-	129	5.5	-	250
Potassium	7.5	-	30	5.9	-	16	5.6	-	10.4	5.6	-	25	4.0	-	46
Sodium	520	-	840	310	-	863	393	-	735	310	-	863	130	-	2620
Sulfate	1120	-	2800	628	-	2826	1116	-	2015	628	-	2826	294	-	6180
TDS	2028	-	3486	1380	-	3320	1800	-	3180	1380	-	3486	796		12264
Minor Constituents															
Ammonia (as N)	ND	-	0.48	0.10	-	0.33	<0.05	-	0.31	ND	-	0.48	0.01	-	4.4
Nitrate (as N)	ND	-	1.5	0.10	-	0.93	<0.05	-	0.78	ND	-	1.5	0.1	-	1.8
Nitrite (as N)	ND	-	0.1	0.02	-	0.06			ND	ND	-	0.1	0.001	-	0.13
Aluminum	ND	-	0.5	0.05	-	0.88	0.07	-	2.23	ND	-	2.23	0.02	-	0.52
Arsenic	ND	-	0.01	0.01	-	0.04	0.008	-	0.10	ND	-	0.10	0.004	-	0.074
Barium	ND	-	0.05	0.05	-	0.10	0.02	-	0.10	ND	-	0.10	0.02	-	0.30
Boron	ND	-	0.9	0.05	-	0.49	0.20	-	0.30	ND	-	0.90	0.01	-	1.96
Cadmium	ND	-	0.01	ND	-	0.01			<0.01	ND	-	0.01	0.001	-	0.08
Chromium	ND	-	0.04	0.01	-	0.03	0.01	-	0.14	ND	-	0.14	0.003	-	0.08
Copper	ND	-	0.028	ND	-	0.02	0.01	-	0.02	ND	-	0.028	0.001	-	0.08
Fluoride	0.04	-	0.60	0.10	-	1.07	0.5	-	0.6	0.04	-	1.07	0.13	-	1.60
Iron	ND	-	1.11	0.01	-	4.10	0.04	-	0.80	ND	-	4.10	0.06	-	89
Lead	ND	-	0.05	0.01	-	0.05	0.002	-	0.140	ND	-	0.140	0.01	-	0.06
Manganese	0.10	-	0.34	0.03	-	0.87	0.10	-	0.[illegible]2	0.03	-	0.87	0.01	-	1.80

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TABLE 1.4 (CONCLUDED)

NINE MILE LAKE

BASELINE WATER QUALITY

DATA SUMMARY

PARAMETER	Pattern 2 Range		Pattern 3 Range		Pattern 4 Range		Site Range		Regional Monitors	
	Low	High	Low	High	Low	High	Low	High	Low	High
Minor Constituents (cont'd)										
Mercury	ND	0.0001	ND	0.0005		<0.0001	ND	0.0005	0.0001	0.001
Molybdenum	ND	0.01	ND	0.01	0.005	0.210	ND	0.210	0.001	0.090
Nickel	ND	0.02	0.01	0.19	0.01	0.07	ND	0.19	0.008	0.10
Selenium	ND	0.01	0.01	0.04	0.00[illegible]	0.180	ND	0.18	0.002	0.03
Vanadium	ND	0.05	0.01	0.45	0.02	0.32	ND	0.45	0.01	2.1
Zinc	ND	0.04	0.01	0.04	0.01	0.05	ND	0.05	0.001	0.16
Silicon	3.0	8.0	1.0	15	8.0	11.3	1.0	15	3.6	13.1
Radiochemistry										
Uranium (as U_3O_8)	0.015	0.750	0.002	0.200	0.041	0.392	0.002	0.750	0.001	1.7
Radium-226 (pCi/l)	19	717	1.5	274	15	360	1.5	717	0.5	213
Thorium-230 (pCi/l)	ND	5.1	0.5	41.9	0	11	0	41.9	0.4	24.6

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[1] All units expressed in mg/l except as noted.

[2] All data for field measurement parameters taken from Nine Mile Lake (NML) analyses.

[3] Site range composite of Patterns 2,3 and 4 baseline data.

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baseline ranges and/or below the limits of detection. Radium levels in the production well are somewhat high (500 pCi/l), but the average of all interior wells is 211 pCi/l which is well within the site baseline range. Also, stabilization monitoring of wells P-1A and I-2 indicates a decline in radium levels of greater than 100 pCi/l since the February sampling. Other than soluble salts, all parameters have been restored to site baseline ranges (Table 1.4).

Analysis of water quality data from Pattern 1 monitor wells and other wells down gradient of the pattern suggests that an area of affected groundwater extends from the pattern interior down gradient to well M-54 and dissipates in the vicinity of well WF-74 (see Figure 1.1). Wells WF-74, WF-75, and M-8A were completed in December 1981 to define the area and nature of affected groundwater adjacent to Pattern 1. Subsequent sampling of the wells indicated that M-8A and WF-75 were unaffected by leach solution. Well WF-74 yielded a slightly elevated TDS level which indicates the well may be on the leading edge of a contaminant plume originating from Pattern 1. Table 1.5 describes key water quality parameters for the three new wells and monitor well M-54.

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Table 1.5

Pattern 1 Water Quality - New Wells
February 1982

Parameter	Pattern Baseline Range	M-8A	WF-74	WF-75	M-54
pH	6.6 - 7.1	7.2	6.2	7.0	6.2
Cond.	2860 - 3650	3100	4700	3250	7200
Ca	71 - 104	126	255	102	191
Cl	1.8 - 4.9	41	56	37	68
Mg	46 - 63	48	118	57	81
K	7.0 - 16.2	10.3	14.7	11.9	15
Na	560 - 772	549	802	575	1300
SO_4	1100 - 1450	1341	2419	1485	3449
TDS	2225 - 2780	2250	3800	2407	6260
V	ND - 0.10	0.09	0.048	0.076	0.01
U_3O_8	0.002 - 2.00	0.263	0.354	0.283	0.147
Ra-226	0.6 - 92	18	200	70	550

The data confirms that elevated TDS concentrations in WF-74 and M-54 are largely due to calcium, sodium, sulfate, and magnesium. Comparison of water quality in wells P1-A, M-54 and WF-74 clearly shows the effects of dilution as a function of distance from Pattern 1. Figure 1.2 illustrates that sodium sulfate and TDS levels all approach Pattern 1 baseline values within a distance of 230 feet from P-1A and are well within site baseline ranges. As with the pattern interior, downdip residual contaminants consist of major ions which pose essentially no environmental or health hazard.

1.4 Pattern 1 - Conclusions

Groundwater within Pattern 1 has been restored to background water use category limitations for all parameters of concern. Residual contaminants consist of soluble salts which pose no significant environmental or health hazard and are within

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Figure 1.2

Pattern 1 Water Quality

Parameter Concentrations VS. Distance

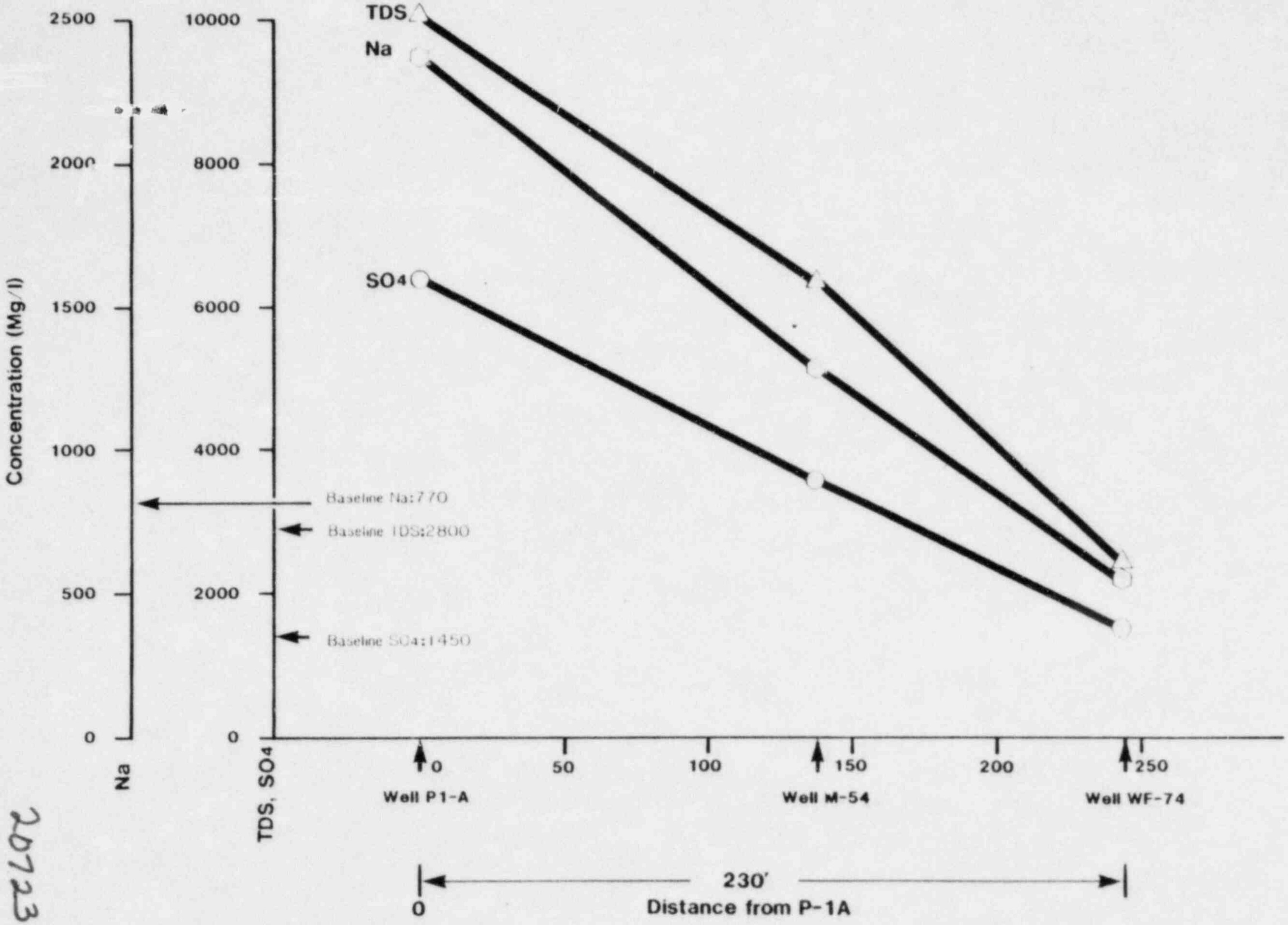

FIGURE 1.2

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natural ranges recorded for the aquifer. Radium concentrations in some interior and down gradient wells exceed Pattern 1 baseline values but are within overall site baseline range. Independent evaluations regarding the ultimate fate of radium conclude that radium concentrations will greatly diminish within a short travel distance due to ion exchange reactions with formation clays as well as dilution and mixing as natural groundwater flow is reestablished.

Based on previous experience, it would appear that further restoration efforts would be ineffective in achieving permanent water quality improvement. Results of the last two restoration programs, both using best available technology, have shown temporary improvements in water quality, but rapid deterioration and stabilization at a high level of TDS. Well monitoring since the last restoration effort indicates stabilization has occurred at a point which would not constitute a degradation of premining water use suitability.

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2.0 Operational History - Pattern 2

Pattern 2 is a five-spot pattern consisting of a central production well ringed by four injection wells on a 50-foot radius and four monitor wells located 100 feet from the injection wells. Wells were completed in the lower ore zone of the Teapot Sandstone with screened completion intervals in the monitor wells and water jet perforations in the production and injection wells.

An extensive baseline water quality analytical program was conducted in an attempt to accurately characterize background water quality and compare analytical variability among commercial laboratories. One round of samples were split and sent to five different commercial laboratories for analyses with duplicate and coded samples included. Analyses revealed substantial differences for identical samples from lab to lab as well as within individual laboratories as seen in Table 2.1. The observed variability illustrated the difficulty of establishing valid baseline conditions, particularly for trace elements present at concentrations approaching the limits of detection.

2.1 Pattern 2 Leaching

Like Pattern 1, leaching was conducted with a sulfuric acid lixiviant at concentrations up to four grams/liter and hydrogen perioxide as the oxidant. Leaching began in December 1977 and was very successful as uranium headgrades peaked at about 300 ppm before well plugging problems due to fungus growth and chemical precipitation were encountered in April 1978. A combination of mechanical and chemical treatments reduced the

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	PRODUCTION WELL #15							MONITOR WELL #20							MONITOR WELL #2				
	RMGC	C & G	CEP	WAMCO	NML	EBERLINE	AVG	RMGC	C & G	CEP	WAMCO	NML	EBERLINE	AVG	RMGC	C & G	CEP	WAMCO	NML
pH, UNITS	7.6	7.7	7.1 7.2	7.5* 7.6	6.6		7.3±0.4	6.9 8.3 0.4*	7.4 7.4 6.6	7.3 7.3	7.6	6.9 6.9 6.7		7.3±.6	7.2	7.5	7.2 7.2	7.4* 7.6	6.8 6.4 6.8
Eh, MILLIVOLTS	+79	+270	+18	+84* +83	+334		145±126	+100 +140 +105*	+295 +295	+59 +63	+80 +74	+290 +411 +318		186±126	-92	+270	+57 +44	+74	+400 +310
CONDUCTIVITY, MICROMHOS	3500	3650	2990 3000	3700* 3660	3000		3357±342	4600 7200 4300*	4000 4002	3610 3700	3970	4000 3700 3200		3844±424	3500	2850	2410 2250	2800* 2850	3100 3300
TOTAL DISSOLVED SOLIDS (TDS)	3250	3122	2914* 3001	3272 3348*			3151±169	3390 3390*	3218 3200	3260 3153	2486 3325			3303±114	2240	2182	2028 2178 2068*	2344* 2538 2277 2285	
ALKALINITY AS $CaCO_3$ (AIK)		210		216* 212			213±13		210 210 250		256			231±2500		230		228* 224	
ALUMINUM (Al)	ND(0.04)	ND(0.05)	0.1 0.1				0.07±0.0	ND(0.5)	ND(0.05)	0.1 0.1				0.19±0.21		ND(0.05)	0.1 0.2		
AMMONIA (NH_3)	ND(0.01)	0.04	0.06* 0.03 0.01	ND(0.1) ND(0.1)*			0.05±0.03	0.01 ND(.01) ND(.01)*	0.16 0.15 0.16	0.02 0.01	0.18			0.08±0.08	ND(0.05)	0.10	0.01 0.02 0.03*	0.12 0.12	
BORON (B)	0.19	ND(1.0)	1.0* 0.6 0.4	ND(0.1)			0.54±0.39	0.29	ND(10) ND	0.1 0.2	ND(0.1)			.34±.38	0.22	ND(1.0)	0.6 0.4 0.9*	ND(0.1)	
BICARBONATE (HCO_3)	198	256	223 221	259 263*	291		244±32	205 213 213*	305 305	263 263	292 307 313	256 296 299		272±39	214	281	242 240 251*	273 278*	291 296
CADMIUM (Cd)	ND(0.01)	ND(0.002)	ND(0.001) ND				.004	ND(0.02)	ND(0.01)	ND(0.001) ND				0.01±0.01	ND(0.01)	ND(0.002)	ND(0.001) ND		
CALCIUM (Ca)	128	121	100* 97 96	117* 125	141		118.1±16	117 124 127 125* 124*	215 129 [illegible]	102 110	112	134 149 [illegible]		130±27	79	75	54* 50 75	74* 77	97 112 123
CHLORIDE (Cl)	39	40	30 40*	50 44*	40 37 39		40±5.3	50 66 58 61* 60*	80 75 60	64 63	72	60 51		64±9	38	40	40 39 38*	48 54*	33 70
CHROMIUM (Cr)	ND(0.04)	ND(0.01)	ND(0.001) ND				.007±.00 0.01±0.02	0.012	ND(0.01)					0.01±0.001	ND(0.04)	ND(0.01)	ND(0.001) ND		
COPPER (Cu)	ND(0.01)	ND(0.01)	0.019 0.016				0.014± 0.005	0.004	ND(0.01)					0.01± 0.004	ND(0.01)	ND(0.01)	0.011 0.011		
FLUORIDE (F)	0.58	0.04	0.26 0.23				0.28±0.22	0.49	0.28	0.33 0.31				0.35±0.09	0.60	0.04	0.26 0.35		
TOTAL IRON (Fe)	0.32	0.57	0.89* 0.79 0.79	0.41* 0.30			0.61±0.22	0.32 ND(.04) ND(.04)*	0.44 0.40 0.40	0.71 0.71	0.08 0.15			0.31±0.21 .33±.25	0.80	0.36	0.50* 0.45 0.63	ND(0.02)* ND(0.02) 0.45	
LEAD (Pb)	ND(0.04)	ND(0.05)	ND(0.001) ND				.03±.02	0.032	ND(0.05)	ND(0.001) ND				0.02±0.03	ND(0.04)	ND(0.05)	0.001 0.001		
MAGNESIUM (Mg)	94	93	91* 94 93	112* 129	113		102±14	42 85 85 85* 86*	75 72 71	83 83	107	90 105 58 103		80±23	48	33	49* 53 53	65* 80	67 50 41
MANGANESE (Mn)	0.26	0.20	0. 4* 0.24 0.24				0.22±0.1	0.21	0.16 0.16	0.29 0.29				0.22±0.07	0.26	0.30	0.24 0.24 0.15*		
NITRATE (NO_3)	ND(0.1)	0.30	0.6* 0.2 0.2	ND(0.1) ND*			0.26±0.21	0.6 0.3 ND(0.1)*	0.013 0.32 0.30	0.2 0.2	ND(0.1) ND			0.20±0.19	ND(0.1)	0.23	0.2 0.2 0.1*	0.5* ND(0.1)	
NITRITE (NO_2)	ND(0.01)	ND(0.01)	ND(0.1)*	ND(0.01) ND*			0.0	ND(0.01) ND(0.01)*	ND(0.01) ND	ND(0.1) ND				.01	ND(0.01)	ND(0.01)	ND(0.1) ND ND*	ND(0.01) ND*	
PHOSPHATE (PO_4)	ND(0.3)		0.3 0.3				0.37±0.12			0.1 0.3				0.2±0.14	ND(0.5)		0.7 0.8		
POTASSIUM (K)	9	17	11* 11 11	10* 10			11.3±2.6	13 54 51 50* 50*	59 58 16	13 59	57 58 19			43±20	14	21	19* 17 16	14* 14 17 17	
SILICA (SiO_2)	3	6.5	6.2 6.2				5.5±1.7	4.0	4.1	6.5 6.2				5.2±1.4		6.4	6.2 6.1		
SODIUM (Na)	715	745	660* 690 668	775* 775			718±48	755 780 770 780* 780*	775 765 992	715 715	840 835 730			787±73	540	555	539* 533 536	560* 580 545 535	
SULFATE (SO_4)	1950	1980	1930* 1994 1890	1670 1800*	2290		1938±178	2800 1800 2000*	1950 1925 2450	1946 2001	1810	2230 2240 1810 2090		2081±289	1450	1300	1231 1263 1199*	1260 1260*	1430 1260
URANIUM (U_3O_8)	0.253	0.230	0.213* 0.181 0.216	0.400 0.340*			0.26±0.08	0.750 0.608 0.588 0.618* 0.55_*	0.500 0.064	0.511 0.450	0.105	0.600 0.740		0.51±0.22	0.127	0.100	0.143* 0.106 0.125	0.170 0.135 0.120 0.084 0.180*	
VANADIUM (V_2O_5)	0.005	ND(0.05)	0.01 0.01	ND(0.05) ND*			0.02±0.02	ND(0.05) ND(0.004)* ND(0.004)*	ND(0.02) ND ND	ND(0.01) ND	ND(0.05)			0.01±0.02	0.004	ND(0.05)	0.01 0.01	ND(0.05) ND*	
ZINC (Zn)	0.03	0.01	0.01 0.01				0.02±0.01	0.029	0.02	ND(0.01) ND				0.01±0.01	0.02	0.01	0.02 0.02		
GROSS ALPHA	540	399±97	1240±70 1280±70			790±50	850±400	640±50	1290±70	738±53 807±55			370±40	769±335		275±69	603±48 555±46		
GROSS BETA	820	902±119	165±5 179±5			1000±100	451.5	490±50	264±6	113±4 126±4			610±20	321±222		463±87	68±3 69±3		
LEAD 210 (Pb 210)	ND	44±6	27.5±1.7 31.5±1.7			0±10	25.7±18.5	1.4±0.9	13.8±1.5	10.5±1.1 11.5±1.2			25±11	12.4±8.36	ND	19±5	8.5±1.1 9.3±1.1		
RADIUM 226 (Ra-226)	ND	45.7±10.4	669±23 717±21			330±10	440±311.5	270±50	220±9	94.5±3.3 84.4±7.5			220±10	178±83	ND	19.1±2.6	279±11 286±11		
THORIUM 230 (TH 230)	ND	51.2±9.1	ND(0.6) ND			2.8±1.6	18.2±28.6	4±5	ND(0.6)	ND(0.6) ND			1.8±0.4	1.8±1.6	ND	17.4±3.7	ND(0.6) ND		

RMGC = ROCKY MOUNTAIN GEOCHEMICAL CORP., WEST JORDAN, UTAH
C&G = CHEMICAL & GEOLOGICAL LABORATORIES, CASPER, WYO.
CEP = CONTROLS FOR ENVIRONMENTAL POLLUTION, INC., SANTA FE, NM
WAMCO = WAMCO LAB, CASPER, WYO.
NML = NINE MILE LAKE LABORATORY
EBERLINE = EBERLINE, ALBUQUERQUE, NM
ND = NOT DETECTABLE (LIMIT OF DETECTION)
AVG = MEAN ± STANDARD DEVIATION
Values as mg/l or pCi/l

THE PARAMETERS LISTED BELOW WERE NON-DETECTABLE FOR ALL LABS INVOLVED:
MERCURY (0.0001)
MOLYBDENUM (0.01)
SELENIUM (0.01)
CARBONATE (0.00)
ARSENIC (0.01)
SULFITE (0.1)
FREE ACID (0.00)
BARIUM (0.05)

OFFICIAL DOCKET COPY

*BLIND SAMPLE SPLIT

WELL ANALYSIS

		MONITOR WELL #22							MONITOR WELL #23							MONITOR WELL #24							
EBER LINE	AVG	RMGC	C & G	CEP	WAMCO	NML	EBER LINE	AVG	RMGC	C & G	CEP	WAMCO	NML	EBER LINE	AVG	RMGC	C&G	CEP	WAMCO	NML	EBER LINE	AVG	TOTAL AVERAGE
	7.1±0.4	7.0 7.1	6.9* 6.9* 6.7 7.5 7.5	7.3 7.3	7.3	6.7 6.4 6.5		7.01±0.40	7.2 8.1	7.1* 7.1* 6.6 6.9 6.9	7.3 7.4	7.4 7.4*	6.7 6.4 6.7		7.1±.4		6.9 6.9 7.1 7.3* 7.3*	7.5 7.5	7.5	6.9 7.2 6.7 6.5 6.9		7.1±0.3	7.0±0.1
	178±145	+110 +160	+285 +305* +305* +295 +295	+41 +51	+85	+294 +405 +385		232±126	+110 +140	+275 +310 +310 +310* +310*	+43 +24	+73 +73*	+293 +399 +375		218±133	+40 +112 +88*	+280 +310 +310 +310* +310*	-7 -2	+74	+75 +293 +283 +389 +362		269±83	205±44
	2738±427	3900 3800	3225* 3225* 3225 3225 3225	2800 3200	3210	3200 3300 3200		3287±278	3500 2750	3050 2700 2700 2700* 2700*	2850 2730	2840 2800*	1950 2900 3100		2805±331	3200 3000 3200*	2775 2700* 2700* 2775 2800	2500 2400	2850	3000 2950 2400 2500 3300 2400		2837±279	3148±428
	2238±152	2850 2720	2937 2460* 2504* 2550 2580	2642 2703	2538 2858 2746 2738			2679±148	2600 2210	2452 2087* 2150*	2153 2224	2312* 2274 2550 2194 2490			2308±172	2403 2300 2300*	2462 2321* 2285* 2019 2040	2264 2066*	2182 2274 2188 2094 2617 2264			2299±200	2663±466
	227±3		200 220* 220* 240 240		216			223±15		230 230 230* 230* 210		240 248*			231±12		231 270* 208* 230 230		248			228±12	226±7
	0.12±.08	ND(0.5)	ND(0.05)	0.1 .11				.19±.2	ND(0.5)	ND(0.05)	0.2 0.2				0.24±0.18	ND(0.5)	ND(0.05)	0.2 0.2				0.24±0.19	
	0.06±0.05	ND(0.01) ND(0.01)	0.15 0.10 0.10 ND(0.01)* ND*	0.02 0.02	0.12			0.05±0.06	ND(0.01) ND(0.01)	0.07 0.1 0.1 ND(0.01)* ND*	0.02 0.02	0.48* ND(0.1)			0.08±0.14	0.06 ND(.01) ND(.01)*	0.10 ND(0.01) 0.02* 0.02* 0.10	0.02 0.03 0.11*	ND(0.1)			0.05±0.04	
	0.54±0.36	0.11	ND(1.0) ND* ND* ND*	0.1 0.2	ND(0.1)			0.21±0.34	0.31	ND(1.0) ND ND* ND*	ND(0.1) ND	ND(0.1)			.38±.43	2.4	ND(1.0) ND ND* ND*	0.9* ND(0.1) ND	ND(0.1)			1.1±.96	
	274±40	193 175	244 268* 268* 293 293	226 225	263	279 275 302 315		259±41	205 210	256 281 281 281* 281*	240 242	292 302*	275 302 286 291		268±31	220 198 203*	281 268* 250* 281 281	243 243 345*	303	325 296 299 307 293		273±42	265±12
	.004	0.002	ND(0.002)	ND(0.020) ND				.001±.0005	0.005	ND(0.002)	ND(0.001) ND				0.002± 0.002	0.002		ND(0.001) ND(0.001)	ND(0.002)		.001±.0005	ND(0.001)	
	82±23	104 107 106	73 88* 91* 140 140	90 90	103	149 114 135 138		114±21	96 83 84	75* 81* 135 84 89	57 70	80 82*	138 160 94 127		96±29	98 95 96 93* 96*	84 84 112 98* 89*	60* 87 87	91	112 126 119 142 117 105		100±18	106±17
	44±12	31 31 29	50* 45* 40 40 40	35 33	36	36 28 35		36±8.3	41 46 42	70* 60* 40 50 45	41 41	36 52*	36 38		43±13	42 33 33 32* 32*	50 55 56 150* 160*	30 30 29*	40	27 30 18 26 9		44±37	45±9.7
	0.01±0.02	0.014	ND(0.01)	ND(0.001) ND				0.01±0.01	0.012	ND(0.01)	ND(0.001) ND				0.012	0.014	ND (0.01)	0.014 0.014				0.01±0.002	
	0.01	0.014	ND(0.01)	0.014 0.014				0.01±.002	0.006	ND(0.01)	0.028 0.028				0.021±0.013	0.014	ND(0.01)	ND(0.001) ND(0.001)				0.01±0.01	
	0.31±0.23	0.53	0.25	0.25 0.28				0.32±0.14	0.53	0.25	0.23 0.22				0.31±0.15	0.53	0.20	0.26 0.27				0.32±0.15	
	0.43±0.29	0.48 0.2 0.2	0.70 0.40* 0.35* 0.42 0.42	[illegible] 0.79	0.48			0.48±0.31	0.72 ND(.04) ND(.04)	0.38 0.01* 0.02* 0.04 0.04	1.08 1.11	<0.02* <0.02 0.13			.24±.29	0.32 ND(.04) ND(.04)*	0.25 0.23 0.52 0.12* 0.12*	0.75* 0.72 0.72	0.16 0.16			0.32±0.28	
	0.02±0.03	0.038	ND(0.05)	ND(0.001) ND ND				0.021± 0.031	0.022	ND(0.05)	0.003 0.003				.02±0.02	0.024	ND(0.05)	ND(0.001) ND(0.001)				0.02±0.02	
	56±11.5	80 72 72	73* 76* 53 70 53	76 74	83	86 66 70 62		71±9	66 49 49	53* 44* 48 48 43	55 54	21 67*	25 63 60 59		50±13	30 50 31 50* 31*	56 56 31 48* 55*	53* 54 55	89	55 38 41 72 53		52±13	68±20
	0.20±0.07	0.24	0.18 0.18 0.18* 0.17*	0.29 0.29				.2±.1	0.18	0.12* 0.12* 0.14 0.13	0.29 0.29				0.18±0.08	0.15	0.16 0.16 0.12* 0.12*	0.12* 0.19 0.19	0.00			0.14±0.05	
	0.20±0.14	0.3 ND(0.1)	0.33 0.33 ND(0.01)* ND*	0.2 0.2	ND(0.1)			0.17±0.13	ND(0.1)		0.3 0.3	ND(0.1) ND(0.1)*			0.16±.09	0.1 ND(0.1) 0.6*	1.5 0.9 0.9 ND(0.01)* ND(0.01)*	0.2 0.2 0.1*	ND(0.1)			0.39±0.48	
	(0.01)	0.01 ND(0.01) ND(0.01)	ND(0.01) ND ND* ND*	ND(0.1) ND	ND(0.01)			0.02±0.04	0.04 ND(.01)	ND(0.01) ND ND ND	ND(0.1) ND(0.1)	ND(0.01) ND*			.02±.01	0.03 ND(.01) ND(.01)*	0.95 ND(0.01) ND(0.01)* ND(0.01)* ND(0.01)*	[illegible] [illegible] ND(0.1)	ND(0.01)			0.11±0.27	
	0.67±0.15			0.9				0.9			0.8 0.8				0.8			0.9				0.9	
	16.6±2.4	11 8 7.5	12 15* 15* 15 14	9 9	9 11 10 9			11.2±2.8	14 22 22	30* 29* 17 30 30	24 25	19* 19 14 16 22			22±6	5 8 8 7.5* 7.5*	14 14 11 14* 13*	9* 8 9	10 13 10 9 9 9			10.1±2.4	19±12
	6.23±0.15	4.0	4.5	7.8 7.1				5.9±1.9	5.0	4.3	8.0 7.5				6.2±1.8	4.0	7.5	7.8 7.9				6.8±1.9	
	547±15	630 630 625	582* 610* 724 608 620	606 603	625 675 670			631±38	590 525 525	521* 550* 586 579 565	521 531	550 610 560* 520 560			552±29	540 550 545 550* 545*	507 530 615 589* 565*	526* 538	570 575 725 575 580 520			537±37	628±103
	1295±87	2000	1500* 1430* 1830 1350 1510	1543 1593	1540	1720 1890 1670 1620		1649±170	1750 1650	1200* 1150* 1490 1350 1325	1298 1288	1120 1255*	1220 1410		1348±188	1800 1500 1550*	1210 1230 1500 1280* 1250*	1302* 1327 1290	1260	1600 1360 1390 1410		1395±162	1657±331
	0.13±0.03	0.015 0.030 0.031	0.026* 0.020 0.030 0.026* 0.016 0.015	0.025 0.025	0.047 0.025 0.027			0.03±.01 .03±.01	0.101 0.081 0.062	0.056* 0.050* 0.076 0.171 0.130 0.130	0.080 0.091	0.375 0.135* 0.060 0.065			.12±.09	0.099 0.072 0.062 0.052* 0.070*	0.100 0.080 0.250 0.036* 0.030* 0.052 0.053	0.063 0.059 0.063*	0.078 0.032 0.035			0.07±0.05	
	0.02±0.02	ND(0.02) 0.004	ND(0.02) ND ND ND* ND*	0.01 0.01	ND(0.05)			.02±.02	ND(0.02) 0.004	ND(0.02) ND* ND* ND ND	0.02 0.01	ND(0.05) ND*			.02±.02	ND(0.02) ND(0.004) 0.004*	ND(0.02) ND ND ND* ND*	ND(0.01) ND	ND(0.05)			0.01±0.02	
	0.02±0.01	0.036	ND(0.01) ND	ND(0.01) ND				0.02±0.02	0.031	0.01	ND(0.01) ND				.02±.01	0.081	0.03	0.08 0.08				0.07±0.03	
380±40	453±153	380±30	1010±60	634±49 610±48			350±30	593±269	270±30	635±49	584±47 652±10			390±40	506±168	840±40	2750±90	1590±70 1520±70			940±60	1394±528	760±345
380±20	245±206	100±40	172±5	92±2 93±4			380±20	167±123	69±26	109±4	77±3 86±3			340±20	136±11.5	370±30	295±6	175±5 183±5			570±20	379±286	810±1242
0±10	9.2±7.8		11.6±1.4	10.5±1.2 9.9±1.3			8±5.4	7.9±4.7	0.4±0.9	8.4±1.5	11.7±1.2 11.9±1.2			26±12	11.6±9.2	6.0±0.9	16.2±0.4	11.7±1.3 11.5±1.2			28±12	14.6±8.3	13.6±6.4
98±1	161±123	200±40	135±5	198±10 188±8			190±10	182±27	150±20	143±3	287±14 287±14			240±10	221±71	510±70	2.1±0.4	599±14 533±15			50±1	342±291	234±112
0.53±0.30	6.2±9.7	2±4	ND(0.6)	ND(0.6) ND			1.2±0.5	1.1±.6	4±5	ND(0.6)	ND(0.6) 0.8±0.4			0.90±0.28	1.4±1.5	0±3		ND(0.6) 0.7±0.4			0.63±0.24	0.48±0.32	4.8±6.8

TABLE 2.1

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plugging problem sufficiently to allow mining to continue. Leaching was conducted from December 1, 1977, through September of 1978 during which time approximately 13 pore volumes of groundwater were produced from the pattern. Pattern 2 mining results confirmed the feasibility of mobilizing and recovering uranium from the Nine Mile Lake ore body using an acidic leach solution. The test also indicated vanadium was sufficiently mobilized to warrant consideration as a recoverable by-product during (proposed) production scale mining.

2.2 Pattern 2 Restoration - Phase 1

During the spring and summer of 1978, restoration research test work conducted for RME by Stearns-Roger and Hazen Research indicated a combination of chemical treatment followed by reverse osmosis (RO) would most effectively restore groundwater. While the RO restoration circuit was being designed and installed, a modified groundwater sweep with reinjection of process and raffinate (barren production fluid) water was conducted. Uranium recovery by means of ion exchange (IX) resin was continued. This restoration phase began in early September 1979 and continued through mid-January 1978 when uranium levels in the production fluid were reduced to 16 ppm and a 33 gpm RO unit was brought on line.

Restoration using sequential lime and soda ash (Na_2CO_3) precipitation steps followed by RO treatment began in mid-January 1979. Figure 2.1 shows the restoration circuit. The circuit produced a "clean" RO permeate which was blended with process

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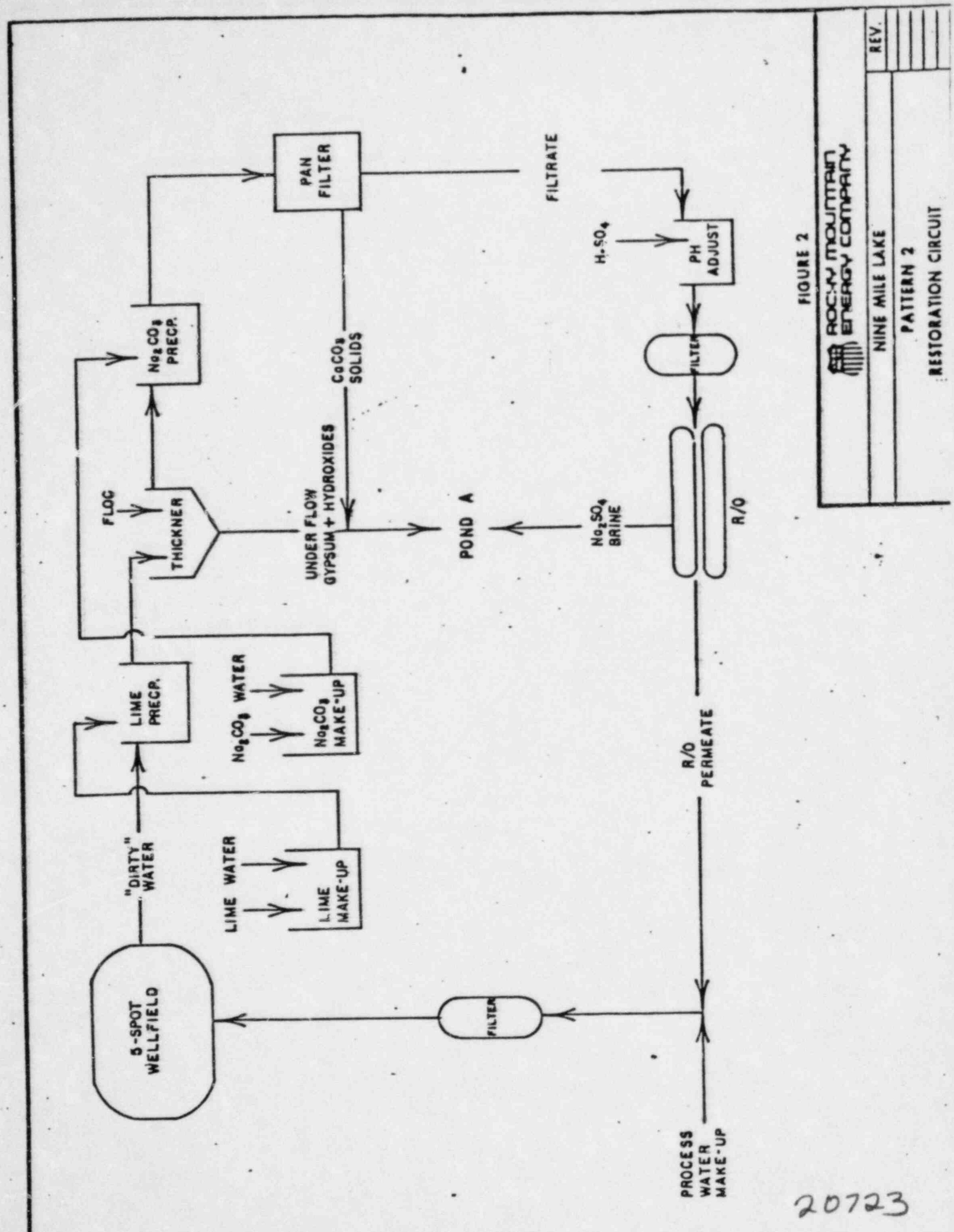

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FIGURE 2.1

water and reinjected while the RO brine and precipitated solids were discharged to the lined evaporation pond. During this time, ongoing bench test work at the University of Texas suggested that reinjection of a high TDS solution might speed restoration. Research indicated hydrogen ions from the sulfuric acid lixiviant were strongly absorbed by colloidal clay particles within the host formation keeping groundwater pH at low levls. The low pH (2.5 to 3.5) caused parameters whose solubility is controlled by pH levels, such as uranium, vanadium, iron, etc. to remain in solution at concentrations well above baseline. In order to raise the pH, hydrogen ions absorbed on formation clays had to be exchanged with calcium, sodium, or other cations. It was thought that reinjecting a high pH (9.0 to 10.0) calcium rich solution would cause the desired ion exchange reactions to occur.

A test of the high TDS reinjection was started February 12, 1979, but discontinued after three days when a precipitate began to form in the injection tank. Analysis of the precipitate proved it to be gypsum ($CaSO_4$). The gypsum was formed when calcium ions combined with naturally high sulfate levels (>1,000 mg/l) in the groundwater. It was feared continued injection of the calcium rich solution could cause gypsum buildup within the formation with resultant well plugging, therefore, reinjection was discontinued.

Restoration was halted following the high TDS

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reinjection test due to lack of pond capacity and did not resume until mid-May 1979. In the interim, different high pH, high TDS solutions were tested with varying degrees of success. A solution containing sodium hydroxide (NaOH) at a pH of 9-10 proved to be most effective at maintaining high TDS levels while minimizing heavy metal mobilization and well plugging problems. From May through August 14, 1979, injection of a high pH, high sodium hydroxide solution at about 30 gpm was maintained. Table 2.2 compares production fluid water quality prior to and following reinjection of sodium hydroxide.

Table 2.2

Pattern 2 Water Quality
NaOH Restoration

Parameter	Baseline Range	Production Fluid April '79	Aug. '79
Ca	50-160	114	62
SO_4	1,120-2,800	2,930	1,440
U_3O_8	0.015-0.750	4.4	1.6
V	0.05	32.2	18.1
Fe	ND-1.11	12.1	7.0
pH	6.4-6.9	4.2	5.5

Note: All values reported as mg/l except pH (std. units)

The data indicates the high pH NaOH solution effectively increased pH levels by replacing hydrogen ions absorbed on clays with sodium ions, without causing undesirable mobilization of heavy metal ions. By mid-August, sulfate and calcium levels were within baseline range and no significant water quality improvement

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was occurring so NaOH injection was terminated. A final sweep of the pattern interior by injecting "clean" formation water and recovering "affected" groundwater from the production well continued until September 4, 1979, when the pattern was shut down to evaluate restoration stability. At that time, all major parameters had been restored to baseline ranges (see Table 2.3). Parameters remaining at greater than baseline levels were iron, vanadium and radium; parameters whose solubility is largely pH dependent.

Table 2.3

Pattern 2 Water Quality
Post Restoration (Sept. 4, 1979)

Parameter	Baseline Range	Production Fluid (11/3/78)	Production Fluid (9/4/79)
pH	6.4-6.9	1.5	6.1
TDS	2,028-3,846	6,750	2,360
Ca	50-149	128	60
SO_4	1,120-2,290	5,745	1,380
Fe	0.20-0.89	154	3.6
V	0.05	430	11.4
U_3O_8	0.015-0.750	43	0.6
Ra-226	46-717	6,060*	1,300

Note: All values reported as mg/l except pH (std. units) and radium-226 (pCi/l).
*Sample taken June 1978.

Monthly stabilization sampling of pattern monitor wells following restoration indicated some water quality deterioration, particularly in well M-21 located down gradient from Pattern 2. Additional sampling of injection wells combined with computer modeling of leaching and restoration flow nets suggested some outlying areas around the pattern interior were not adequately swept during restoration. Leaching was conducted at an average injection flow rate of about 40 gpm while restoration flow rates averaged about 20 gpm injection and 21 gpm production. Although the total number of pore volumes produced during phase 1 restoration (11.5 P.V.) nearly equaled that for mining (13.3 P.V.), the lower restoration flow rates resulted in a smaller drawdown cone and area of influence than during leaching.

Continued monitoring during late 1979 and early 1980 confirmed scattered areas of affected groundwater were present around the pattern interior and slowly migrating down dip. Limited pond capacity and Pattern 3 leaching operations precluded immediate full scale corrective actions until August of 1980.

Pattern 2 Restoration - Phase 2

In August, pumping was resumed in the downdip injection well (I-17) and continued through early November 1980 while a second restoration program was developed. The second restoration phase was designed to: (1) further improve water quality within the pattern interior by raising pH and reducing trace metal concentrations, particularly vanadium and (2) draw outlying areas of affected groundwater back into the pattern interior. The plan was to pump affected water to the plant, reduce radionuclide and heavy metal concentrations through a lime/barium chloride precipitation process, and reinject the lime overflow product. Production and injection was rotated among all pattern interior wells in order to sweep outlying areas of the pattern contacted during leaching.

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This restoration phase continued from mid-November through February 25, 1981, at a production rate of 15 to 17 gpm with injection rates of 14 to 16 gpm. Total production was about 3.5 million gallons or 3.4 pore volumes. Substantial volumes of affected groundwater were recovered from areas which were apparently only partially swept previously. Attempts to reduce vanadium concentrations by means of ion exchange and/or activated charcoal, zeolite, and mechanical filtration were only partially successful. Table 2.4 compares production fluid water quality prior to phase 2 restoration and shortly before restoration was discontinued.

Table 2.4

Pattern 2 Water Quality
Phase 2 Restoration

Parameter	Baseline	Production Fluid 9/4/80	Production Fluid 2/4/81
pH	6.4-6.9	5.6	5.8
TDS	1,028-3,846	3,060	2,960
Ca	50-149	89	136
SO_4	1,120-2,290	2,058	2,017
Fe	0.20-0.89	4.7	4.2
V	0.05	4.4	3.8
U_3O_8	0.015-0.750	0.97	0.38

Note: All values reported as mg/l except pH (std. units).

Data analysis shows little improvement within the pattern interior occurred as water quality remained within ranges observed during the previous 10 months of stability monitoring.

Monitoring during March, April, and May of 1981 indicated some deterioration of water quality was recurring, particularly in the vicinity of monitor well M-21. The source of contaminated groundwater was believed to be diluted "pods" of affected water from outlying areas which were drifting downdip due to natural groundwater flow. A decision was made to drill a new well, PL-73, between the injection well (I-17) and a monitor well (M-21) on the downdip side of the pattern. Figure 2.2 shows well PL-73 in relation to other Pattern 2 wells.

Restoration - Phase 3

On May 17, 1981, production from the newly completed well and well I-17 started in order to draw affected groundwater downdip of the pattern back toward the pattern interior. Initially, well PL-73 was pumped at 10 gpm and I-17 at 5 gpm with production fluid routed to the lime treatment circuit. As water quality began to approach baseline conditions in M-21 and show substantial improvement in PL-73, production from PL-73 was discontinued. Pumping rates were increased from 5 to 10 gpm in well I-17 in mid-July and maintained through the end of the month. Table 2.5 describes key water quality indicator parameters during this time period.

Significant water quality improvement occurred as affected groundwater was recovered from the area downdip of the pattern. Vanadium concentrations in well PL-73 were reduced from nearly 10 mg/l to less than 1 mg/l. Iron dropped from 4 mg/l to less than 1. Water quality within the pattern interior (I-17) showed little change although TDS levels were reduced 400 to 500

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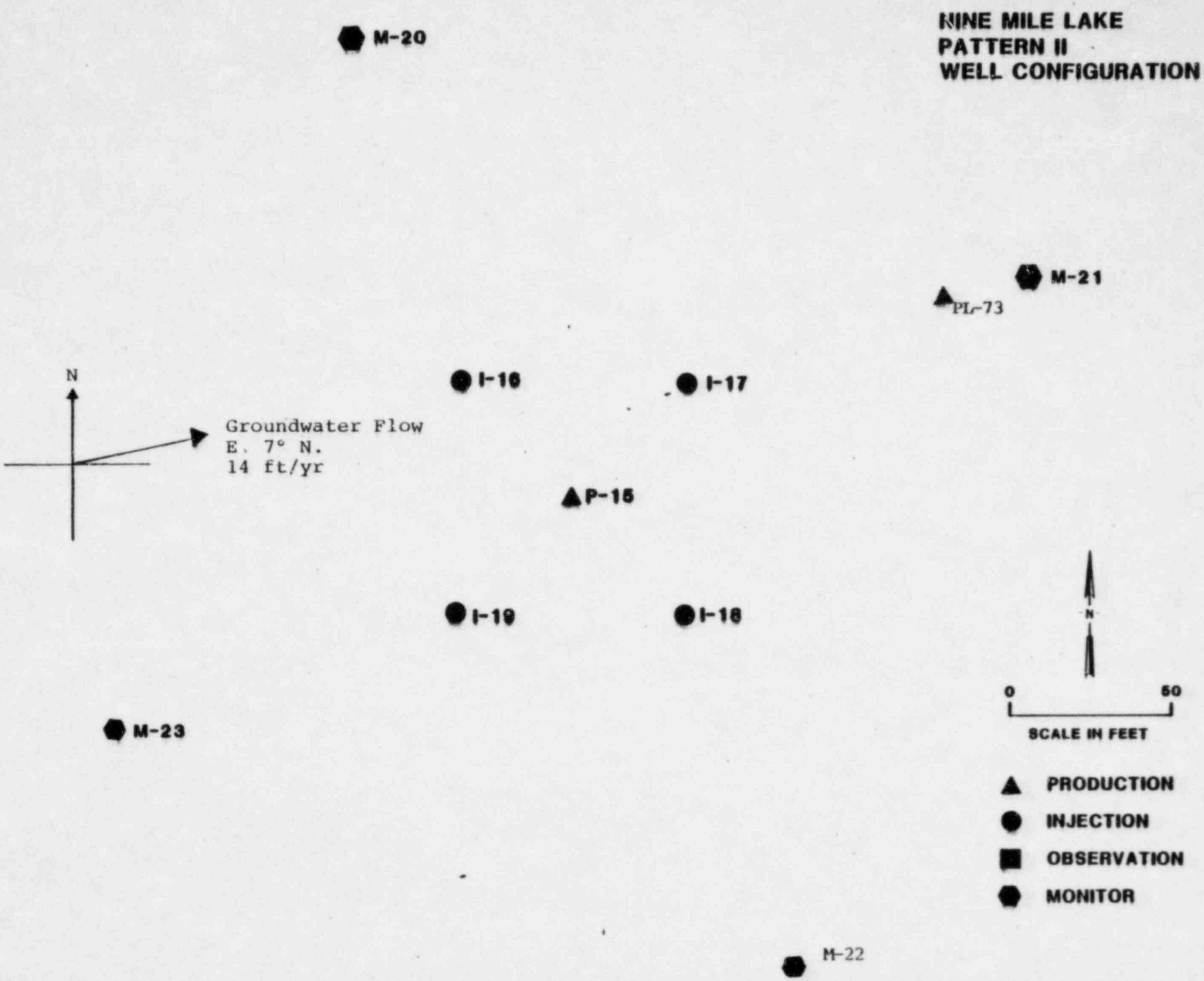

NINE MILE LAKE
PATTERN II
WELL CONFIGURATION

FIGURE 2.2

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mg/l. Generally, parameters remained within ranges observed previously during stabilization monitoring periods.

Table 2.5

Pattern 2 Water Quality
Phase 3 Restoration
Production Fluid

Well I-17	pH	TDS	SO_4	Fe	U_3O_8	V
5/20/81	-	3,000	1,845	0.40	0.17	1.9
6/3/81	6.6	2,700	1,635	0.17	0.12	3.6
6/17/81	6.2	2,760	1,579	0.40	0.09	3.3
6/30/81	6.0	2,600	1,609	0.30	0.09	2.4
7/9/81	6.2	2,480	1,672	0.51	0.09	2.2
7/22/81	5.9	2,540	1,551	1.00	0.13	2.3
7/28/81	5.9	2,480	1,610	0.77	0.21	2.4
Well PL-73						
5/20/81	-	3,480	2,185	4.2	0.45	8.6
6/3/81	6.1	3,040	1,981	1.8	0.31	2.2
6/17/81	6.2	2,960	1,719	0.50	0.31	1.4
6/30/81	6.2	3,000	1,634	0.60	0.21	0.9
7/9/81	6.4	2,900	1,812	0.17	0.26	0.5

Note: All values reported as mg/l excepth pH (standard units).

Restoration - Phase 4

Production from the pattern was resumed in November of 1981 in an attempt to retrieve any remaining "pods" of unrestored groundwater and to prevent interference with Pattern 3 restoration efforts. Initial production was 20 gpm evenly split from wells P-15 and I-17 then switched entirely to I-17 for a month and a half and back to P-15 for a final sweep of the pattern interior. Restoration was terminated on February 1, 1982, after removal of 1.6 million gallons of affected groundwater from the central and downdip areas of the pattern. Table 2.6 presents the water

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Table 2.6

Pattern 2
Water Balance Summary

Operational Mode	Production (gal.)	Pore Volumes	Injection (gal.)	Pore Volumes	Net Production (gal.)
Leaching (12/77-9/78)	13,834,274	13.3	12,371,300	11.9	1,462,974
Restoration Phase 1 (10/78-9/79)	11,943,934	11.5	9,756,709	9.4	2,187,225
Phase 2 (9/80-2/81)	3,494,050	3.4	1,611,607	1.5	
Phase 3 (5/81-7/81)	1,358,004	1.3	0	-	1,358,004
Phase 4 (11/81-2/82)	1,580,620	1.5	0	-	1,580,620
Restoration TOTAL	18,376,608	17.7	11,368,316	10.9	5,125,849
			TOTAL WATER CONSUMPTION		6,588,823

Total number of restoration pore volumes = 133% of mining pore volumes

[1] One Pore Volume = 1,043,000 gallons

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balance summary for Pattern 2 leaching and restoration operations. The total restoration effort produced 18.4 million gallons (17.7 PV) of affected groundwater during 22 months versus 13.8 million gallons (13.3 PV) produced during leaching.

2.3 Pattern 2 Post Restoration Water Quality

Samples obtained in February 1982 immediately following restoration termination show that all major constituents had been restored to pattern baseline range for the interior wells (P-15, I-16A, I-17, I-18, and I-19). Tables P2-1 through P2-9 present well sampling results from all Pattern 2 production, injection, and monitor wells as of February 1982. Copies of EPA certified laboratory results are included in Appendix B. The data indicates that in addition to all major constituents, trace elements had also been restored to pattern baseline range with the exception of iron and silicon. Aluminum, vanadium, and zinc concentrations were slightly above baseline in some of the interior wells with an average value of 3.4 mg/l iron and 0.7 mg/l vanadium for all production and injection wells.

Pattern monitor wells were also well within baseline range for all major and minor parameters except silicon (SiO_2) and vanadium in well M-21. There are no federal or state standards for silicon in groundwater, regardless of use category. Final restoration efforts were successful in restoring groundwater in the vicinity of monitor well M-21 to near baseline conditions. All parameters but silicon, aluminum, and vanadium were within Pattern 2 baseline ranges. Aluminum concentrations were 0.6 mg/l

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TABLE P2-1

NINE MILE LAKE
PATTERN 2
P-15

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/2/82	(BLIND SPLIT) NML 2/2/82	CDM 2/2/82	NML 3/8/82	NML 4/8/82	NML 5/9/82	PATTERN AVE. 2/2/82
pH	5.4-6.9	6.7	5.7	5.7	6.6	6.0	6.0	6.0	
Conductivity	1950-4000	3339	3750	3750	3210	3400	3400	3500	
Major Constituents									
Bicarbonate	256-315	257	60	60	70	121	108	129	
Carbonate	0-0	0	0	0	0	0	0	0	
Alkalinity as $CaCO_3$	210-258	228	49	49	58	99	89	106	
Calcium	50-160	111	119	104	110	165	124	153	
Chloride	9-80	46	36	39	35	41	44	58	
Magnesium	12-129	76	48	52	62	64	59	64	
Potassium	7.5-30.0	14.8	11.9	11.7	8.7	15.7	11.3	10.8	
Sodium	520-840	674	723	667	680	715	658	500	
Sulfate	1120-2800	1769	1824	1775	1840	1894	1761	1452	1575
TDS	2028-3486	2852	3020	2960	2790	2840	2710	2300	2610
Anion/Cation		102	96	101	100	103	100	101	
Minor Constituents									
Ammonia as N	ND-0.48	0.08	----	----	0.2				
Nitrate as N	ND-0.6	0.26	----	----	0.05				
Nitrite as N	ND-0.04	0.05	----	----	0.05				
Aluminum	ND-0.2	0.13	1.2	1.2	1.3				
Arsenic	ND-0.01	0.01	----	----	0.034				
Barium	ND-0.05	0.05	----	----	0.2				
Boron	ND-1.0	0.29	----	----	0.2				
Cadmium	ND-0.01	0.01	0.02	0.01	0.009				
Chromium	ND-0.014	0.006	0.03	0.04	0.01				
Copper	ND-0.028	0.015	----	----	0.027				
Fluoride	0.04-0.60	0.32	0.4	0.4	0.1				
Iron	ND-1.11	0.42	3.31	3.33	2.0	2.05	3.10	1.80	3.43
Lead	ND-0.05	0.010	0.10	0.12	0.005				
Manganese	0.10-0.34	0.22	----	0.17	0.11				
Mercury	0.0001	0.0001	----	----	0.0001				
Molybdenum	0.01	0.004	----	----	0.005				
Nickel	Not Taken	----	0.05	0.03	0.03				
Selenium	ND-0.01	0.01	----	----	0.005				
Vanadium	ND-0.05	0.05	3.4	2.9	4.0	2.94	2.119	0.85	.766
Zinc	ND-0.04	0.02	0.26	0.27	0.36				
Silicon (SiO_2)	3.0-8.0	5.7	29	29	31				
Radiochemistry									
Uranium as U_3O_8	0.015-0.750	0.239	0.271	0.247	0.283	0.147	0.174	0.114	
Radium-226	19-717	233	876	---	730	974		540	
Thorium-230	ND-5.1	3.4	18.6	----	41	26.6			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P2-2

NINE MILE LAKE
PATTERN 2
I-17

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/10/82	CDM 2/10/82	NML 3/8/82	NML 4/8/82	NML 5/6/82
pH	6.4-6.9	6.7	6.5	7.2	6.4	6.5	6.3
Conductivity	1950-4000	3339	2700	2750	2700	2900	3000
Major Constituents							
Bicarbonate	256-315	257	246	195	231	234	228
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	202	161	189	192	187
Calcium	50-160	111	76	73	80	92	84
Chloride	9-80	46	23	26	33	36	46
Magnesium	12-129	76	48	48	54	61	57
Potassium	7.5-30.0	14.8	10.4	7.3	9.7	9.6	9.2
Sodium	520-840	674	511	480	551	548	600
Sulfate	1120-2800	1769	1177	1250	1369	1321	1498
TDS	2028-3486	2852	2100	1940	2220	2540	2480
Anion/Cation		102	97	104	99	102	99
Minor Constituents							
Ammonia as N	ND-0.48	0.08	----	<0.2			
Nitrate as N	ND-0.6	0.26	----	<0.05			
Nitrite as N	ND-0.04	0.05	----	<0.05			
Aluminum	ND-0.2	0.13	0.34	<0.5			
Arsenic	ND-0.01	0.01	----	0.007			
Barium	ND-0.05	0.05	----	<0.2			
Boron	ND-1.0	0.29	----	0.3			
Cadmium	ND-0.01	0.01	<0.01	0.006			
Chromium	ND-0.014	0.006	----	<0.01			
Copper	ND-0.028	0.015	0.005	0.010			
Fluoride	0.04-0.60	0.32	0.55	0.1			
Iron	ND-1.11	0.42	1.17	0.74	0.85	1.73	1.44
Lead	ND-0.05	0.010	0.04	<0.005			
Manganese	0.10-0.34	0.22	0.13	0.12			
Mercury	<0.0001	0.0001	----	0.0002			
Molybdenum	<0.01	0.004	----	<0.005			
Nickel	Not Taken	---	0.04	0.05			
Selenium	<0.01	0.01	----	<0.005			
Vanadium	ND-0.05	0.05	0.79	0.48	0.18	0.234	0.05
Zinc	ND-0.04	0.02	0.05	0.052			
Silicon (SiO_2)	3.0-8.0	5.7	10.8	11.0			
Radiochemistry							
Uranium as U_3O_8	0.015-0.750	0.239	0.149	0.177	0.133	0.139	0.106
Radium-226	19-717	233	250	230	325		180
Thorium-230	ND-5.1	3.4	1.7	1.8	0.6		

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P2-3

NINE MILE LAKE
PATTERN 2
I-16A

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/10/82	CDM 2/10/82
pH	6.4-6.9	6.7	6.7	7.2
Conductivity	1950-4000	3339	2900	3000
Major Constituents				
Bicarbonate	256-315	257	281	228
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	230	188
Calcium	50-160	111	86	87
Chloride	9-60	46	35	29
Magnesium	12-129	76	49	51
Potassium	7.5-30.0	14.8	9.9	7.4
Sodium	520-840	674	579	590
Sulfate	1120-2800	1769	1334	1350
TDS	2028-3486	2852	2360	2130
Anion/Cation		102	99	95
Minor Constituents				
Ammonia as N	ND-0.48	0.08	——	<0.2
Nitrate as N	ND-0.6	0.26	——	<0.05
Nitrite as N	ND-0.04	0.05	——	<0.05
Aluminum	ND-0.2	0.13	0.23	<0.5
Arsenic	ND-0.01	0.01	——	0.013
Barium	ND-.05	0.05	——	<0.2
Boron	ND-1.0	0.29	——	0.4
Cadmium	ND-0.01	0.01	<0.01	0.005
Chromium	ND-0.014	0.006	——	<0.01
Copper	ND-0.028	0.015	0.007	0.011
Fluoride	0.04-0.60	0.32	0.36	<0.1
Iron	ND-1.11	0.42	2.77	2.0
Lead	ND-0.05	0.010	0.05	<0.005
Manganese	0.10-0.34	0.22	0.15	0.14
Mercury	0.0001	0.0001	——	<0.0001
Molybdenum	0.01	0.004	0.02	<0.005
Nickel	Not Taken		0.04	0.08
Selenium	0.01	0.01	——	<0.005
Vanadium	ND-0.05	0.05	0.03	0.128
Zinc	ND-0.04	0.02	0.02	0.033
Silicon (SiO_2)	3.0-8.0	5.7	21.6	20.0
Radiochemistry				
Uranium as U_3O_8	0.015-0.750	0.239	0.065	0.110
Radium-226	19-717	233	92	36
Thorium-230	ND-5.1	3.4	7.7	5.5

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NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P2-4

NINE MILE LAKE
PATTERN 2
I-18

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/10/82	CDM 2/10/82
pH	6.4-6.9	6.7	6.0	6.2
Conductivity	1950-4000	3339	3400	3200
Major Constituents				
Bicarbonate	256-315	257	115	80
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	94	66
Calcium	50-160	111	120	110
Chloride	9-80	46	41	33
Magnesium	12-129	76	55	55
Potassium	7.5-30.0	14.8	11.7	7.7
Sodium	520-840	674	690	670
Sulfate	1120-2800	1769	1747	1711
TDS	2028-3486	2852	2720	2500
Anion/Cation		102	97	96
Minor Constituents				
Ammonia as N	ND-0.48	0.08	——	0.3
Nitrate as N	ND-0.6	0.26	——	<0.05
Nitrite as N	ND-0.04	0.05	——	<0.05
Aluminum	ND-0.2	0.13	0.55	<0.5
Arsenic	ND-0.01	0.01	——	0.032
Barium	ND-0.05	0.05	——	<0.2
Boron	ND-1.0	0.29	——	0.3
Cadmium	ND-0.01	0.01	<0.01	0.005
Chromium	ND-0.014	0.006	——	0.01
Copper	ND-0.028	0.015	0.006	0.011
Fluoride	0.04-0.60	0.32	0.27	<0.1
Iron	ND-1.11	0.42	5.89	5.9
Lead	ND-0.05	0.010	0.03	0.005
Manganese	0.10-0.34	0.22	0.18	0.17
Mercury	<0.0001	0.0001	——	<0.0001
Molybdenum	<0.01	0.004	——	<0.005
Nickel	Not Taken	——	0.08	0.09
Selenium	ND-0.01	0.01	——	<0.005
Vanadium	ND-0.05	0.05	0.18	0.25
Zinc	ND-0.04	0.02	0.31	0.26
Silicon (SiO_2)	3.0-8.0	5.7	41.0	36.0
Radiochemistry				
Uranium as U_3O_8	0.015-0.750	0.239	0.031	0.053
Radum-226	19-717	233	146	71
Thorium-230	ND-5.1	3.4	26	5.1

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm) pH (standard units) and radionuclides (pCi/l).

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TABLE P2-5

NINE MILE LAKE
PATTERN 2
I-19

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/10/82	CDM 2/10/82
pH	6.4-6.9	6.7	6.8	7.3
Conductivity	1950-4000	3339	3500	3250
Major Constituents				
Bicarbonate	256-315	257	136	107
Carbonate	0-0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	111	88
Calcium	50-160	111	136	130
Chloride	9-80	46	64	51
Magnesium	12-129	76	55	58
Potassium	7.5-30.0	14.8	11.8	8.6
Sodium	520-840	674	610	620
Sulfate	1120-2800	1769	1714	1770
TDS	2028-3486	2852	2660	2580
Anion/Cation		102	104	104
Minor Constituents				
Ammonia as N	ND-0.48	0.08	—	3.9
Nitrate as N	ND-0.6	0.26	—	<0.05
Nitrite as N	ND-0.04	0.05	—	<0.05
Aluminum	ND-0.2	0.13	0.11	<0.5
Arsenic	ND-0.01	0.01	—	0.005
Barium	ND-0.05	0.05	—	<0.2
Boron	ND-1.0	0.29	—	0.3
Cadmium	ND-0.01	0.01	<0.01	<0.005
Chromium	ND-0.014	0.006	—	0.01
Copper	ND-0.028	0.015	0.002	0.012
Fluoride	0.04-0.60	0.32	0.37	<0.1
Iron	ND-1.11	0.42	5.04	5.2
Lead	ND-0.05	0.010	0.02	<0.005
Manganese	0.10-0.34	0.22	0.18	0.19
Mercury	0.0001	0.0001	—	<0.0001
Molybdenum	0.01	0.004	—	<0.005
Nickel	Not Taken		0.02	0.05
Selenium	0.01	0.01	—	<0.005
Vanadium	ND-0.05	0.05	0.09	0.074
Zinc	ND-0.04	0.02	0.02	0.021
Silicon (SiO_2)	3,0-8.0	5.7	20.6	26.0
Radiochemistry				
Uranium as U_3O_8	0.015-0.750	0.239	0.011	0.038
Radium-226	19-717	233	13	11
Thorium-230	ND-5.1	3.4	0.2	2.2

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NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

TABLE P2-6

NINE MILE LAKE
PATTERN 2
M-20

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/8/82	CDM 2/8/82	NML 3/9/82	NML 4/8/82	NML 5/6/82
pH	6.4-6.9	6.7	6.8	7.2	6.6	6.8	6.4
Conductivity	1950-4000	3339	3100	3200	3500	3600	3600
Major Constituents							
Bicarbonate	256-315	257	279	246	304	297	290
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	229	204	249	243	238
Calcium	50-160	111	88	89	111	109	118
Chloride	9-80	46	30	29	35	35	49
Magnesium	12-129	76	56	61	73	72	73
Potassium	7.5-30.0	14.8	10.9	8.0	11.6	11.4	11.3
Sodium	520-840	674	558	570	710	748	694
Sulfate	1120-2800	1769	1379	1490	1857	1728	1921
TDS	2028-3486	2852	2220	2330	2860	2849	3120
Anion/Cation		102	102	104	98	103	96
Minor Constituents							
Ammonia as N	ND-0.48	0.08	----	<0.2			
Nitrate as N	ND-0.6	0.26	----	<0.05			
Nitrite as N	ND-0.04	0.05	----	<0.05			
Aluminum	ND-0.2	0.13	0.42	<0.5			
Arsenic	ND-0.01	0.01	----	<0.005			
Barium	ND-0.05	0.05	----	<0.2			
Boron	ND-1.0	0.29	----	0.3			
Cadmium	ND-0.01	0.01	<0.01	0.005			
Chromium	ND-0.014	0.006	----	0.01			
Copper	ND-0.028	0.015	0.017	0.010			
Fluoride	0.04-0.60	0.32	0.57	0.2			
Iron	ND-1.11	0.42	0.48	0.33	0.37	0.62	0.43
Lead	ND-0.05	0.010	0.07	<0.005			
Manganese	0.10-0.34	0.22	0.14	0.14			
Mercury	0.0001	0.0001	----	<0.0001			
Molybdenum	0.01	0.004	----	<0.005			
Nickel	Not Taken		0.02	0.04			
Selenium	0.01	0.01	----	<0.005			
Vanadium	ND-0.05	0.05	0.03	0.25	0.01	0.013	0.03
Zinc	ND-0.04	0.02	0.01	0.026			
Silicon (SiO_2)	3.0-8.0	5.7	7.2	8.0			
Radiochemistry							
Uranium as U_3O_8	0.015-0.750	0.239	0.279	0.283	0.326	0.339	0.389
Radium-226	19-717	233	146	130			180
Thorium-230	ND-5.1	3.4	1.4	0.6			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm),
pH (standard units) and radionuclides (pCi/l).

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TABLE P2-7

NINE MILE LAKE
PATTERN 2
M-21

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/3/82	CDM 2/3/82	NML 3/10/82	NML 4/8/82	NML 5/6/82
pH	6.4-6.9	6.7	6.6	7.0	6.7	6.7	6.4
Conductivity	1950-4000	3339	2750	2800	2600	2600	2700
Major Constituents							
Bicarbonate	256-315	257	283	239	287	281	281
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	232	198	235	230	230
Calcium	50-160	111	87	80	88	88	113
Chloride	9-80	46	29	26	32	35	46
Magnesium	12-129	76	47	51	47	57	58
Potassium	7.5-30.0	14.8	9.6	7.0	9.8	9.5	9.3
Sodium	520-840	674	564	550	524	544	533
Sulfate	1120-2800	1769	1332	1300	1263	1253	1427
TDS	2028-3486	2852	2200	2060	2120	2175	2260
Anion/Cation		102	101	98	99	102	97
Minor Constituents							
Ammonia as N	ND-0.48	0.08	----	<0.2			
Nitrate as N	ND-0.6	0.26	----	<0.05			
Nitrite as N	ND-0.04	0.05	----	<0.05			
Aluminum	ND-0.2	0.13	0.52	0.6			
Arsenic	ND-0.01	0.01	----	<0.005			
Barium	ND-0.05	0.05	----	<0.2			
Boron	ND-1.0	0.29	----	0.4			
Cadmium	ND-0.01	0.01	0.01	<0.005			
Chromium	ND-0.014	0.006	0.03	0.01			
Copper	ND-0.028	0.015	----	0.010			
Fluoride	0.04-0.60	0.32	0.7	0.2			
Iron	ND-1.11	0.42	0.56	0.26	0.29	0.46	0.36
Lead	ND-0.05	0.010	0.07	<0.005			
Manganese	0.10-0.34	0.22	----	0.13			
Mercury	<0.0001	0.0001	----	<0.0001			
Molybdenum	<0.01	0.004	----	<0.005			
Nickel	Not Taken	----	0.01	0.06			
Selenium	ND-0.01	0.01	----	0.005			
Vanadium	ND-0.05	0.05	1.10	1.6	0.91	1.573	1.92
Zinc	ND-0.04	0.02	0.06	0.10			
Silicon (SiO_2)	3.0-8.0	5.7	7.8	8.0			
Radiochemistry							
Uranium as U_3O_8	0.015-0.750	0.239	0.198	0.165	0.150	0.122	0.181
Radium-226	19-717	233	286	270			280
Thorium-230	ND-5.1	3.4	12	2.3			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P2-8

NINE MILE LAKE
PATTERN 2
M-22

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/5/82	CDM 2/5/82	NML 3/10/82	NML 4/8/82	NML 5/6/82
pH	6.4-6.9	6.7	6.6	7.1	6.7	6.7	6.6
Conductivity	1950-4000	3339	3100	3000	3000	2900	2900
Major Constituents							
Bicarbonate	256-315	257	262	214	273	260	268
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	215	177	224	213	220
Calcium	50-160	111	96	95	107	101	116
Chloride	9-80	46	31	26	32	35	42
Magnesium	12-129	76	68	66	57	68	68
Potassium	7.5-30.0	14.8	10.9	8.1	11.0	10.3	10.1
Sodium	520-840	674	606	600	545	556	581
Sulfate	1120-2800	1769	1546	1500	1408	1277	1468
TDS	2028-3486	2852	2540	2310	2294	2175	2460
Anion/Cation		102	101	97	99	105	101
Minor Constituents							
Ammonia as N	ND-0.48	0.08	----	<0.2			
Nitrate as N	ND-0.6	0.26	----	<0.05			
Nitrite as N	ND-0.04	0.05	----	<0.05			
Aluminum	ND-0.2	0.13	0.32	<0.5			
Arsenic	ND-0.01	0.01	----	<0.005			
Barium	ND-0.05	0.05	----	<0.2			
Boron	ND-1.0	0.29	----	0.1			
Cadmium	ND-0.01	0.01	<0.01	0.005			
Chromium	ND-0.014	0.006	----	0.01			
Copper	ND-0.028	0.015	0.017	0.013			
Fluoride	0.04-0.60	0.32	0.62	0.2			
Iron	ND-1.11	0.42	0.55	0.38	0.33	0.56	0.45
Lead	ND-0.05	0.010	0.05	<0.005			
Manganese	0.10-0.34	0.22	0.18	0.17			
Mercury	<0.0001	0.0001	----	<0.0001			
Molybdenum	<0.01	0.004	----	0.005			
Nickel	Not Taken	0.02	0.03	<0.07			
Selenium	<0.01	0.01	----	<0.005			
Vanadium	ND-0.05	0.05	0.17	0.20	0.01	0.013	0.05
Zinc	ND-0.04	0.02	0.01	0.018			
Silicon (SiO_2)	3.0-8.0	5.7	7.9	9.0			
Radiochemistry							
Uranium as U_3O_8	0.015-0.750	0.239	0.016	0.032	0.023	0.008	0.035
Radium-226	19-717	233	372	220			210
Thorium-230	ND-5.1	3.4	0.5	0.8			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P2-9

NINE MILE LAKE
PATTERN 2
M-23

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/5/82	CDM 2/5/82	NML 3/10/82	NML 4/8/82	NML 5/7/82
pH	6.4-6.9	6.7	6.7	7.0	6.7	6.7	6.1
Conductivity	1950-4000	3339	2700	2800	2600	2500	2900
Major Constituents							
Bicarbonate	265-315	257	277	232	289	282	139
Carbonate	0-0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	210-258	228	227	192	237	231	114
Calcium	50-160	111	74	72	87	79	144
Chloride	9-80	46	31	25	32	35	49
Magnesium	12-129	76	44	48	52	48	47
Potassium	7.5-30.0	14.8	9.5	6.9	9.9	9.5	10.9
Sodium	520-840	674	526	460	513	517	490
Sulfate	1120-2800	1769	1215	1220	1210	1235	1480
TDS	2028-3486	2852	2100	1930	2040	2063	2460
Anion/Cation		102	101	107	101	99	97
Minor Constituents							
Ammonia as N	ND-0.48	0.08	----	<0.2			
Nitrate as N	ND-0.6	0.26	----	<0.05			
Nitrite as N	ND-0.04	0.05	----	<0.05			
Aluminum	ND-0.2	0.13	0.14	<0.5			
Arsenic	ND-0.01	0.01	----	<0.005			
Barium	ND-0.05	0.05	----	<0.2			
Boron	ND-1.0	0.29	----	0.1			
Cadmium	ND-0.01	0.01	<0.01	<0.005			
Chromium	ND-0.014	0.006	----	0.01			
Copper	ND-0.028	0.015	0.005	0.013			
Fluoride	0.04-0.60	0.32	0.60	0.2			
Iron	ND-1.11	0.42	0.28	0.38	0.16	0.27	3.54
Lead	ND-0.05	0.010	0.06	0.005			
Manganese	0.10-0.34	0.22	0.11	0.17			
Mercury	<0.0001	0.0001	----	<0.0001			
Molybdenum	<0.01	0.004	----	<0.005			
Nickel	Not Taken	----	0.03	0.07			
Selenium	<0.01	0.01	----	<0.005			
Vanadium	0.05	0.05	0.34	0.20	0.14	0.102	0.03
Zinc	0.04	0.02	0.02	0.018			
Silicon (SiO_2)	3.0-8.0	5.7	8.3	9.0			
Radiochemistry							
Uranium as U_3O_8	0.015-0.750	0.239	0.224	0.271	0.253	0.250	0.055
Radium-226	19-717	233	301	220			18
Thorium-230	ND-5.1	3.4	1.3	1.0			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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which is below DEQ standards of 5 mg/l for Class II and III groundwater Vanadium levels were reduced to less than 2 mg/l which is within the baseline range calculated from regional monitor wells completed in the Teapot sandstone (see Table 1.4).

Well monitoring since February 1982 confirms that water quality within the pattern interior has remained fairly stable over a four month period. Sodium, sulfate, TDS, iron, vanadium, and uranium levels actually appear to be decreasing in the central production well, P-15 (see Table P2-1). Injection well I-17 has shown an apparent increase in sodium, sulfate, TDS, and iron concentrations suggesting that the process of chemical equilibrium is occurring in the pattern interior. Data analysis indicates no significant trends and all parameters remain within baseline ranges.

Samples obtained from monitor well M-21 over a four month period following final restoration also indicate stability. Calculations performed prior to the phase 4 restoration program indicated that 90 to 95 percent of all leaching induced contamination had been removed by the first three restoration attempts. Computer modeling of leaching restoration flow nets implied residual contaminants were concentrated in small pods which gradually migrated downdip during shutdown periods. Stabilization monitoring of monitor wells M-21 and M-22 through May 1982 indicates a substantial volume of residual affected groundwater was recovered in the final restoration phase. Any

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remaining "pods" of affected groundwater would, therefore, constitute less than 5 percent of total groundwater volume affected by leaching.

2.4 Pattern 2 Conclusions

Results of Pattern 2 groundwater restoration efforts clearly represent a substantial improvement in acid restoration technology from the first test pattern. Nearly all major parameters were restored to premining ranges during the initial restoration program. In fact, restoration was believed to be successful enough to fulfill regulatory agency demonstrated restoration requirements for a commercial scale facility.

In September of 1979 when initial restoration was complete, DEQ and NRC had no definitive restoration criteria for R&D uranium solution mining operations. Approval to begin Pattern 3 leaching was contingent upon submittal of data "showing that restoration (of Pattern 2) is close." On September 21, 1979, written authorization to proceed with Pattern 3 testing was received from the DEQ based on information and water quality data concerning Pattern 2 restoration presented to the DEQ in a September 6, 1979, meeting. It was RME's understanding that this action constituted DEQ approval of Pattern 2 restoration. See Section 6.1 and Appendix E for referenced materials.

Subsequent Pattern 2 restoration activities were conducted entirely through RME initiative and were designed to

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supplement the original program by addressing portions of the pattern previously considered restored. The data presented in this report confirms that remedial actions were generally quite effective and have resulted in restoration of affected groundwater to a condition and quality consistent with premining use suitability.

3.0 Operational History - Pattern 3

Favorable results of Pattern 2 leaching and restoration tests warranted additional investigation as to the feasibility of mining the Teapot on a production scale basis with an acidic leach solution. The ore body at Nine Mile Lake frequently occurs as "stacked" ore zones separated by a semipermeable lignite-shale zone within the host sandstone. A primary purpose of the Pattern 3 test was to evaluate the feasibility of simultaneous upper and lower ore zone production. Secondary objectives were to test different well completion procedures and the effectiveness of a seven spot pattern using greater well spacing intervals.

The pattern was constructed with six injection wells surrounding two central production wells at a radius of 60 feet. Injection wells were completed by selective hydraulic perforation and slotting in both ore zones. Production wells were completed independently with one in the upper ore zone (well P-53) and another in the lower ore zone (well P-50).

Monitor wells were completed by screening the lower zones and perforating in the upper ore zone. Segregation of well

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completion intervals was not considered necessary as previous experience and preliminary Pattern 3 hydrologic studies indicated a negligible potential for leakage between upper and lower zones. through the lignite-shale zone. Monitor wells were installed approximately 100 feet from the injection well ring. The close proximity of injection and monitor wells was necessary due to permit area restrictions; ideally monitor wells should have been at least 150 to 200 feet from the injection well ring.

3.1 Pattern 3 Leaching

Following a short period of pretreatment, leaching began the first week of September 1979 using a sulfuric acid lixiviant. Total injection flow rates were set at 58 gpm with the flow evenly split among the 6 injection wells. Injection streams were controlled with one flow and pressure monitoring system per well. Because upper and lower ore zone permeabilities were very similar, injection flow streams were expected to split evenly between upper and lower ore zones. Production rates were initially maintained at 60 gpm with half the flow coming from the upper ore zone (well P-53) and half from the lower ore zone (well P-50).

By late September, uranium head grades were rising rapidly in P-50 (lower zone) production fluid but not the upper zone (P-53) which suggested injection flow rates were possibly imbalanced. The pattern was shut down October 1 for additional hydrology testing.

Vertical flow profile tests had been planned prior to

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leaching but not performed due to equipment availability. During the first week of October, necessary equipment arrived on site and vertical flow profile tests were conducted on all wells. Test results revealed that injection flow rates were not balanced between upper and lower ore zones in all injection wells. Flow rates into the upper ore zone were found to be significantly greater than those into the lower ore zone.

Plans were made to isolate upper and lower ore zone injection streams. Packers and flow measuring equipment were ordered while dual zone injection continued as before. By October 24, packing equipment had arrived and installation began.

The lower ore zone was isolated by installing mechanical packers at the top of the ore interval and running two inch heavy duty PVC piping through the packers for injection purposes. Upper zone injection was accomplished by running a two inch stringer through the well head and injecting between the five inch casing and lower zone injection piping.

Almost immediately after resuming dual zone injection, wells began pressuring up in the lower ore zone. After several days, injection was discontinued, packers were pulled, and the wells airlifted. Material removed during airlifting indicated a fungus growth had plugged up the lower zone completion interval causing wells to pressure up and most of the injection flow to go into the upper ore zone. This period of unbalanced injection flow probably reinforced earlier injection flow patterns resulting in

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an expanded upper ore flow net.

Routine sampling of pattern monitor wells showed evidence of an excursion occurrence in two wells, M-40 and M-43, on November 13, 1979. Figure 3.1 shows the location and configuration of Pattern 3 wells. Repeat sampling confirmed the presence of excursion indicator parameters at concentrations above upper control limits and notification of excursion status given to the NRC and DEQ on November 16.

Injection rates had been reduced in three injection wells on the M-40 (northeast) side of the pattern following the November 13 sampling. On the 15th, all injection was stopped and production from both ore zones increased while M-40 and M-43 were resampled. Selective ore zone sampling of both wells indicated only the upper ore zone was in excursion status which was later confirmed by additional sampling and the completion of two new monitor wells. Appendix C contains a detailed chronology of excursion confirmation and corrective actions taken.

For the purposes of this report, it is adequate to know that the excursion occurrence was confined to the upper ore zone and remedial actions were effective in controlling the event. By early December, water quality in wells M-40 and M-43 had improved considerably as had groundwater in the new upper ore zone monitor well (M-40B). Limited production from the lower ore zone was resumed December 6 with total injection flows of about 20 gpm and

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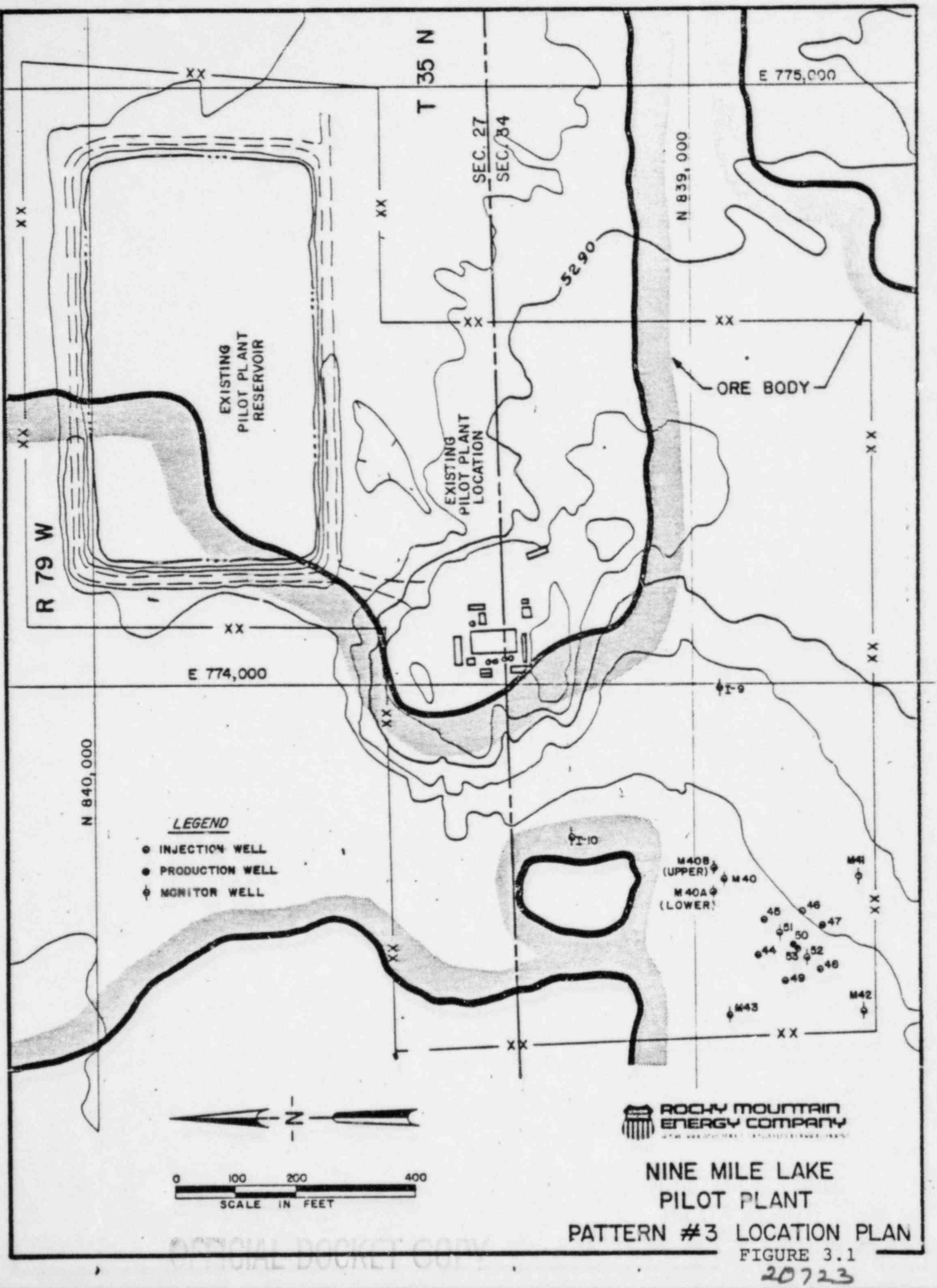

ROCKY MOUNTAIN ENERGY COMPANY

NINE MILE LAKE
PILOT PLANT
PATTERN #3 LOCATION PLAN

FIGURE 3.1

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no injection on the M-40 side of the pattern. A pumping rate of 5 to 20 gpm was maintained from the upper ore zone (P-53) throughout November and December to retrieve outlying flow streams.

A variety of oxidants were tested in the lower ore zone during the first quarter of 1980. Sporadic problems were encountered with well plugging, frozen lines, and equipment failures. Although uranium head grades from the lower ore zone were satisfactory, they were substantially lower than average Pattern 2 head grades. Upper ore zone headgrades averaged only 20 to 30 ppm uranium.

Attempts to resume an upper/lower ore zone production balance met with little success. Throughout January of 1980, pumping from the upper zone was maintained at 5 gpm with no injection while lower ore zone production averaged 22 gpm. During February and March, production from the lower zone continued while different oxidants were tested. By March 24, all acid injection was discontinued and on April 1, 1980, all injection into the pattern was terminated. Production continued at 5 gpm from each ore zone in order to maintain a hydraulic gradient while project development alternatives were considered.

Because of difficulties experienced with restoration of previous acid test patterns, it was decided to test a carbonate leach solution in a new test pattern. A request to defer Pattern 3 restoration was granted by the DEQ and NRC with the understanding that RME would restore the pattern following the

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carbonate leach test. RME proposed to restore Pattern 3 by means of a groundwater sweep if the carbonate test (Pattern 4) proved successful or by some procedure suitable for a production scale operation if the test were unsuccessful. Consequently, Pattern 3 was placed in a "hold" mode which continued from April 1, 1980, until August 1981. During this time, an average bleed of 10 gpm was maintained with occasional adjustments to control solution migration.

3.2 Pattern 3 Restoration

Disappointing results from the carbonate leach test prompted a reevaluation of the geologic resource at Nine Mile Lake as well as the feasibility of a commercial mine. In June of 1981, RME concluded that a viable project would be questionable considering uranium market conditions, technological limitations of restoration techniques, and regulatory agency requirements for demonstrating restoration. License applications for a production scale facility were withdrawn and Pattern 3 restoration plans developed.

Computer modeling of proposed restoration schemes indicated groundwater would be restored most effectively by using a modified groundwater sweep combined with reinjection of treated water.

The first program objective was to consolidate peripheral groundwater affected during mining within the pattern interior. This was done by simultaneous injection of "clean"

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water in wells located beyond areas affected during mining and pumping affected groundwater from the pattern interior. A series of new wells (WF-69 through WF-72) were completed in both ore zones along an arc bordering the northeast quadrant of the pattern forming a "water fence." Refer to Figure 1.1 in Section 1 for well locations. Monitor wells M-40A and M-40B were also incorporated in the water fence to provide overlapping injection flow nets, thus prevently any outward movement of affected groundwater. In addition to sweeping down gradient portions of the pattern contaminated during leaching, the water fence wells were designed to create a hydraulic barrier between Patterns 3 and 4.

Restoration began August 25, 1981, and continued through January 1982. Production was started at about 40 gpm and gradually increased to 70 gpm during the first month of operation. Production was primarily from wells P-50 and P-53, but injection wells were also pumped on a rotating basis. Production fluid was routed to an RO unit, the product combined with "clean" formation water and reinjected in the water fence wells at a rate of 7 to 8 gpm per well. Figure 3.2 shows the water treatment circuit which incorporated a lime precipitation/reaction process, in addition to the RO unit, for treating RO reject and Pattern 2 production fluid prior to discharge. Table 3.1 describes Pattern 3 water quality for key parameters before restoration began.

Note that lower zone water quality shows greater effects of prolonged contact with acid lixiviant (e.g., low pH, high van-

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NINE MILE LAKE PILOT PROJECT
REVERSE OSMOSIS - LIME CIRCUITS
FINAL RESTORATION

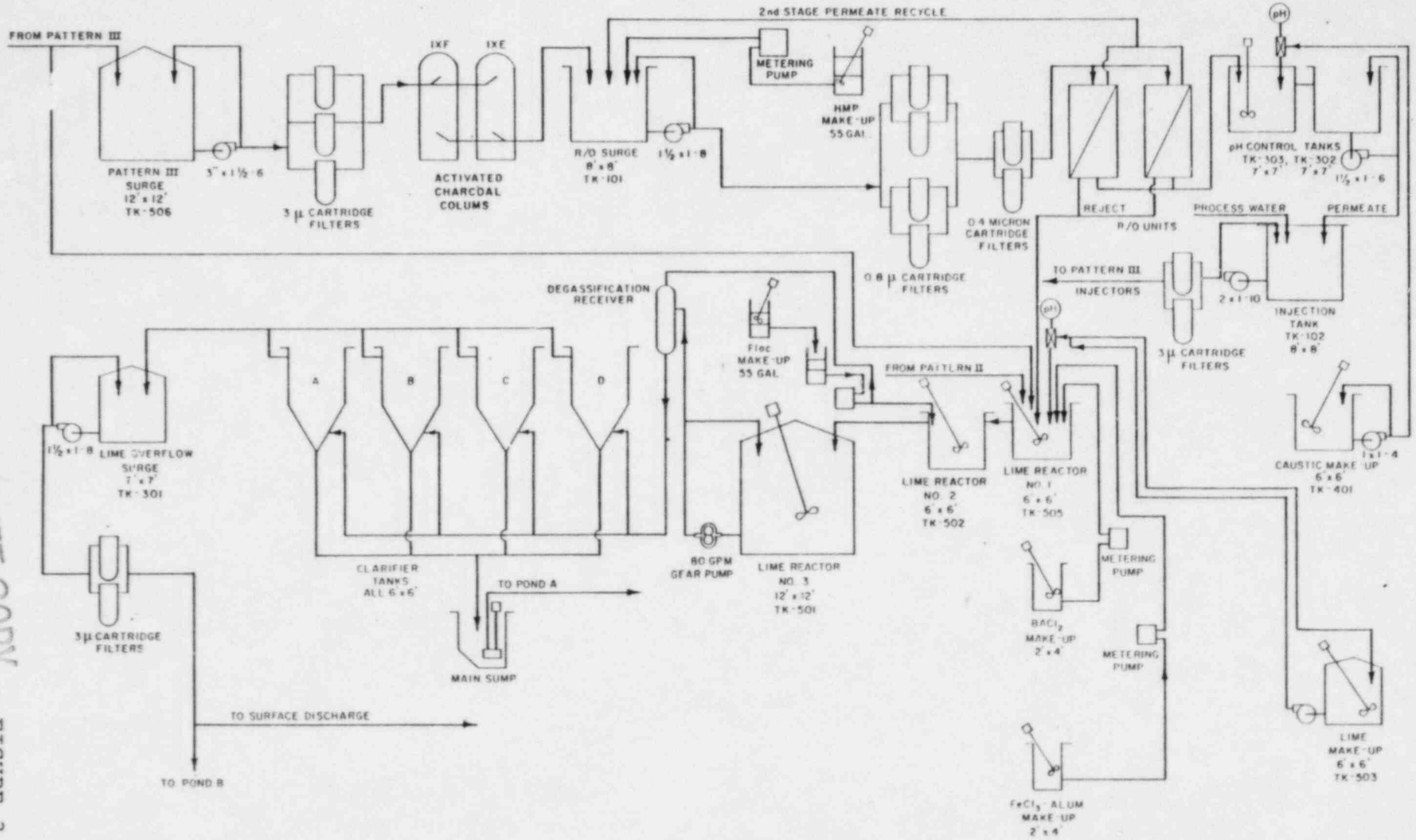

FIGURE 3.2

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adium, and uranium) than the upper zone which would be expected since upper zone leaching was terminated earlier than lower zone.

Table 3.1

Pattern 3 Water Quality
Prerestoration (August 1981)

Parameter	Baseline Range	Well Number Px50 (lower)	P-53 (upper)	I-45 (injector)	M-40 (monitor)
pH	6.4-7.2	4.6	5.1	5.4	6.5
Ca	41-135	49	82	-	89
Fe	0.01-4.10	2.9	3.4	2.3	0.37
Na	310-863	354	486	-	543
SO_4	628-2,826	964	1,371	1,532	1,244
TDS	1,380-3,320	1,640	2,260	2,420	2,080
V	0.01-0.45	7.2	3.8	2.9	0.79
U_3O_8	0.002-0.200	0.876	0.295	0.280	0.195

Note: All values reported as mg/l except pH (standard units).

Restoration continued from September through December using the water fence wells for injection while pumping from various combinations of the 2 production and 6 injection wells. Pumping from the pattern interior was continually adjusted to facilitate clean up of heavily contaminated areas by frequently monitoring production fluid and monitor well water quality. By early December, it appeared that affected groundwater around the pattern edges had been effectively drawn into the pattern interior by the push-pull sweep action.

During the second half of December, the water fence was shut down except wells M-40 and M-40B. Injection lines were moved to interior wells I-44, I-46, I-47, and I-49 to facilitate an effective sweep of the pattern interior. Production was continued

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from wells P-50, P-53, and whichever injections wells were not being used as producers. This operational mode continued at a production rate of 55 to 70 gpm until February 2, 1982, when restoration was terminated.

A total of 14.6 million gallons (5.8 PV) were produced from the pattern during restoration; nearly identical to production during leaching (5.6 PV). Table 3.2 summarizes the water balance during leaching, "hold" and restoration operations. Although more than 7 million gallons were produced during the "hold" phase, limited clean up of the pattern resulted due to the very low (5 to 10 gpm) pumping rates.

The entire restoration program was far more successful than previous efforts. The modified groundwater sweep using the water fence injection wells performed as predicted by computer modeling. Restoration of affected groundwater to the goal of original use suitability was accomplished with a number of pore volumes similar to that for mining, within a time period of less than six months.

3.3 Post Restoration Water Quality

All groundwater constituents have been restored to pattern baseline levels or better except vanadium and radium in some interior wells. Table P3-1 through P3-13 present assay results from the February sampling of all pattern wells.

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Table 3.2

Pattern 3
Water Balance Summary

OPERATIONAL MODE	PRODUCTION (GAL.)	PORE[1] VOLUMES	INJECTION (GAL.)	PORE VOLUMES	NET PRODUCTION (GAL.)
Pretreatment & Leaching (7/79 - 3/80)	14,092,084	5.6	11,032,772	4.4	3,447,522
Holding Phase (4/80 - 7/81)	7,404,709	2.9	0	0	7,404,709
Restoration (8/81 - 2/82)	14,680,577	5.8	11,800,916	4.7	2,880,241
Totals	36,177,370	14.3	22,833,688	9.1	13,732,472

One Pore Volume = 2,527,000 gallons.

Total number of restoration pore volumes = 107% of mining pore volumes.

TABLE P3-1

NINE MILE LAKE
PATTERN 3
PRODUCTION WELL 50

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML PRE-FENCE 08/27/81	NML POST-FENCE 12/15/81	NML POST-SWEEP 02/02/82	CDM POST-SWEEP 02/02/82	NML 03/08/82	NML 04/15/82	NML 05/09/82
Field									
pH	6.4-7.2	6.9	4.6	6.1	6.4	7.7	6.3	6.3	6.5
Conductivity	1375-3500	2381	2700	2100	1600	2000	1600	1640	1600
Major Constituents									
Bicarbonate	224-426	328	17	40	104	81	121	131	134
Carbonate	0	0	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	14	33	85	67	98	107	110
Calcium	41-135	74	49	58	21	30	34	36	35
Chloride	20-55	35	29	27	20	25	23	27	32
Magnesium	13-71	35	36	29	22	22	23	20	20
Potassium	5.9-16.0	10.4	9.0	7.6	6.9	5.0	7.1	6.7	6.0
Sodium	310-863	506	354	320	310	280	321	290	287
Sulfate	628-2826	1244	964	770	675	664	651	615	656
TDS	1380-3320	2034	1640	1520	1200	1060	1118	1059	1100
Anion/Cation					99	104	105	102	98
Minor Constituents									
Ammonia as N	0.10-0.33	0.15	--		----	<0.2			
Nitrate as N	0.10-0.93	0.21	--		----	<0.05			
Nitrite as N	0.02-0.06	0.02	--		----	<0.05			
Aluminum	0.05-0.88	0.18	0.95		0.21	<0.5			
Arsenic	0.01-0.04	0.02	--		----	0.008			
Barium	0.05-0.10	0.05	--		----	<0.2			
Boron	0.05-0.49	0.20	--		----	0.2			
Cadmium	<0.01	<0.02	<0.01		0.01	<0.005			
Chromium	0.01-0.03	0.01	0.06		----	0.01			
Copper	0.01-0.02	<0.01	0.01		----	0.005			
Fluoride	0.10-1.07	0.64	--		0.5	0.1			
Iron	0.01-4.10	1.02	2.9	0.8	0.72	0.46	0.69	0.74	0.89
Lead	0.01-0.05	0.02	0.04		0.05	<0.005			
Manganese	0.03-0.87	0.22	0.11		0.58	0.049			
Mercury	<0.0001	<0.0001	--		----	<0.0001			
Molybdenum	<0.01	<0.01	0.49		----	0.008			
Nickel	0.01-0.19	0.02	0.05		0.05	0.03			
Selenium	0.01-0.04	0.02	--		----	0.045			
Vanadium	0.01-0.45	0.18	7.2	1.8	0.61	0.83	5.90	2.275	0.65
Zinc	0.01-0.04	0.02	0.36		0.04	0.067			
Silicon (SiO_2)	1.0-15.0				18.7	18			
Radiochemistry									
Uranium as U_3O_8	0.002-0.200	0.060	0.876	0.350	0.163	0.212	0.263	0.123	0.114
Radium-226	1.5-274	100	682	596	666	560	3460		3400
Thorium-230	0.5-41.9	6	21.0	21	2.7	6.8	28.1		

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).
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TABLE P3-2

NINE MILE LAKE
PATTERN 3
PRODUCTION WELL 53

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML PRE-FENCE 08/27/81	NML POST-FENCE 12/15/81	NML POST-SWEEP 02/02/82	(SPLIT) NML POST-SWEEP 02/02/82	CDM POST-SWEEP 02/02/82	NML 03/09/82	NML 04/15/82	NML 05/06/82
Field										
pH	6.4-7.2	6.9	5.1	5.4	6.0	(6.0)	7.4	5.8	5.7	5.6
Conductivity	1375-3500	2381	2200	1975	1450	(1450)	1800	1625	1575	1550
Major Constituents										
Bicarbonate	224-426	328	33	Trace	51	(51)	36	57	57	54
Carbonate	0	0	0	0	0	(0)	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	27	Trace	42	(42)	30	48	48	44
Calcium	41-135	74	82	46	24	(23)	24	25	26	26
Chloride	20-55	35	33	31	18	(18)	20	21	27	31
Magnesium	13-71	35	51	19	21	(20)	20	16	16	18
Potassium	5.9-16.0	10.4	11.4	7.3	6.7	(6.6)	5.0	6.5	6.8	6.0
Sodium	310-863	506	486	295	288	(318)	290	283	291	278
Sulfate	628-2826	1244	1371	807	694	(707)	662	644	694	728
TDS	1380-3320	2034	2260	1400	1140	(1100)	1010	1000	1090	1160
Anion/Cation					101	96	99	100	98	94
Minor Constituents										
Ammonia as N	0.10-0.33	0.15	--		----	----	<0.2			
Nitrate as N	0.10-0.93	0.21	--		----	----	0.06			
Nitrite as N	0.02-0.06	0.02	--		----	----	<0.05			
Aluminum	0.05-0.88	0.18	3.75		0.35	(0.45)	<0.5			
Arsenic	0.01-0.04	0.02	--		----	----	0.018			
Barium	0.05-0.10	0.05	--		----	----	<0.2			
Boron	0.05-0.49	0.20	--		----	----	0.2			
Cadmium	<0.01	<0.02	<0.01		0.01	(0.01)	<0.005			
Chromium	0.01-0.03	0.01	0.06		0.01	(0.04)	<0.01			
Copper	0.01-0.02	<0.01	<0.01		----	----	<0.005			
Fluoride	0.10-1.07	0.64	--		0.30	(0.32)	0.1			
Iron	0.01-4.10	1.02	3.4	0.5	0.25	(0.47)	0.25	1.49	3.16	2.60
Lead	0.01-0.05	0.02	0.09		0.05	(0.02)	<0.005			
Manganese	0.03-0.87	0.22	0.26		0.49	(0.53)	0.045			
Mercury	<0.0001	<0.0001	--		----	----	<0.0001			
Molybdenum	<0.01	<0.01	0.17		----	----	<0.005			
Nickel	0.01-0.19	0.02	0.10		0.08	(0.02)	0.03			
Selenium	0.01-0.04	0.02	--		----	----	0.126			
Vanadium	0.01-0.45	0.18	3.84	1.4	0.99	(1.10)	1.38	1.77	2.379	1.40
Zinc	0.01-0.04	0.02	0.39		0.08	(0.06)	0.099			
Silicon (SiO_2)	1.0-15.0				12.1	(12.1)	13			
Radiochemistry										
Uranium as U_3O_8	0.002-0.200	0.060	0.295	0.1000	.067	(0.085)	0.071	0.115	0.141	0.140
Radium-226	1.5-274	100	457	469	466	----	310	613		710
Thorium-230	0.5-41.9	6	37.4	12	2.9	----	7.2	25.7		

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).
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TABLE P3-4

NINE MILE LAKE
PATTERN 3
I-46

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/24/82	CDM 2/24/82	NML 3/10/82	NML 4/9/82	NML 5/9/82
pH	6.4-7.2	6.9	7.1	7.1	7.0	6.9	6.9
Conductivity	1375-3500	2381	1800	2200	1950	1920	1825
Major Constituents							
Bicarbonate	224-426	328	207	162	218	284	199
Carbonate	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	170	134	179	167	163
Calcium	41-135	74	46	51	67	54	57
Chloride	20-55	35	26	18	26	27	31
Magnesium	13-71	35	30	30	33	29	32
Potassium	5.9-16.0	10.4	6.0	4.4	7.2	6.9	6.4
Sodium	310-863	506	297	300	372	345	336
Sulfate	628-2826	1244	710	719	845	777	758
TDS	1380-3320	2034	1222	1170	1420	1340	1320
Anion/Cation			106	100	101	100	101
Minor Constituents							
Ammonia as N	0.10-0.33	0.15	----	<0.2			
Nitrate as N	0.10-0.93	0.21	----	<0.05			
Nitrite as N	0.02-0.06	0.02	----	<0.05			
Aluminum	0.05-0.88	0.18	0.55	0.9			
Arsenic	0.01-0.04	0.02	----	<0.005			
Barium	0.05-0.10	0.05	0.18	<0.2			
Boron	0.05-0.49	0.20	----	0.2			
Cadmium	<0.01	0.02	0.01	<0.005			
Chromium	0.01-0.03	0.01	----	<0.01			
Copper	0.01-0.02	0.01	0.011	0.005			
Fluoride	0.10-1.07	0.64	0.25	<0.1			
Iron	0.01-4.10	1.02	2.55	2.1	1.55	2.25	1.22
Lead	0.01-0.05	0.02	0.08	0.020			
Manganese	0.03-0.87	0.22	0.18	0.120			
Mercury	<0.0001	0.0001	----	<0.0001			
Molybdenum	<0.01	0.01	----	<0.005			
Nickel	0.01-0.19	0.02	0.04	0.02			
Selenium	0.01-0.04	0.02	----	0.014			
Vanadium	0.01-0.45	0.18	0.47	0.37	0.31	0.13	0.16
Zinc	0.01-0.04	0.02	0.07	0.058			
Silicon (SiO_2)	1.0-15.0		11.5	12			
Radiochemistry							
Uranium as U_3O_8	0.002-0.200	0.060	0.049	0.058	0.228	0.040	0.017
Radium-226	1.5-274	100	311	320			280
Thorium-230	0.5-41.9	6	86.3	120			

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-5

NINE MILE LAKE
PATTERN 3
I-44

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/19/82	CDM 2/19/82
pH	6.4-7.2	6.9	7.0	7.0
Conductivity	1375-3500	2381	2700	3000
Major Constituents				
Bicarbonate	224-426	328	257	180
Carbonate	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	211	145
Calcium	41-135	74	54	89
Chloride	20-55	35	43	25
Magnesium	13-71	35	54	55
Potassium	5.9-16.0	10.4	8.3	6.6
Sodium	310-863	506	478	430
Sulfate	628-2826	1244	1080	1100
TDS	1380-3320	2034	1846	1770
Anion/Cation			99	105
Minor Constituents				
Ammonia as N	0.10-0.33	0.15	----	<0.2
Nitrate as N	0.10-0.93	0.21	----	<0.05
Nitrite as N	0.02-0.06	0.02	----	<0.05
Aluminum	0.05-0.88	0.18	0.07	<0.5
Arsenic	0.01-0.04	0.02	----	<0.005
Barium	0.05-0.10	0.05	0.15	<0.2
Boron	0.05-0.49	0.20	----	0.2
Cadmium	<0.01	<0.02	0.01	0.007
Chromium	0.01-0.03	0.01	----	0.01
Copper	<0.01-0.02	<0.01	0.019	0.006
Fluoride	0.10-1.07	0.64	0.48	0.1
Iron	0.01-4.10	1.02	0.06	0.38
Lead	0.01-0.05	0.02	0.05	0.027
Manganese	0.03-0.87	0.22	0.21	0.178
Mercury	<0.0001	<0.0001	----	<0.0001
Molybdenum	<0.01	<0.01	----	<0.005
Nickel	0.01-0.19	0.02	0.04	0.04
Selenium	0.01-0.04	0.02	----	0.010
Vanadium	0.01-0.45	0.18	0.13	0.19
Zinc	0.01-0.04	0.02	0.15	0.105
Silicon (SiO_2)	1.0-15.0		10.7	10
Radiochemistry				
Uranium as U_3O_8	0.002-0.200	0.060	0.089	0.099
Radium-226	1.5-274	100	319	200
Thorium-230	0.5-41.9	6	5.6	5.4

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-6

NINE MILE LAKE
PATTERN 3
I-45

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/24/82	CDM 2/24/82
pH	6.4-7.2	6.9	6.4	6.7
Conductivity	1375-3500	2381	1550	1800
Major Constituents				
Bicarbonate	224-426	328	104	77
Carbonate	0	0	0	0
Alkalinity as $CaCO_3$	184-426	270	85	63
Calcium	41-135	74	30	33
Chloride	20-55	35	23	18
Magnesium	13-71	35	19	17
Potassium	5.9-16.0	10.4	9.4	7.7
Sodium	310-863	506	258	260
Sulfate	628-2826	1244	599	615
TDS	1380-3320	2034	990	974
Anion/Cation			102	100
Minor Constituents				
Ammonia as N	0.10-0.33	0.15	----	<0.2
Nitrate as N	0.10-0.93	0.21	----	<0.05
Nitrite as N	0.02-0.06	0.02	----	<0.05
Aluminum	0.05-0.88	0.18	0.28	<0.5
Arsenic	0.01-0.04	0.02	----	0.007
Barium	0.05-0.10	0.05	0.23	<0.2
Boron	0.05-0.49	0.20	----	0.2
Cadmium	<0.01	<0.02	<0.01	<0.005
Chromium	0.01-0.03	0.01	----	<0.01
Copper	0.01-0.02	<0.01	0.008	0.005
Fluoride	0.10-1.07	0.64	0.50	<0.1
Iron	0.01-4.10	1.02	1.43	2.1
Lead	0.01-0.05	0.02	0.02	0.020
Manganese	0.03-0.87	0.22	0.05	0.120
Mercury	<0.0001	<0.0001	----	<0.0001
Molybdenum	<0.01	<0.01	----	<0.005
Nickel	0.01-0.19	0.02	0.04	0.02
Selenium	0.01-0.04	0.02	----	0.014
Vanadium	0.01-0.45	0.18	0.52	0.37
Zinc	0.01-0.04	0.02	0.05	0.058
Silicon (SiO_2)	1.0-15.0		15.1	12
Radiochemistry				
Uranium as U_3O_8	0.002-0.200	0.060	0.114	0.087
Radium-226	1.5-274	100	-----	500
Thorium-230	0.5-41.9	6	-----	15

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-7

NINE MILE LAKE
PATTERN 3
I-47

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/24/82	CDM 2/24/82
pH	6.4-7.2	6.9	7.0	7.2
Conductivity	1375-3500	2381	3200	3500
Major Constituents				
Bicarbonate	224-426	328	308	248
Carbonate	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	252	205
Calcium	41-135	74	90	110
Chloride	20-55	35	32	36
Magnesium	13-71	35	67	62
Potassium	5.9-16.0	10.4	9.8	7.7
Sodium	310-863	506	528	510
Sulfate	628-2826	1244	1350	1440
TDS	1380-3320	2034	2231	2210
Anion/Cation			103	96
Minor Constituents				
Ammonia as N	0.10-0.33	0.15	----	<0.2
Nitrate as N	0.10-0.93	0.21	----	<0.05
Nitrite as N	0.02-0.06	0.02	----	<0.05
Aluminum	0.05-0.88	0.18	0.08	<0.5
Arsenic	0.01-0.04	0.02	----	0.0007
Barium	0.05-0.10	0.05	----	<0.2
Boron	0.05-0.49	0.20	----	0.2
Cadmium	<0.01	<0.02	<0.01	0.005
Chromium	0.01-0.03	0.01	----	<0.01
Copper	<0.01-0.02	<0.01	0.051	0.007
Fluoride	0.10-1.07	0.64	0.44	0.2
Iron	0.01-4.10	1.02	4.89	3.5
Lead	0.01-0.05	0.02	0.10	0.016
Manganese	0.03-0.87	0.22	0.35	0.243
Mercury	<0.0001	<0.0001	----	0.0003
Molybdenum	<0.01	<0.01	----	<0.005
Nickel	0.01-0.19	0.02	0.10	0.05
Selenium	0.01-0.04	0.02	----	0.006
Vanadium	0.01-0.45	0.18	0.12	0.15
Zinc	0.01-0.04	0.02	0.31	0.123
Silicon (SiO_2)	1.0-15.0		10.5	10
Radiochemistry				
Uranium as U_3O_8	0.002-0.200	0.060	0.137	0.153
Radium-226	1.5-274	100	142	94
Thorium-230	0.5-41.9	6	6.8	9.3

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-8

NINE MILE LAKE
PATTERN 3
I-48A

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/24/82	CDM 2/24/82
pH	6.4-7.2	6.9	6.4	6.5
Conductivity	1375-3500	2381	1850	2100
Major Constituents				
Bicarbonate	224-426	328	135	99
Carbonate	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	111	82
Calcium	41-135	74	24	41
Chloride	20-55	35	27	30
Magnesium	13-71	35	30	26
Potassium	5.9-16.0	10.4	7.0	5.5
Sodium	310-863	506	315	310
Sulfate	628-2826	1244	703	742
TDS	1380-3320	2034	1400	1180
Anion/Cation			100	99
Minor Constituents				
Ammonia as N	0.10-0.33	0.15	----	<0.2
Nitrate as N	0.10-0.93	0.21	----	<0.05
Nitrite as N	0.02-0.06	0.02	----	<0.05
Aluminum	0.05-0.88	0.18	1.30	1.2
Arsenic	0.01-0.04	0.02	----	0.031
Barium	0.05-0.10	0.05	----	<0.2
Boron	0.05-0.49	0.20	----	0.2
Cadmium	<0.01	<0.02	<0.01	<0.005
Chromium	0.01-0.03	0.01	----	<0.01
Copper	<0.01-0.02	<0.01	0.13	0.005
Fluoride	0.10-1.07	0.64	0.62	0.1
Iron	0.01-4.10	1.02	1.22	1.0
Lead	0.01-0.05	0.02	0.06	<0.005
Manganese	0.03-0.87	0.22	0.13	0.086
Mercury	<0.0001	<0.0001	----	0.0001
Molybdenum	<0.01	<0.01	0.05	0.008
Nickel	0.01-0.19	0.02	0.04	0.02
Selenium	0.01-0.04	0.02	----	<0.005
Vanadium	0.01-0.45	0.18	1.25	1.14
Zinc	0.01-0.04	0.02	0.07	0.061
Silicon (SiO_2)	1.0-15.0		15.3	15
Radiochemistry				
Uranium as U_3O_8	0.002-0.200	0.060	0.148	0.130
Radium-226	1.5-274	100	451	400
Thorium-230	0.5-41.9	6	30.9	58

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-9

NINE MILE LAKE
PATTERN 3
I-49

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/24/82	CDM 2/24/82
pH	6.4-7.2	6.9	7.1	7.1
Conductivity	1375-3500	2381	3200	3500
Major Constituents				
Bicarbonate	224-426	328	279	212
Carbonate	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	229	175
Calcium	41-135	[illegible]4	88	110
Chloride	20-55	35	50	38
Magnesium	13-71	35	64	62
Potassium	5.9-16.0	10.4	9.2	7.3
Sodium	310-863	506	621	520
Sulfate	628-2826	1244	1492	1400
TDS	1380-3320	2034	2720	2240
Anion/Cation			100	98
Minor Constituents				
Ammonia as N	0.10-0.33	0.15	----	<0.2
Nitrate as N	0.10-0.93	0.21	----	<0.05
Nitrite as N	0.02-0.06	0.02	----	<0.05
Aluminum	0.05-0.88	0.18	0.32	<0.5
Arsenic	0.01-0.04	0.02	----	<0.005
Barium	0.0[illegible]-0.10	0.05	----	<0.2
Boron	0.05-0.49	0.20	----	0.2
Cadmium	< 0.01	<0.02	< 0.01	<0.005
Chromium	0.01-0.03	0.01	----	<0.01
Copper	<0.01-0.02	<0.01	0.019	0.007
Fluoride	0.10-1.07	0.64	0.65	0.2
Iron	0.01-4.10	1.02	3.67	2.9
Lead	0.01-0.05	0.02	0.07	0.010
Manganese	0.03-0.87	0.22	0.37	0.247
Mercury	<0.0001	<0.0001	----	0.0016
Molybdenum	<0.01	<0.01	----	<0.005
Nickel	0.01-0.19	0.02	0.13	0.06
Selenium	0.01-0.04	0.02	----	0.017
Vanadium	0.01-0.45	0.18	0.20	0.16
Zinc	0.01-0.04	0.02	0.14	0.116
Silicon (SiO_2)	1.0-15.0		11.6	12
Radiochemistry				
Uranium as U_3O_8	0.002-0.200	0.060	0.144	0.200
Radium-226	1.5-274	100	-----	350
Thorium-230	0.5-41.9	6	-----	32

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-10

NINE MILE LAKE
PATTERN 3
M-40

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/18/82	CDM 2/18/82	NML 5/8/82
pH	6.4-7.2	6.9	7.1	7.2	7.1
Conductivity	1375-3500	2381	2400	2800	1630
Major Constituents					
Bicarbonate	224-426	328	255	198	207
Carbonate	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	209	163	170
Calcium	41-135	74	77	76	48
Chloride	20-55	35	29	26	28
Magnesium	13-71	35	53	47	30
Potassium	5.9-16.0	10.4	7.9	5.8	5.2
Sodium	310-863	506	516	430	289
Sulfate	628-2826	1244	1244	1070	704
TDS	1380-3320	2034	1990	1770	1180
Anion/Cation			100	101	96
Minor Constituents					
Ammonia as N	0.10-0.33	0.15	---	<0.2	
Nitrate as N	0.10-0.93	0.21	---	<0.05	
Nitrite as N	0.02-0.06	0.02	---	<0.05	
Aluminum	0.05-0.88	0.18	0.28	<0.5	
Arsenic	0.01-0.04	0.02	---	<0.005	
Barium	0.05-0.10	0.05	---	<0.2	
Boron	0.05-0.49	0.20	---	<0.2	
Cadmium	<0.01	<0.02	<0.01	0.006	
Chromium	0.01-0.03	0.01	---	<0.01	
Copper	0.01-0.02	<0.01	0.014	0.011	
Fluoride	0.10-1.07	0.64	0.50	0.1	
Iron	0.01-4.10	1.02	0.06	3.1	0.99
Lead	0.01-0.05	0.02	0.05	0.097	
Manganese	0.03-0.87	0.22	0.33	0.422	
Mercury	<0.0001	<0.0001	---	<0.0001	
Molybdenum	<0.01	<0.01	0.02	0.006	
Nickel	0.01-0.19	0.02	0.06	0.06	
Selenium	0.01-0.04	0.02	---	0.012	
Vanadium	0.01-0.45	0.18	0.04	0.072	0.04
Zinc	0.01-0.04	0.02	0.48	0.042	
Silicon (SiO_2)	1.0-15.0		6.5	6	
Radiochemistry					
Uranium as U_3O_8	0.002-0.200	0.060	0.091	0.116	0.092
Radium-226	1.5-274	100	34.7	25	19
Thorium-230	0.5-41.9	6	2.1	1.7	

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-11

NINE MILE LAKE
PATTERN 3
M-41

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/18/82	CDM 2/18/82	NML 3/10/82	NML 4/9/82	NML 5/9/82
pH	6.4-7.2	6.9	6.9	7.3	7.0	7.0	7.0
Conductivity	1375-3500	2381	1680	2000	1690	1630	1580
Major Constituents							
Bicarbonate	224-426	328	187	146	223	206	218
Carbonate	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	153	121	183	169	179
Calcium	41-135	74	34	40	45	36	45
Chloride	20-55	35	20	25	21	25	29
Magnesium	13-71	35	29	25	27	21	27
Potassium	5.9-16.0	10.4	7.8	6.1	7.7	6.9	7.2
Sodium	310-863	506	292	280	321	290	286
Sulfate	628-2826	1244	670	653	700	596	667
TDS	1380-3320	2034	1130	1070	1100	1076	1180
Anion/Cation			98	98	100	99	97
Minor Constituents							
Ammonia as N	0.10-0.33	0.15	---	<0.2			
Nitrate as N	0.10-0.93	0.21	---	0.05			
Nitrite as N	0.02-0.06	0.02	---	<0.05			
Aluminum	0.05-0.88	0.18	0.31	<0.5			
Arsenic	0.01-0.04	0.02	---	<0.005			
Barium	0.05-0.10	0.05	---	<0.2			
Boron	0.05-0.49	0.20	---	0.2			
Cadmium	<0.01	<0.02	<0.01	0.005			
Chromium	0.01-0.03	0.01	---	<0.01			
Copper	0.01-0.02	<0.01	0.005	0.011			
Fluoride	0.10-1.07	0.64	0.96	0.2			
Iron	0.01-4.10	1.02	0.08	0.11	3.48	1.09	4.56
Lead	0.01-0.05	0.02	0.03	<0.005			
Manganese	0.03-0.87	0.22	0.06	0.056			
Mercury	<0.0001	<0.0001	---	<0.0001			
Molybdenum	<0.01	<0.01	0.37	0.005			
Nickel	0.01-0.19	0.02	0.04	0.05			
Selenium	0.01-0.04	0.02	---	0.032			
Vanadium	0.01-0.45	0.18	0.21	0.134	0.62	0.169	0.25
Zinc	0.01-0.04	0.02	0.03	0.027			
Silicon (SiO_2)	1.0-15.0		6.9	6			
Radiochemistry							
Uranium as U_3O_8	0.002-0.200	0.060	0.041	0.066	0.095	0.069	0.114
Radium-226	1.5-274	100	34.5	30			45
Thorium-230	0.5-41.9	6	0.7	0.1			

NOTE: All units expressed in mg/l (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-12

NINE MILE LAKE
PATTERN 3
M-42

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/18/82	CDM 2/18/82	NML 3/8/82	NML 4/7/82	NML 5/6/82
pH	6.4-7.2	6.9	6.6	6.9	6.5	6.6	6.4
Conductivity	1375-3500	2381	2800	3400	3000	2900	2800
Major Constituents							
Bicarbonate	224-426	328	265	203	265	266	257
Carbonate	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	217	167	217	218	211
Calcium	41-135	74	90	90	96	94	102
Chloride	20-55	35	30	37	35	38	43
Magnesium	13-71	35	53	57	63	59	61
Potassium	5.9-16.0	10.4	9.7	7.2	9.2	9.4	9.9
Sodium	310-863	506	561	530	520	518	567
Sulfate	628-2826	1244	1417	1370	1337	1325	1377
TDS	1380-3320	2034	2200	2090	2190	2174	2216
Anion/Cation			104	99	99	99	101
Minor Constituents							
Ammonia as N	0.10-0.33	0.15	---	<0.2			
Nitrate as N	0.10-0.93	0.21	---	0.09			
Nitrite as N	0.02-0.06	0.02	---	<0.05			
Aluminum	0.05-0.88	0.18	0.35	1.2			
Arsenic	0.01-0.04	0.02	---	0.023			
Barium	0.05-0.10	0.05	---	0.2			
Boron	0.05-0.49	0.20	---	0.2			
Cadmium	<0.01	<0.02	<0.01	0.005			
Chromium	0.01-0.03	0.01	---	<0.01			
Copper	0.01-0.02	<0.01	0.004	0.010			
Fluoride	0.10-1.07	0.64	0.57	0.2			
Iron	0.01-4.10	1.02	0.21	7.3	1.25	2.54	1.98
Lead	0.01-0.05	0.02	0.04	<0.005			
Manganese	0.03-0.87	0.22	0.13	0.170			
Mercury	<0.0001	<0.0001	---	<0.0001			
Molybdenum	<0.01	<0.01	---	<0.005			
Nickel	0.01-0.19	0.02	0.01	0.03			
Selenium	0.01-0.04	0.02	---	0.105			
Vanadium	0.01-0.45	0.18	0.17	0.70	0.09	0.247	0.10
Zinc	0.01-0.04	0.02	0.25	0.043			
Silicon (SiO_2)	1.0-15.0		8.3	8			
Radiochemistry							
Uranium as U_3O_8	0.002-0.200	0.060	0.068	0.130	0.086	0.110	0.131
Radium-226	1.5-274	100	80	84	70		52
Thorium-230	0.5-41.9	6	2.3	9.2	3.4		

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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TABLE P3-13

NINE MILE LAKE
PATTERN 3
M-43

	PATTERN BASELINE RANGE	PATTERN BASELINE MEAN	NML 2/18/82	CDM 2/18/82	NML 3/8/82	NML 4/9/82	NML 5/5/82
pH	6.4-7.2	6.9	6.9	7.4	7.0	7.0	5.9
Conductivity	1375-3500	2381	1720	2000	1700	1700	1750
Major Constituents							
Bicarbonate	224-426	328	210	158	217	214	209
Carbonate	0	0	0	0	0	0	0
Alkalinity as $CaCO_3$	184-349	270	172	130	178	175	171
Calcium	41-135	74	37	41	29	43	47
Chloride	20-55	35	20	21	21	24	29
Magnesium	13-71	35	28	25	16	25	27
Potassium	5.9-16.0	10.4	7.5	5.5	5.3	6.9	6.7
Sodium	310-863	506	297	290	232	303	332
Sulfate	628-2826	1244	645	653	650	636	739
TDS	1380-3320	2034	1120	1090	1040	1145	1240
Anion/Cation			101	100	85	106	99
Minor Constituents							
Ammonia as N	0.10-0.33	0.15	----	<0.2			
Nitrate as N	0.10-0.93	0.21	----	<0.05			
Nitrite as N	0.02-0.06	0.02	----	<0.05			
Aluminum	0.05-0.88	0.18	0.17	<0.5			
Arsenic	0.01-0.04	0.02	----	<0.005			
Barium	0.05-0.10	0.05	----	<0.2			
Boron	0.05-0.49	0.20	----	0.2			
Cadmium	<0.01	<0.02	<0.01	0.005			
Chromium	0.01-0.03	0.01	----	<0.01			
Copper	0.01-0.02	<0.01	0.004	0.006			
Fluoride	0.10-1.07	0.64	0.96	0.3			
Iron	0.01-4.10	1.02	0.03	0.25	0.75	1.05	1.21
Lead	0.01-0.05	0.02	0.03	<0.005			
Manganese	0.03-0.87	0.22	0.04	0.045			
Mercury	<0.0001	<0.0001	----	<0.0001			
Molybdenum	<0.01	<0.01	----	<0.005			
Nickel	0.01-0.19	0.02	0.02	0.02			
Selenium	0.01-0.04	0.02	----	0.096			
Vanadium	0.01-0.45	0.18	0.43	0.36	0.36	0.117	0.05
Zinc	0.01-0.04	0.02	0.02	0.028			
Silicon (SiO_2)	1.0-15.0		7.4	7			
Radiochemistry							
Uranium as U_3O_8	0.002-0.200	0.060	0.292	0.341	0.254	0.252	0.226
Radium-226	1.5-274	100	94	70	131		110
Thorium-230	0.5-41.9	6	0.2	0.9	2.6		

NOTE: All units expressed in mgl/ (ppm) except conductivity (umhos/cm), pH (standard units) and radionuclides (pCi/l).

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Average vanadium concentrations for all interior wells is 0.57 mg/l with a high value of 1.38 mg/l. Average radium concentration is 342 pCi/l which is slightly above Pattern 3 baseline range, but well below the high site baseline value of 714 pCi/l (Table 1.4). All other parameters including uranium, arsenic, selenium, cadmium, chromium, etc. are within baseline ranges. Average TDS levels for all interior wells is about 1600 mg/l which is lower than the baseline mean of 2034.

Monitor well data suggests that affected groundwater in outlying portions of the pattern, particularly in the vicinity of wells M-40 and M-43, was retrieved during restoration. Both M-40 and M-43 yielded samples containing several mg/l uranium and vanadium during leaching. These constituents were reduced to baseline levels as were all other parameters of concern.

Stabilization monitoring results since February 1982 have been extremely encouraging. Unlike Patterns 1 and 2, little, if any, deterioration of water quality has been observed, (see Tables P3-1 and P3-2). The one notable exception is radium in the lower ore production zone well (P-50). Some increase in radium levels would be expected in the lower ore zone due to the length of contact with leaching solution, but the March sample result of 3400 pCi/l seems anomalously high. Results of the final six month stabilization monitoring samples (August 1, 1982) should clarify the situation.

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3.4 Pattern 3 Conclusions

Post restoration groundwater quality is sufficient to warrant consideration as proof of demonstrated restoration of an acid leach test pattern. Substantial improvement over previous acid restoration attempts is obvious. The successful results are primarily due to restoration flow rates equal to or greater than leaching flow rates and the effectiveness of water fence injection wells and an abbreviated leaching period.

4.0 Contaminant Migration Models

Two contaminant migration models were used to estimate the magnitude and extent of groundwater constituent movement from Patterns 1,2 and 3 at Nine Mile Lake (see Appendix B). One model, developed by Rocky Mountain Energy evaluated the dual effects of dispersion/dilution and partial clay ion adsorption on the downdip movement of radium-226 from Pattern 1 and Pattern 3. The other model, developed by a consultant, was used to investigate the possible fates of radium, uranium, vanadium, iron and lead for all three acid patterns (Patterns 1,2 and 3). It utilized a mass transport dispersion equation and did not consider ion adsorption except as a reversible temporary retardent. To keep models simple, neither evaluation considered the migration-inhibiting effects of natural formation tendencies to reduce groundwater oxygen content or neutralize solutions.

In summary, migration calculations performed by Rocky Mountain Energy estimate that radium from Pattern 1, in the area

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near monitor well M-54, will migrate approximately 93 feet before concentrations will reach maximum background levels recorded for the pattern. Pattern 3 modeling results suggest 51 feet will be required to lower radium levels to pattern background conditions. The model prepared by the consultant predicted maximum radium travel distances of 3800 feet for Pattern 1, 0 feet for Pattern 2 and 4150 feet for Pattern 3.

Results of modeling performed by the consultant for uranium, vanadium, iron and lead were different than those obtained for radium. All constituents except vanadium in Pattern 2 will disperse to pattern baseline within one mile of travel. Vanadium will disperse to a level similar to Pattern 2 baseline with eight miles, but will more rapidly approach the highest baseline recorded for all patterns; this is estimated to occur within 1600 feet. Slow groundwater movement and retardation effects due to clay ion adsorption/desorption effects results in especially long travel times for all parameters (decades to centuries).

Of the two models presented, information from the RME model should be considered most representative of actual conditions. It assumes a very minor amount of clay ion adsorption and reasonable dilution. The consultant model, on the other hand, provides information useful in evaluating the absolutely worst conditions which may occur, i.e. dilution with no permanent clay ion adsorption. Ultimate contaminant movement will probably be much less than described in either model. Acid neutralizing capacity of the formation and the reducing environment in the groundwater will play a major role in retarding constituent migration. Again, geochemical reactions which could greatly inhibit contaminant movement were not considered in the consultant model.

Both contaminant migration analyses are presented in their entirety in Appendix B.

5.0 Regional Aquifer Impact

Post restoration water quality has been thoroughly evaluated to determine whether any undesirable or potentially hazardous aquifer impacts might occur from residual groundwater contaminants. As discussed, RME and a geohydrologic consultant have performed independent analyses of the probable fate of groundwater constituents of particular concern within the aquifer.

A literature review and field inspection of groundwater wells known to be located within a 3½ mile radius of the R&D permit area has been conducted. Regional aquifer water quality has been evaluated based upon water sampling data collected over a period of several years from more than 14 wells completed in the Teapot sandstone.

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5.1 Aquifer Water Quality

Results of these investigations suggest the potential for adverse environmental or health impacts due to post restoration water quality is negligible. Groundwater constituents which could conceivably pose some health hazards are limited to high radium and vanadium concentrations. Although concentrations of these parameters now exceed baseline ranges for some Pattern 1,2, and 3 wells, it must be emphasized that baseline radium concentrations were 20 to 50 times greater than DEQ maximum permissible levels for Class I, II or III groundwaters (DEQ Water Quality Rules and Regulations, Chapter VIII, Quality Standards for Wyoming Groundwaters). Similarly, site baseline vanadium concentrations as high as 0.45 mg/l (Pattern 3) were recorded, which exceeds Class II and III standards (0.1 mg/l) by a factor of greater than 4. Sampling of regional monitor wells completed in the Teapot Sandstone have yielded baseline vanadium concentrations as high as 2.1 mg/l.

In fact, use of Teapot Sand groundwater for anything other than industrial purposes (DEQ Class IV) would require extensive treatment. Baseline sampling of 18 Pattern 2,3, and 4 wells showed that at least 7 parameters exceeded DEQ Class III standards while at least 10 parameters exceeded maximum allowable Class II standards. Tables 5.1 and 5.2 compare Patterns 2 and 3 baseline water quality with DEQ use category standards. Parameters which exceed Class II or III standards include such potentially toxic elements as arsenic, chromium, lead and selenium (see Appendix C).

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TABLE 5.1

GROUNDWATER CLASSIFICATION ANALYSIS

NINE MILE LAKE

PATTERN 2 (Wells P-15, M-20, M-21, M-22, M-23, M-24) BASELINE

USE CATEGORY	I (DOMESTIC)			II (AGRICULTURE)			III (LIVESTOCK)			IV (INDUSTRIAL)		
PARAMETER	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells Above Standard
Aluminum (Al)	-	-	-	5.0		0	5.0		0	-		
Ammonia (NH)	0.5		0	-	-	-	-	-	-	-		
Arsenic (As)	0.05		0	0.1		0	0.2		0	-		
Barium (Ba)	1.0		0	-	-	-	-	-	-	-		
Boron (B)	0.75		2	0.75		2	5.0		0	-		
Cadmium (Cd)	0.01	ND (0.02)	?	0.01	ND (0.02)	?	0.05		0	-		
Chloride (Cl)	250		0	100.0		2	2000		0	-		
Chromium (Cr)	0.05		0	0.1		0	0.05		0	-		
Cobalt (Co)	-	-	-	0.05	NA	NA	1.0	NA	NA	-		
Copper (Cu)	1.0		0	0.2		2	0.5		0	-		
Fluoride (F)	2.4		0	-	-	-	-	-	-	-		
Iron (Fe)	0.3	x	6	5.0		0	-	-	-	-		
Lead (Pb)	0.05		0	5.0		0	0.1		0	-		
Manganese (Mn)	0.05	x	6	0.2		5	-	-	-	-		
Mercury (Hg)	0.002		0	-	-	-	0.00005		?	-		
Nickel (Ni)	-	-	-	0.2	NA	NA	-	ND (.0001)		-		
Nitrate (NO_3)	10.0		0	-	-	-	-	-	-	-		
Nitrite (NO_2)	1.0		0	-	-	-	10.0		0	-		
Selenium (Se)	0.01		0	0.02		0	0.05		0	-		
Sulfate (SO_4)	250	x	6	200	x	6	3000		0	-		
Total Dissolved Solids (TDS)	500	x	6	2000	x	6	5000		0	-		
Uranium (U)	5.0		0	5.0		0	5.0		0	-		
Vanadium (V)	-	-	-	0.1		0	0.1		0	-		
Zinc (Zn)	5.0		0	2.0		0	25.0		0	-		
pH	6.5-9.0*		5	6.5-9.0*		0	6.5-8.5*		5	-		
Radium 226 + 228	5*	x	6	5*	x	6	5*	x	6	-		
Gross Alpha	15*	x	6	15*	x	6	15*	x	6	-		
Total No. of Parameters Exceeding Criteria	-	6	≥ 43	-	4	≥ 35	-	2	≥ 17	-	0	0

*All units in mg/l except pH (std. units), Ra (pCi/l) and Gross Alpha (pCi/l) NA=Not Assayed ND=Non Detectable

TABLE 5.2
GROUNDWATER CLASSIFICATION ANALYSIS
NINE MILE LAKE
PATTERN 3 (Wells M-40, M-41, M-42, M-43, P-50, P-53, USM-52) BASELINE

USE CATEGORY	I (DOMESTIC)			II (AGRICULTURE)			III (LIVESTOCK)			IV (INDUSTRIAL)		
PARAMETER	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells Above Standard
Aluminum (Al)	-	-	-	5.0		0	5.0		0	-		
Ammonia (NH)	0.5		0	-	-	-	-	-	-	-		
Arsenic (As)	0.05		0	0.1		0	0.2		0	-		
Barium (Ba)	1.0		0	-	-	-	-	-	-	-		
Boron (B)	0.75		0	0.75		0	5.0		0	-		
Cadmium (Cd)	0.01		0	0.01		0	0.05		0	-		
Chloride (Cl)	250		0	100.0		0	2000		0	-		
Chromium (Cr)	0.05		0	0.1		0	0.05		0	-		
Cobalt (Co)	-	-	-	0.05	NA	NA	1.0	NA	NA	-		
Copper (Cu)	1.0		0	0.2		0	0.5		0	-		
Flouride (F)	2.4		0	-	-	-	-	-	-	-		
Iron (Fe)	0.3	x	7	5.0		0	-	-	-	-		
Lead (Pb)	0.05		1	5.0		0	0.1		0	-		
Manganese (Mn)	0.05	x	7	0.2	x	5	-	-	-	-		
Mercury (Hg)	0.002		0	-	-	-	0.00005	ND (.0005)	?	-		
Nickel (Ni)	-	-	-	0.2		0	-	-	-	-		
Nitrate (NO_3)	10.0		0	-	-	-	-	-	-	-		
Nitrite (NO_2)	1.0		0	-	-	-	10.0		0	-		
Selenium (Se)	0.01	x	5	0.02	x	5	0.05		0	-		
Sulfate (SO_4)	250	x	7	200	x	7	3000		0	-		
Total Dissolved Solids (TDS)	500	x	7	2000	x	5	5000		0	-		
Uranium (U)	5.0		0	5.0		0	5.0		0	-		
Vanadium (V)	-	-	-	0.1	x	6	0.1	x	6	-		
Zinc (Zn)	5.0		0	2.0		0	25.0		0	-		
pH	6.5-9.0*		2	6.5-9.0*		0	6.5-8.5*		2	-		
Radium 226 + 228	5*	x	7	5*	x	7	5*	x	7	-		
Gross Alpha	15*	x	7	15*	x	7	15*	x	7	-		
Total No. of Parameters Exceeding Criteria	-	7	≥50	-	7	≥42	-	3	≥22	-	0	0

*All units in mg/l except pH (std. units), Ra (pCi/l) and Gross Alpha (pCi/l) NA=Not Assayed ND=Non Detectable

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The logical conclusion is that both baseline and post restoration groundwater is of such poor quality that it is only suitable for industrial use (Class IV) unless costly, technologically complex water purification processes could successfully remove undesirable elements.

5.2 Contaminant Migration Results

Results of both the most probable and worst case analyses of probable residual contaminant fate conclude that vanadium and radium concentrations should be reduced to site baseline ranges within a relatively short distance. Based on post restoration water quality, as defined by the February well sampling results, RME predicts elevated radium concentrations downdip of Pattern 1 and within Pattern 3 would decrease to respective baseline levels within 100 ft. travel distance. The worst case analysis, which assumes no adsorption of radionuclides by formation clays, predicts Patterns 1 and 3 radium levels will diminish to less than200 pCi/l within one quarter mile travel distance. Regional monitor wells indicate radium concentrations up to 213 pCi/l while site baseline concentrations exceed 700 pCi/l.

Consultant modeling of ion dispersion predicts a worst case requirement of about 1600 ft. travel distance for Pattern 2 vanadium levels ($\bar{x}$=0.79 mg/l) to reach site upper baseline range limits (0.45 mg/l). Again, regional monitor well sampling has resulted in values greater than 2 mg/l vanadium which is five times the maximum concentration level assumed to represent site baseline. It would therefore appear that aquifer use suitability would not be impaired as a result of high post restoration vanadium or radium concentrations.

5.3 Regional Aquifer Use

State Engineer records and field inspections provide reasonable evidence that there are no existing wells within a distance of four miles downgradient of the test site wells which appropriate groundwater from the Teapot.

As shown in Table 5.3 and on Drawing No. 50-13-140-71 (map pocket: Figure 5.1) the nearest downdip well completed in the Mesaverde formation is number 26050, located approximately 4 miles southeast of the R&D permit area. Field inspections conducted in June of 1978 and 1982 found no evidence of the well suggesting that it has either been abandoned or was never completed. Even if the well did exist, the supposed location, reported depth to static water and total depth would all suggest the well was completed in the Parkman member of the Mesaverde Formation rather than the Teapot member. The two sand units are separated by 300 to 500 feet of the Pumpkin Buttes shale which forms an effective aquatard between them.

The only other well of record completed in the Mesaverde Formation downdip of the project is well number 13221, located more than seven miles southeast of the R&D permit area. Like the

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TABLE 5.3
NINE MILE LAKE
REGIONAL WELLS OF INTEREST

Well Number[1]	Formation[2]	Description[3]	Distance and Direction from R&D Site	
16819	Fox Hills	T.D. = 204'; W.L. = 76'	7,000 ft.	SE
16800	Wind Blown Sand	T.D. = 170'; W.L. = 15'; Not Found	16,500 ft.	E NE
16818	Lewis Shale (?)	T.D. = 175'; W.L. = 15'	17,700 ft.	NE
16810	Fox Hills	T.D. = 175'; W.L. = 40'	22,000 ft.	E
29657	Fox Hills	T.D. = 80'; W.L. = 30'; Not Found	21,000 ft.	E SE
2930	Fox Hills	T.D. = 98'; W.L. = 40'	23,000 ft.	E SE
26050	Mesa Verde	T.D. = 420'; W.L. = 260'; Not Found	21,000 ft.	SE
2926	Wind Blown Sand	T.D. = 20'; W.L. ' 4'; Not Found	30,000 ft.	SE
13221	Mesa Verde(?)	T.D. = 100'; W.L. = 50'; Not Found	39,000 ft.	SE
21889	Teapot(?)	T.D. = 294'; W.L. = 252'	19,500 ft.	NW
21890	Teapot(?)	T.D. = 175'; W.L. = 149'	26,000 ft.	NW
15507	Mesa Verde	T.D. = 488'; W.L. = 75'	10,200 ft.	W NW

[1] Well number designated by Wyoming State Engineer.

[2] Geologic formation from which groundwater is appropriated.

[3] T.D. = total depth of well; W.L. = depth to static water level, not found means well could not be located in the field.

Source of Data: Wyoming State Engineer's Office and field reconnaissance (June 1978, June 1982)

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  ☒ FILMED ON APERTURE CARD NO 8210180405-01 well previously discussed, efforts to locate the well in the field were unsuccessful.

All other known wells within four miles downdip of the project area are reportedly completed in strata overlying the Teapot Sandstone.

Within a three mile radius of the test site, only two additional wells other than RME wells, are known to be completed in the Teapot. They are wells number 21889 and 21890 which are located approximately 3.7 and 4.9 miles northeast of the test site. The strike of the Teapot Sandstone is northwest to southeast and the dip is east-northeast at 6 to 7 degrees which controls the direction of groundwater flow; that is easterly toward the central axis of the Powder River Basin. It is highly improbable that water quality in any well located four miles up strike from the project site could possibly be affected by site groundwater conditions, particularly since regional groundwater flow and velocity were computed to be 19 ft./yr. in the direction of the dip of the formation.

There are no public water supply wells of record within three miles of the property. Homes located west of Interstate Highway I-25 and the western outcrop of the Teapot Sandstone (known as "The Reefs" and shown on Figure 5.1) obtain water from private wells in the Parkman Sandstone.

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In conclusion, evaluation of regional aquifer use implies that no existing sources of water supply within a distance of greater than four miles of the site will be affected by residual contaminants from test mining activities.

6.0 Regulatory Compliance

Regulations of the Land and Water Quality Divisions of the Wyoming Department of Environmental Quality applicable to groundwater classification and restoration requirements for R & D facilites have been thoroughly reviewed, as have DEQ and NRC license or permit requirements, to determine RME compliance status.

6.1 License and Permit Compliance

To properly evaluate restoration compliance status it is necessary to first recognize that test activities began at the Nine Mile Lake site in November, 1976. At that time, the Wyoming DEQ had no regulations specifically governing solution mining. Initial test work was authorized by DEQ through the issuance of a License to Explore by Dozing (No. LE-4, issued May 15, 1975) and by NRC through an amendment (October 15, 1976) to Source Material License SUA-1228 which was originally issued for in situ research work at RME's Bear Creek property. Neither license specifically addressed the topic of groundwater restoration requirements or restoration criteria.

In an amendment request dated August 31, 1977, RME proposed that "pumping of the production well will continue until the

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chemistry returns to that of pre-leach condition." No numerical restoration criteria were ever proposed by RME or stipulated by license, as was also the case with post restoration stabilization monitoring. In October of 1978, restoration of Pattern 1 to "pre-leach conditions" was thought to have been accomplished so the pattern was shut down as restored.

Subsequent attempts to improve Pattern 1 water quality were conducted entirely through RME initiative and were not required by regulatory agencies through either permit or license conditions. Initial leaching and restoration activities were completed at least 18 months before the Wyoming Department of Environmental Quality promulgated rules and regulations regarding in situ uranium solution mining (Land Quality Division In Situ Mining Act, W.S. 35-11-426 through W.S. 35-11-436, adopted May 1980 and Water Quality Division Rules and Regulations, Chapters VIII and IX, adopted September, 1980).

Pattern 2 leaching activities were begun in December 1977, also prior to promulgation of the above referenced regulations. Activities were again authorized by NRC through Source Material License SUA-1228 and DEQ via License to Explore No. LE-4. No license amendments were required as original license applications contained plans for additional test patterns following Pattern 1 leaching. As with Pattern 1, no specific restoration criteria goals or numerical target values were ever proposed by RME or required by DEQ and NRC regulations or licenses.

Leaching activities in Pattern 3 were also initiated prior to adoption of stringent regulations specifying groundwater restoration requirements. Approval for Pattern 3 leaching activities, which began in September 1979, was contingent upon demonstrating restoration of Patterns 1 and 2 (see letter, dated May 9, 1978 from Doyl Fritz, DEQ District IV Engineer to A.D. Luck, RME; in Appendix E).

On August 8, 1979 RME requested DEQ approval to initiate test work in Pattern 3 (DEQ "Note to the File" from Dennis Morrow, District IV Engineer; Appendix E). Subsequent to the request, a meeting was held with DEQ personnel to review Pattern 2 restoration status on September 6, 1979. Present at the meeting were RME's project environmental specialist and project superintendent, the DEQ District IV Engineer and Land Quality Division chief hydrologist. Based on DEQ's review of Pattern 2 restoration data, verbal approval to proceed with Pattern 3 testing was granted (Appendix E). This approval was confirmed in writing on September 21, 1979 in a letter, also in Appendix E, from the District Engineer to RME.

On October 11, 1979 RME provided a written summary of Pattern 2 restoration, Pattern 3 baseline water quality data and proposed Pattern 3 restoration plans to the DEQ (Appendix E). In that submittal, RME committed to "return Pattern 3 groundwater to

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baseline use category as was established prior to leaching" (RME Nine Mile Lake Project, In Situ Leaching Research and Development Application, page R-2).

Groundwater in Pattern 3 has now been restored to baseline use category and approved conditions for restoration have been fulfilled.

6.2 Compliance with DEQ Regulations

In addition to having complied with all license and permit requirements regarding groundwater restoration, RME has met the requirements of DEQ rules and regulations concerning groundwater restoration promulgated in recent years.

Land Quality Division Rules and Regulations pertinent to in situ mining are enumerated in Chapter XXI and were adopted pursuant to W.S. 35-11-426 through W.S. 35-11-436. Section 4 of Chapter XXI, which specifically addresses Research and Development License Applications, states the application shall:

> "4.a. Demonstrate that the operation is designed to:
>
> (1) Evaluate the mineability or workability of a mineral deposit using in situ mining techniques.
>
> (2) Affect the land surface, surface waters and groundwater of the state to the minimum extent necessary.
>
> (3) Provide premining, operational and post mining data, information and experience that will be used for developing reclamation techniques for in situ mining."

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All test work at Nine Mile Lake has been conducted in accordance with both the letter and intent of these regulations. It is RME's understanding that legislation and subsequent regulations authorizing R&D in situ mining operations were developed upon the premise that not all R&D operations would prove to be successful. Furthermore, it is RME's belief that regulatory agencies issue R&D licenses for the express purpose of allowing companies to test proposed mining and restoration techniques at a scale which would not create unacceptable environmental impacts should the test be less than successful.

Section 2.a. of Land Quality Division Chapter XXI also states "Applicable sections of Chapters VIII and IX, Water Quality Division Rules and Regulations shall also apply to in situ mining operations." Although WQD Chapters VIII and IX were not adopted until September of 1980 or one year after Pattern 3 testing began, RME has reviewed all project activities from a Chapter VIII and IX compliance perspective.

Section 5.a. of Water Quality Division Chapter VIII states:

> "5.a. Classification of groundwater of the state shall be based on the water quality standards of this chapter; excepting a Class I Groundwater of the state shall be classified by ambient water quality and the technical practibility and economic reasonableness of treating ambient water quality to meet use suitability standards." (emphasis added)

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Section 5.b. states:

> "5.b. Underground water quality *shall be classified for an aquifer which is or may be affected by a subsurface discharge* or other activity identified in Section 4.a. of these regulations." (*emphasis* added)

These regulations clearly require that groundwater in any aquifer which was being affected by a subsurface discharge should have been classified at the time the regulations became effective. Section 4.b of Chapter VIII states "Groundwaters of the state are classified by use, and by ambient water quality." Because there was no prior use of groundwater within the Nine Mile Lake permit area, before appropriation for industrial miscellaneous use by RME, classification should have therefore been based on prior use (industrial) and ambient water quality.

Ambient water quality exceeds at least twelve Class I standards, ten Class II standards and seven Class III standards. It is apparent then that groundwater should have been classified as Class IV, Industrial Use on the basis of either prior use or ambient water quality. To date, no groundwater classification has been given to RME by the DEQ although RME has requested such action (see Appendix E - letter from RME to DEQ dated 2/11/82).

Section 4.d. (7) (c) of WQD Chapter VIII requires that "A discharge into an aquifer containing Class IV (A) or IV (B) Groundwater of the State shall not result in the water being unfit for its intended use." The intended use of groundwater from the

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aquifer at the Nine Mile Lake project was for the purpose of mineral production. Testing activities have not resulted in the water being unfit for that use.

Finally, Section 4.d.(7)(f) of Chapter VIII states:

> 4.d(7)(f) "A discharge into an aquifer with Class IV (A) Groundwater of the State shall not result in biological, hazardous, toxic or potentially toxic materials...in concentrations or amounts which exceed maximum allowable concentrations...or which exceed background concentrations of the underground water, whichever is greater, at any place or places of withdrawal or natural flow to the surface." (emphasis added)

Previously related analyses (Sections 4.0 and 5.0) imply that even if hazardous or potentially toxic materials are now present in restored groundwater at levels which exceed background concentrations, it is highly improbable that they would exceed background levels at any place or places of withdrawal.

It is RME's contention that all permit and license obligations regarding restoration requirements have been fully met as have pertinent regulatory agency requirements.

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NINE MILE LAKE

GROUNDWATER RESTORATION REPORT

APPENDICES

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APPENDIX A

NINE MILE LAKE

WATER QUALITY DATA FOR PATTERNS 1, 2, & 3

Section	Content
A-1	Pattern 1 Water Quality Data
A-2	Pattern 2 Water Quality Data
A-3	Pattern 3 Water Quality Data

Note: When comparing analytical results between Nine Mile Lake (NML) and CDM laboratories, some discrepancies will be evident. Based on previous experience, RME suggests that NML values for field and major constituent parameters are more accurate than CDM values. CDM analytical results for minor constituents (trace metals) are generally more reliable than NML data due to lower detection limits and more sensitive analytical equipment.

CDM

environmental engineers, scientists, planners, & management consultants

CAMP DRESSER & McKEE INC.

11455 West 48th Avenue
Wheat Ridge, Colorado 80033
303 422-0469

March 24, 1982
Page 1 of 6

Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
Casper, WY 82602

RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

APPENDIX A-1
PATTERN 1

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14031-14-1 NM-I1 2-23-82	700-14031-14-2 NM-P1A 2-24-82	700-14031-14-3 NM-I2 2-24-82	700-14031-14-4 NM-I3 2-23-82	700-14031-14-5 NM-I4 2-23-82
Determination (mg/L)					
pH	7.1	6.9	6.7	7.2	7.4
Conductivity, µmhos/cm	3900	14000	12000	16000	16000
Bicarbonate (as HCO_3)	135	270	230	389	481
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	112	223	190	322	398
Calcium, total	110	340	310	370	390
Chloride	40	99	103	115	113
Magnesium ~~Manganese~~, total	62	161	154	182	167
Potassium, total	6.0	12	11	12	12
Sodium, total	630	2300	2000	2600	2700
Sulfate (as SO_4)	1700	6190	5020	6490	6580
TDS (at 180°C)	2590	9150	7570	10,100	10,100
Anion/Cation	0.99	0.96	1.04	1.01	1.02
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2

These samples are scheduled to be disposed of 30 days after the date of this report.

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RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation	700-14031-14-1	700-14031-14-2	700-14031-14-3	700-14031-14-4	700-14031-14-5
Sponsor Designation	NM-I1	NM-P1A	NM-I2	NM-I3	NM-I4
	2-23-82	2-24-82	2-24-82	2-23-82	2-23-82
Determination (mg/L)					
Nitrate (as N)	0.07	<0.05	<0.05	<0.05	0.53
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	<0.5	<0.5	<0.5
Arsenic, total	<0.005	<0.005	<0.005	0.006	<0.005
Barium, total	<0.2	<0.2	<0.2	0.2	<0.2
Boron	0.3	0.2	0.4	0.4	0.4
Cadmium, total	0.006	0.011	0.010	0.014	0.012
Chromium, total	0.03	0.02	0.03	0.03	0.02
Copper, total	0.012	0.116	0.015	0.017	0.020
Fluoride	<0.1	0.1	<0.1	<0.1	<0.1
Iron, total	2.4	1.3	0.52	0.54	2.8
Lead, total	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese, total	0.228	0.278	0.307	0.300	0.388
Mercury, total	<0.0001	<0.0001	<0.0001	0.0005	<0.0001
Molybdenum, total	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel, total	0.05	0.12	0.10	0.15	0.12
Selenium, total	0.013	0.013	0.007	0.020	0.007
Vanadium, total	0.056	0.139	0.104	0.056	0.056
Zinc, total	0.041	0.054	0.061	0.062	0.040
Silica (as SiO_2)	23	6	25	8	15

These samples are scheduled to be disposed of 30 days after the date of this report.

Pat Spieles
March 24, 1982
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RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation	700-14031-14-6	700-14031-14-7	700-14031-14-8	700-14031-14-9	700-14031-14-10
Sponsor Designation	NM-I5 2-23-82	NM-M6 2-23-82	NM-M7 2-25-82	M-8A 2-25-82	NM-M9 2-25-82
Determination (mg/L)					
pH	6.7	6.6	7.1	7.3	7.2
Conductivity, µmhos/cm	15,000	7,200	4,500	3,600	3,200
Bicarbonate (as HCO_3)	261	198	284	257	210
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	216	164	234	212	171
Calcium, total	370	220	140	120	73
Chloride	99	80	37	31	31
agnesium ~~Manganese~~, total	176	114	73	53	44
Potassium, total	13	9.2	8.1	8.3	7.2
Sodium, total	2500	1400	830	530	~~4.90~~ 490
Sulfate (as SO_4)	6260	3760	2000	1440	1200
TDS (at 180°C)	9200	5580	3130	2310	1970
Anion/Cation	1.03	0.97	1.04	0.96	0.98
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (as N)	<0.05	<0.05	1.1	<0.05	<0.05
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	<0.5	0.6	<0.5
Arsenic, total	<0.005	<0.005	<0.005	<0.005	<0.005
Barium, total	<0.2	<0.2	<0.2	<0.2	<0.2

These samples are scheduled to be disposed of 30 days after the date of this report.

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RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14031-14-6 NM-I5 2-23-82	700-14031-14-7 NM-M6 2-23-82	700-14031-14-8 NM-M7 2-25-82	700-14031-14-9 M-8AA 2-25-82	700-14031-14-10 NM-M9 2-25-82
Determination (mg/L)					
Boron	0.2	0.3	0.2	0.4	0.2
Cadmium, total	0.012	0.010	<0.005	0.006	0.005
Chromium, total	0.02	0.02	0.01	0.01	0.01
Copper, total	0.017	0.011	0.009	0.008	0.007
Fluoride	0.1	<0.1	0.1	0.1	0.2
Iron, total	0.61	0.68	0.08	0.95	2.8
Lead, total	<0.005	<0.005	<0.005	<0.005	0.014
Manganese, total	0.381	0.320	0.181	0.131	0.119
Mercury, total	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum, total	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel, total	0.12	0.06	0.04	0.03	0.03
Selenium, total	0.011	0.015	0.059	<0.005	0.046
Vanadium, total	0.075	0.028	0.029	0.009	0.085
Zinc, total	0.062	0.050	0.022	0.017	0.020
Silica (as SiO_2)	14	12	8	9	8

These samples are scheduled to be disposed of 30 days after the date of this report.

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Pat Spieles
March 24, 1982
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RE: 700-14031-14
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Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14031-14-11 NM-M11 2-24-82	700-14031-14-12 NM-M12 2-24-82	700-14031-14-13 WF-74 2-25-82	700-14031-14-14 WF-75 2-25-82
Determination (mg/L)				
pH	6.5	6.8	7.1	7.1
Conductivity, µmhos/cm	8,800	4,200	5,000	3,700
Bicarbonate (as HCO_3)	174	221	203	212
Carbonate (as CO_3)	0	0	0	0
Alkalinity (as $CaCO_3$)	144	182	167	175
Calcium, total	310	110	240	110
Chloride	83	36	51	34
gnesium ~~Manganese~~, total	158	75	105	54
Potassium, total	12	8.8	12	9.4
Sodium, total	178	730	860	590
Sulfate (as SO_4)	4800	1830	2510	1510
TDS (at 180°C)	7380	2760	3780	2330
Anion/Cation	1.01	1.02	1.02	1.00
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2
Nitrate (as N)	<0.05	0.90	<0.05	0.09
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	1.5	0.8
Arsenic, total	<0.005	<0.005	<0.005	<0.005
Barium, total	<0.2	<0.2	0.2	<0.2

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RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation	700-14031-14-11	700-14031-14-12	700-14031-14-13	700-14031-14-14
Sponsor Designation	NM-M11	NM-M12	WF-74	WF-75
	2-24-82	2-24-82	2-25-82	2-25-82
Determination (mg/L)				
Boron	0.2	0.2	0.3	0.3
Cadmium, total	0.007	0.007	0.012	0.008
Chromium, total	0.02	0.01	0.02	0.01
Copper, total	0.010	0.005	0.010	0.005
Fluoride	0.1	0.2	0.1	0.1
Iron, total	0.25	0.40	2.7	0.88
Lead, total	<0.005	<0.005	<0.005	<0.005
Manganese, total	0.307	0.168	0.232	0.084
Mercury, total	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum, total	<0.005	<0.005	<0.005	<0.005
Nickel, total	0.11	0.07	0.06	0.02
Selenium, total	0.016	0.066	<0.005	0.019
Vanadium, total	0.117	0.056	0.048	0.076
Zinc, total	0.039	0.26	0.040	0.018
Silica (as SiO_2)	9	7	8	6

These samples are scheduled to be disposed of 30 days after the date of this report.

BY Chris Shugarts
Chris Shugarts
Water Laboratory
Supervisor

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CAMP DRESSER & McKEE INC.

11455 West 48th Avenue
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March 31, 1982
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Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
Casper, WY 82602

RE: 700-14031-14
P.O. AP2-1483, Rel. 604
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14031-14-1 NM-I1 2-23-82	700-14031-14-2 NM-P1A 2-24-82	700-14031-14-3 NM-I2 2-24-82	700-14031-14-4 NM-I3 2-23-82	700-14031-14-5 NM-I4 2-23-82
Determination					
Uranium (as U) dissolved, mg/L	0.066	0.46	0.21	0.17	0.091
Radium-226, dissolved, pCi/L ± counting error	100 ± 10	510 ± 10	190 ± 10	150 ± 10	110 ± 10
Thorium-230, dissolved, pCi/L ± counting error	-0.2 ± 0.3	1.9 ± 0.9	0.3 ± 0.7	0.4 ± 1.1	1.2 ± 0.8

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

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Pat Spieles
March 31, 1982
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RE: 700-14031-14
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REPORT OF ANALYSIS

Lab Designation	700-14031-14-6	700-14031-14-7	700-14031-14-8	700-14031-14-9	700-14031-14-10
Sponsor Designation	NM-I5 2-23-82	NM-M6 2-23-82	NM-M7 2-25-82	M-8A 2-25-82	NM-M9 2-25-82
Determination					
Uranium (as U) dissolved, mg/L	0.38	0.34	0.19	0.19	0.16
Radium-226, dissolved, pCi/L ± counting error	240 ± 10	100 ± 10	8.0 ± 1.1	18 ± 2	58 ± 4
Thorium-230, dissolved, pCi/L ± counting error	2.0 ± 0.8	0.3 ± 0.6	0.2 ± 0.5	0.8 ± 0.6	0.6 ± 0.6

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

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RE: 700-14031-14
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REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14031-14-11 NM-M11 2-23-82	700-14031-14-12 NM-M12 2-23-82	700-14031-14-13 WF-74 2-25-82	700-14031-14-14 WF-75 2-25-82
Determination				
Uranium (as U) dissolved, mg/L	0.075	0.12	0.30	0.24
Radium-226, dissolved, pCi/L ± counting error	100 ± 10	16 ± 2	200 ± 10	70 ± 4
Thorium-230, dissolved, pCi 'L ± counting error	0.6 ± 0.7	0.2 ± 0.4	6.5 ± 1.2	2.1 ± 0.8

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

BY

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APPENDIX A-2
PATTERN 2

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March 17, 1982
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Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
Casper, WY 82602

RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14005-13-1 P-15 2-2-82	700-14005-13-2 M-20 2-8-82	700-14005-13-3 M-21 2-3-82	700-14005-13-4 M-22 2-5-82	700-14005-13-5 M-23 2-5-82
Determination (mg/L)					
pH	6.6	7.2	7.0	7.1	7.0
Conductivity, μmhos/cm	3210	3200	2800	3000	2800
Bicarbonate (as HCO_3)	70	246	239	214	232
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	58	204	198	177	192
Calcium, total	110	89	80	95	72
Chloride	35	29	26	26	25
Manganese, total	62	61	51	66	48
Potassium, total	8.7	8.0	7.0	8.1	6.9
Sodium, total	680	570	550	600	460
Sulfate (as SO_4)	1840	1490	1300	1500	1220
TDS (at 180°C)	2790	2330	2060	2310	1930
Anion/Cation	1.0	0.96	1.02	1.03	0.93
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2

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Pat Spieles
March 17, 1982
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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14005-13-1 P-15 2-2-82	700-14005-13-2 M-20 2-8-82	700-14005-13-3 M-21 2-3-82	700-14005-13-4 M-22 2-5-82	700-14005-13-5 M-23 2-5-82
Determination (mg/L)					
Nitrate (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	1.3	<0.5	0.6	<0.5	<0.5
Arsenic, total	0.034	<0.005	<0.005	<0.005	0.009
Barium, total	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	0.2	0.3	0.4	0.1	0.2
Cadmium, total	0.009	0.005	<0.005	0.005	0.005
Chromium, total	0.01	0.01	0.01	0.01	0.01
Copper, total	0.027	0.010	0.010	0.013	0.011
Fluoride	0.1	0.2	0.2	0.2	0.2
Iron, total	2.0	0.33	0.26	0.38	0.17
Lead, total	<0.005	<0.005	<0.005	<0.005	<0.005
Manganese, total	0.11	0.14	0.13	0.17	0.11
Mercury, total	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum, total	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel, total	0.03	0.04	0.06	0.07	0.06
Selenium, total	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium, total	4.0	0.25	1.6	0.20	0.25
Zinc, total	0.36	0.026	0.10	0.018	0.019
Silica (as SiO_2)	31	8	8	9	8

These samples are scheduled to be disposed of 30 days after the date of this report.

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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation	700-14005-13-6	700-14005-13-7	700-14005-13-8	700-14005-13-9	700-14005-13-10
Sponsor Designation	M-24	OB-1	OB-3	I-16A	I-17
	2-3-82	2-8-82	2-8-82	2-10-82	2-10-82
Determination (mg/L)					
pH	8.0	6.7	7.0	7.2	7.2
Conductivity, µmhos/cm	2700	3800	2800	3000	2750
Bicarbonate (as HCO_3)	242	181	165	228	195
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	200	150	136	188	161
Calcium, total	87	150	110	87	73
Chloride	26	36	29	29	26
Manganese, total	52	75	54	51	48
Potassium, total	6.9	9.5	8.4	7.4	7.3
Sodium, total	480	670	550	590	480
Sulfate (as SO_4)	1220	1900	1480	1350	1250
TDS (at 180°C)	1930	2850	2260	2130	1940
Anion/Cation	0.99	0.99	0.99	1.05	0.96
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	0.6	<0.5	<0.5	<0.5
Arsenic, total	<0.005	0.023	0.017	0.013	0.007
Barium, total	<0.2	<0.2	<0.2	<0.2	<0.2

These samples are scheduled to be disposed of 30 days after the date of this report.

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Pat Spieles
March 17, 1982
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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation	700-14005-13-6	700-14005-13-7	700-14005-13-8	700-14005-13-9	700-14005-13-10
Sponsor Designation	M-24	OB-1	OB-3	I-16A	I-17
	2-3-82	2-8-82	2-8-82	2-10-82	2-10-82
Determination (mg/L)					
Boron	0.3	0.2	0.4	0.4	0.3
Cadmium, total	0.005	<0.005	0.005	0.005	0.006
Chromium, total	0.01	0.01	0.01	<0.01	<0.01
Copper, total	0.012	0.012	0.011	0.011	0.010
Fluoride	0.2	0.1	0.1	<0.1	0.1
Iron, total	1.9	4.4	0.89	2.0	0.74
Lead, total	0.006	<0.005	0.039	<0.005	<0.005
Manganese, total	0.14	0.18	0.15	0.14	0.12
Mercury, total	<0.0001	<0.0001	<0.0001	<0.0001	0.0002
Molybdenum, total	<0.005	<0.005	<0.005	<0.005	<0.005
Nickel, total	0.05	0.07	0.06	0.08	0.05
Selenium, total	<0.005	<0.005	<0.005	<0.005	<0.005
Vanadium, total	0.070	1.2	0.20	0.128	0.48
Zinc, total	0.37	0.13	0.072	0.033	0.052
Silica (as SiO_2)	8	18	20	20	11

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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14005-13-11 I-18 2-10-82	700-14005-13-12 I-19 2-10-82	700-14005-13-13 SM-68 2-16-82
Determination (mg/L)			
pH	6.2	7.3	7.9
Conductivity, µmhos/cm	3200	3250	18,000
Bicarbonate (as HCO_3)	80	107	516
Carbonate (as CO_3)	0	0	0
Alkalinity (as $CaCO_3$)	66	88	426
Calcium, total	110	130	400
Chloride	33	61	150
Manganese, total	55	58	226
Potassium, total	7.7	8.6	17
Sodium, total	670	620	3600
Sulfate (as SO_4)	1711	1770	8770
TDS (at 180°C)	2500	2580	13,800
Anion/Cation	1.04	0.96	1.00
Ammonia (as N)	0.3	3.9	<0.2
Nitrate (as N)	<0.05	<0.05	0.78
Nitrite (as N)	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	31
Arsenic, total	0.032	0.005	0.025
Barium, total	<0.2	<0.2	<0.2

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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation	700-14005-13-11	700-14005-13-12	700-14005-13-13
Sponsor Designation	I-18 2-10-82	I-19 2-10-82	SM-68 2-16-82
Determination (mg/L)			
Boron	0.3	0.3	0.5
Cadmium, total	0.005	<0.005	0.022
Chromium, total	0.01	0.01	0.06
Copper, total	0.011	0.012	0.048
Fluoride	<0.1	<0.1	<0.1
Iron, total	5.9	5.2	39
Lead, total	<0.005	<0.005	0.052
Manganese, total	0.17	0.19	0.46
Mercury, total	<0.0001	<0.0001	0.0001
Molybdenum, total	<0.005	<0.005	<0.005
Nickel, total	0.09	0.05	0.23
Selenium, total	<0.005	<0.005	<0.005
Vanadium, total	0.25	0.074	0.75
Zinc, total	0.26	0.021	0.41
Silica (as SiO_2)	36	26	10

These samples are scheduled to be disposed of 30 days after the date of this report.

BY Chris Shugarts
Chris Shugarts
Water Laboratory
Supervisor

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environmental engineers, scientists, planners, & management consultants

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March 15, 1982
Page 1 of 3

Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation	700-14005-13-1	700-14005-13-2	700-14005-13-3	700-14005-13-4	700-14005-13-5
Sponsor Designation	P-15	M-20	M-21	M-22	M-23
	2-2-82	2-8-82	2-3-82	2-5-82	2-5-82
Determination					
Uranium (as U) total, mg/L	0.24	0.24	0.14	0.027	0.23
Radium-226, total, pCi/L ± counting error	730 ± 10	130 ± 10	270 ± 10	220 ± 10	220 ± 10
Thorium-230, total, pCi/L ± counting error	41 ± 3	0.6 ± 0.6	2.3 ± 0.8	0.8 ± 0.6	1.0 ± 0.6

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14005-13-6 M-24 2-3-82	700-14005-13-7 OB-1 2-8-82	700-14005-13-8 OB-3 2-8-82	700-14005-13-9 I-16A 2-10-82	700-14005-13-10 I-17 2-10-82
Determination					
Uranium (as U) total, mg/L	0.055	0.057	0.12	0.094	0.15
Radium-226, total, pCi/L ± counting error	450 ± 10	220 ± 10	280 ± 10	36 ± 2	230 ± 10
Thorium-230, total, pCi/L ± counting error	0.5 ± 0.6	13 ± 2	6.2 ± 1.2	5.5 ± 1.2	1.8 ± 0.8

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

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Pat Spieles
March 15, 1982
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RE: 700-14005-13
P.O. AP2-1483, Rel. 602
Date Samples Rec'd 2-23-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14005-13-11 I-18 2-10-82	700-14005-13-12 I-19 2-10-82	700-14005-13-13 SM-68 2-16-82
Determination			
Uranium (as U) total, mg/L	0.045	0.032	0.074
Radium-226, total, pCi/L ± counting error	71 ± 4	11 ± 1	10 ± 1
Thorium-230, total, pCi/L ± counting error	5.1 ± 1.1	2.2 ± 0.8	7.1 ± 6.3

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

BY

Bud Summers
Radiochemistry
Supervisor

BS/srf pt

20723

CDM

*environmental engineers, scientists,
planners, & management consultants*

CAMP DRESSER & McKEE INC.

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APPENDIX A-3
PATTERN 3

March 24, 1982
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Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
Casper, WY 82602

RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-1 NM-M40 2-18-82	700-14032-14-2 NM-M40A 2-19-82	700-14032-14-3 NM-M40B 2-19-82	700-14032-14-4 NM-M41 2-18-82	700-14032-14-5 NM-M42 2-18-82
Determination (mg/L)					
pH	7.2	8.1	7.0	7.3	6.9
Conductivity, µmhos/cm	2800	1600	3400	2000	3400
Bicarbonate (as HCO_3)	198	155	216	146	203
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	163	128	179	121	167
Calcium, total	76	36	92	40	90
Chloride	26	20	38	25	37
Manganese, total	47	17	58	25	57
Potassium, total	5.8	5.8	7.2	6.1	7.2
Sodium, total	430	240	500	280	530
Sulfate (as SO_4)	1070	505	1350	653	1370
TDS (at 180°C)	1770	854	2170	1070	2090
Anion/Cation	1.01	1.01	0.96	0.98	0.99
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2

These samples are scheduled to be disposed of 30 days after the date of this report.

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Pat Spieles
March 24, 1982
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RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation	700-14032-14-1	700-[illegible]032-14-2	700-14032-14-3	700-14032-14-4	700-14032-14-5
Sponsor Designation	NM-M40	NM-M40A	NM-M40B	NM-M41	NM-M42
	2-18-82	2-19-82	2-19-82	2-18-82	2-18-82
Determination (mg/L)					
Nitrate (as N)	<0.05	<0.05	0.09	0.05	0.09
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	<0.5	<0.5	1.2
Arsenic, total	<0.005	<0.005	<0.005	<0.005	0.023
Barium, total	<0.2	<0.2	<0.2	<0.2	<0.2
Boron	0.2	0.2	0.2	0.2	0.2
Cadmium, total	0.006	<0.005	<0.005	0.005	0.005
Chromium, total	<0.01	<0.01	<0.01	<0.01	<0.01
Copper, total	0.011	<0.005	0.010	0.011	0.010
Fluoride	0.1	<0.1	0.1	0.2	0.2
Iron, total	3.1	0.43	0.76	0.11	7.3
Lead, total	0.097	<0.005	0.180	<0.005	<0.005
Manganese, total	0.422	0.462	0.420	0.056	0.170
Mercury, total	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Molybdenum, total	0.006	0.009	<0.005	0.005	<0.005
Nickel, total	0.06	<0.02	0.10	0.05	0.03
Selenium, total	0.012	0.015	0.018	0.032	0.105
Vanadium, total	0.072	0.028	0.040	0.134	0.70
Zinc, total	0.42	0.009	0.470	0.027	0.043
Silica (as SiO_2)	6	5	6	6	8

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RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation	700-14032-14-6	700-14032-14-7	700-14032-14-8	700-14032-14-9	700-14032-14-10
Sponsor Designation	NM-M43 2-18-82	NM-M44 2-19-82	I-45 2-24-82	I-46 2-24-82	I-47 2-24-82
Determination (mg/L)					
pH	7.4	7.0	6.7	7.1	7.2
Conductivity, µmhos/cm	2000	3000	1800	2200	3500
Bicarbonate (as HCO_3)	158	180	77	162	248
Carbonate (as CO_3)	0	0	0	0	0
Alkalinity (as $CaCO_3$)	130	145	63	134	205
Calcium, total	41	89	33	51	110
Chloride	21	25	18	18	36
Magnesium ~~Manganese~~, total	25	55	17	30	62
Potassium, total	5.5	6.6	7.7	4.4	7.7
Sodium, total	290	430	260	300	510
Sulfate (as SO_4)	653	1100	615	719	1440
TDS (at 180°C)	1090	1770	974	1170	2210
Anion/Cation	1.0	1.05	1.0	1.0	0.96
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05	<0.05
Aluminum, total	<0.5	<0.5	<0.5	0.9	<0.5
Arsenic, total	<0.005	<0.005	0.007	<0.005	0.007
Barium, total	<0.2	<0.2	<0.2	<0.2	<0.2

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RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-6 NM-M43 2-18-82	700-14032-14-7 NM-M44 2-19-82	700-14032-14-8 I-45 2-24-82	700-14032-14-9 I-46 2-24-82	700-14032-14-10 I-47 2-24-82
Determination (mg/L)					
Boron	0.2	0.2	0.2	0.2	0.2
Cadmium, total	0.005	0.007	0.005	<0.005	0.005
Chromium, total	<0.01	<0.01	<0.01	<0.01	<0.01
Copper, total	0.006	0.006	0.006	0.005	0.007
Fluoride	0.3	0.1	0.2	<0.1	0.2
Iron, total	0.25	0.38	0.95	2.1	3.5
Lead, total	<0.005	0.027	<0.005	0.020	0.016
Manganese, total	0.045	0.178	0.035	0.120	0.243
Mercury, total	<0.0001	<0.0001	0.0021	<0.0001	0.0003
Molybdenum, total	<0.005	<0.005	0.007	<0.005	<0.005
Nickel, total	0.02	0.04	0.03	0.02	0.05
Selenium, total	0.096	0.010	0.019	0.014	0.006
Vanadium, total	0.36	0.19	0.49	0.37	0.15
Zinc, total	0.028	0.105	0.046	0.058	0.123
Silica (as SiO_2)	7	10	15	12	10

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RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-11 I-48A 2-24-82	700-14032-14-12 I-49 2-24-82	700-14032-14-13 P-50 2-2-82	700-14032-14-14 P-53 2-2-82
Determination (mg/L)				
pH	6.5	7.1	7.7	7.4
Conductivity, µmhos/cm	2100	3500	2000	1800
Bicarbonate (as HCO_3)	99	212	81	36
Carbonate (as CO_3)	0	0	0	0
Alkalinity (as $CaCO_3$)	82	175	67	30
Calcium, total	41	110	30	24
Chloride	30	38	25	20
Magnesium ~~Manganese~~, total	26	62	22	20
Potassium, total	5.5	7.3	5.0	5.0
Sodium, total	310	520	280	290
Sulfate (as SO_4)	742	1400	664	662
TDS (at 180°C)	1180	2240	1060	1010
Anion/Cation	0.99	0.98	1.04	0.99
Ammonia (as N)	<0.2	<0.2	<0.2	<0.2
Nitrate (as N)	<0.05	<0.05	<0.05	0.06
Nitrite (as N)	<0.05	<0.05	<0.05	<0.05
Aluminum, total	1.2	<0.5	<0.5	<0.5
Arsenic, total	0.031	<0.005	0.008	0.018
Barium, total	<0.2	<0.2	<0.2	<0.2

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REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-11 I-48A 2-24-82	700-14032-14-12 I-49 2-24-82	700-14032-14-13 P-50 2-2-82	700-14032-14-14 P-53 2-2-82
Determination (mg/L)				
Boron	0.2	0.2	0.2	0.2
Cadmium, total	<0.005	<0.005	<0.005	<0.005
Chromium, total	<0.01	<0.01	<0.01	<0.01
Copper, total	0.005	0.007	<0.005	<0.005
Fluoride	0.1	0.2	0.1	<0.1
Iron, total	1.0	2.9	0.46	0.25
Lead, total	<0.005	0.010	<0.005	<0.005
Manganese, total	0.086	0.247	0.049	0.045
Mercury, total	0.0001	0.0016	<0.0001	<0.0001
Molybdenum, total	0.008	<0.005	0.008	<0.005
Nickel, total	0.02	0.06	0.03	0.03
Selenium, total	<0.005	0.017	0.045	0.126
Vanadium, total	1.14	0.16	0.83	1.38
Zinc, total	0.061	0.116	0.067	0.099
Silica (as SiO_2)	15	12	18	13

These samples are scheduled to be disposed of 30 days after the date of this report.

BY Chris Shugarts
Chris Shugarts
Water Laboratory
Supervisor

CS/tew

20723

CDM

environmental engineers, scientists, planners & management consultants

CAMP DRESSER & McKEE INC.

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March 31, 1982
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Pat Spieles
Rocky Mountain Energy Co.
P.O. Box 3719
Casper, WY 82602

RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-1 NM-M40 2-18-82	700-14032-14-2 NM-M40A 2-19-82	700-14032-14-3 NM-M40B 2-19-82	700-14032-14-4 NM-M41 2-18-82	700-14032-14-5 NM-M42 2-18-82
Determination					
Uranium (as U) dissolved, mg/L	0.098	0.041	0.15	0.056	0.11
Radium-226, dissolved, pCi/L ± counting error	25 ± 2	12 ± 1	37 ± 2	30 ± 2	84 ± 4
Thorium-230, dissolved, pCi/L ± counting error	1.7 ± 0.8	0.0 ± 0.5	1.1 ± 0.6	0.1 ± 0.5	9.2 ± 1.4

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

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Pat Spieles
March 31, 1982
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RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-6 NM-M43 2-18-82	700-14032-14-7 NM-M44 2-19-82	700-14032-14-8 I-45 2-24-82	700-14032-14-9 I-46 2-24-82	700-14032-14-10 I-47 2-24-82
Determination					
Uranium (as U) dissolved, mg/L	0.29	0.084	0.074	0.049	0.13
Radium-226, dissolved, pCi/L ± counting error	70 ± 3	200 ± 10	500 ± 10	320 ± 10	94 ± 4
Thorium-230, dissolved, pCi/L ± counting error	0.9 ± 0.6	5.4 ± 1.2	15 ± 2	120 ± 10	9.3 ± 1.4

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

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Pat Spieles
March 31, 1982
Page 3 of 3

RE: 700-14032-14
P.O. AP2-1483, Rel. 603
Date Samples Rec'd 2-26-82

REPORT OF ANALYSIS

Lab Designation Sponsor Designation	700-14032-14-11 I-48A 2-24-82	700-14032-14-12 I-49 2-24-82	700-14032-14-13 P-50 2-2-82	700-14032-14-14 P-53 2-2-82
Determination				
Uranium (as U) dissolved, mg/L	0.11	0.17	0.18	0.060
Radium-226, dissolved, pCi/L ± counting error	400 ± 10	350 ± 10	560 ± 10	310 ± 10
Thorium-230, dissolved, pCi/L ± counting error	58 ± 3	32 ± 3	6.8 ± 1.2	7.2 ± 1.2

*Variability of the radioactive disintegration process (counting error) at the 95% confidence level, 1.96σ.

These samples are scheduled to be disposed of 45 days after the date of this report.

BY Bud Summers

Bud Summers
Radiochemistry
Supervisor

BS/srf

20723

APPENDIX B

Nine Mile Lake

Contaminant Migration Analyses

Section	Content
B-1	Comparison of Rocky Mountain Energy and Consultant Evaluations
B-2	RME Radium Absorption Calculations
B-3	M.A. Hulbert Report: Potential Migration of Ground Water Constituents from Patterns 1,2, and 3

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APPENDIX B-1

ROCKY MOUNTAIN ENERGY

MEMORANDUM

Date June 14, 1982

To M. R. Neumann

From J. E. Lankenau JEL

Subject Nine Mile Lake
Contaminant Migration Review

In response to your request, the following are my comments regarding the Nine Mile Lake contaminant migration study conducted by M. A. Hulburt:

1. The model used by M. A. Hulburt is a straight dilution model. In general, the use of a model which only incorporates diffusion of ions in the surrounding groundwater would have to be considered the absolute worst case.

2. In defining the proper ion transport mechanism, theory would dictate that the mechanism which yields the <u>shortest</u> distance is the most appropriate.

3. There are three primary mechanisms which should be considered for groundwater ion migration:

    1) Geochemical

       pH, Eh, reaction of contaminants with the changes in groundwater through migration.

    2) Ion Exchange

       The formation clays generally exhibit absorption characteristics for different ion contaminants.

    3) Dilution/Dispersion

4. A direct comparison can be made for radionuclide migration estimates made by RME and M. A. Hulburt. RME used an ion exchange approach rather than the dilution method. Since RME obtained a shorter distance, the ion exchange mechanism should be the controlling factor. M. A. Hulburt considered a retardation coefficient; this coefficient assumes complete IX reversibility. Thus, this method is the same as assuming no IX capacity for the clays, which

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has been proven not to be the case; clays do absorb ions from solution. RME's approach assumed a very small, conservative IX capacity; I feel that these results more adequately describe the actual controlling mechanism.

5. Judging from the distances given by M. A. Hulburt for the other ions (V, Pb, Fe, U) not included in the RME IX study, I feel that the simple dilution mechanism is again inappropriate. All of the other contaminants are affected by pH, Eh, and other ions in the surrounding water. Although hard data (experimental) proof is not available, it is my belief that the migration distances via dilution are overstated by an order of magnitude due to the neglected geochemical effects.

JEL/mr

cc: P. J. Bosse
R. E. Iwanicki
J. A. Yellich
J. A. Yopps

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APPENDIX B-2

Nine Mile Lake
Calculation of Radium Absorption by Formation Clays
January 29, 1982

Assumptions

1) The clays in the Nine Mile Lake formation consist primarily of kaolinite. (J. P. Moran, Wellfield Geologist, geologic logs; Halliburton Pattern 4 Well Completion Study)

2) The clays at Reno consist primarily of montmorillonite. (J. C. Milbourne, Metallurgist; IX Clay Study)

3) The surface clays at NML consist primarily of illite which is similar in absorptive capacity to montmorillonite. (J. C. Milbourne, Metallurgist; RSE Study)

4) The tested total CEC's (cation exchange capacity) for Reno and NML are about 30 and 20 respectively. (J. C. Milbourne)

5) The incremental absorption capacity of the soils study for further radium intake is 4 pCi/gram clay at the incremental radium levels. This is very conservative. (J. E. Lankenau, Chemical Engineer; Retention of Isotopes Study, Hazen Research)

6) If the soils radium CEC is 4 pCi/gram, then Reno formation, due to similar clays as the soils, is also 4 pCi/gram; therefore, comparing the overall total CEC's in assumption 4 (Reno/NML = 1.5/1.0), the NML formation (incremental) radium CEC is 2.6667 pCi/gram. (J. E. Lankenau)

7) The clay content at NML is about 9% with a formation (solid) SG = 2.70.

8) Two contaminant pods will be considered: 1) the area around M-54, and 2) Pattern 3.

9) Radium levels:

	Actual	Baseline
M-54	1,000 pCi/l	500
Pattern 3	550	270

10) Volume of contamination around M-54 is 1.3×10^6 gallons consisting of an area 100 ft radius, 20 ft thick, 28% porosity.

11) Volume of contamination around Pattern 3 is equivalent to the area of the pattern interior: 60 ft radius, 52 ft thick, 28% porosity.

12) The pods will migrate in one direction and will narrow to the width of the radius.

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Nine Mile Lake
Calculation of Radium Absorption
by Formation Clays
January 29, 1982

Pattern 3 Migration/Absorptions

Total Volume of Fluids

(πr^2) (thickness) (porosity) = fluid volume
(π) $(60\ \text{ft})^2$ (52) (0.28) = 164,669.7 ft^3
(164,669.7 ft^3) (7.48 gal/ft^3) (3.785) =
4,662,095.6 liters

Incremental Radium Absorption

600 (actual) - 270 (baseline) = 330 pCi/l

Total Radium

(330 pCi/l) (4,662,095.6 1) = 1,538,491,500 pCi

Amount of Clay Required

1,538,491,500 pCi/2.6667 pCi/gram clay =
576,927,100 grams

Volume Encompassed by Clay Required

(576,927,100 grams) (2.7 gm/cm^3) = 213,676,700 cm^3
(213,676,700 cm^3) (3.531×10^{-5} ft^3/cm^3) =
7,521 ft^3 clay
7,521 ft^3/0.09 = 83,567 ft^3 solid formation
83,567 ft^3/1-0.28 = 116,065 ft^3 actual formation

Migration Distance Calculation

116,065 ft^3/52 ft thick = 2,232 ft^2 area
2,232 ft^2/60 ft wide = <u>37.20 ft movement</u>

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Nine Mile Lake
Calculation of Radium Absorption
by Formation Clays
January 29, 1982

M-54 Migration/Absorption

Total Volume

1.3×10^6 gallons x 3.785 = 4.9205×10^6 liter

Incremental Radium to be Absorbed

$$\underset{\text{(actual)}}{1{,}000 \text{ pCi/l}} - \underset{\text{(baseline)}}{500} = 500 \text{ pCi/l}$$

Total Radium to be Absorbed

(500 pCi/l)(4.9205×10^6 liters) = 2,460,250,000 pCi

Amount of Clay Required

2,460,250,000 pCi/2.6667 pCi/gram clay =
922,582,217 grams

Volume Encompassed by Clay Required

(922,582,217 gram)/(2.7 gm/cm^3) = 341,697,118 cm^3
(341,697,118 cm^3)(3.531×10^{-5} ft^3/cm^3) =
12,065 ft^3 of clay

$$\frac{12{,}065 \text{ ft}^3 \text{ of clay}}{0.09 \ \frac{\text{ft}^3 \text{ clay}}{\text{ft}^3 \text{ formation}}} = 134{,}059 \text{ ft}^3 \text{ solid formation}$$

$$\frac{134{,}059}{1-0.28} = 186{,}193 \text{ ft}^3 \text{ actual formation}$$

Migration Distance Calculation

186,193 ft^3/20 ft thickness = 9,309 ft^2 surface area

9,309 ft^2/100 ft wide = 93.09 ft migration

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Nine Mile Lake
Calculation of Radium Absorption
by Formation Clays
January 29, 1982

References

1) Current Status of Nine Mile Lake Groundwater IOM from P. R. Spieles, January 19, 1982.

2) Halliburton Service Study of Pattern 4, February 17, 1981.

3) A Report on the Ion Exchange Behavior of Reno Creek and Nine Mile Lake Clays IOM from J. C. Milbourne, November 19, 1980.

4) Retention of Radioisotopes and Other Soluble Species on Clay and Sand Sample, consultant report--Hazen Research, Inc., August 30, 1979.

5) Preliminary Soil Investigation for Nine Mile Lake, consultant report--Chen and Associates, August 31, 1978.

6) Geotechnical Investigation and Hydrologic Study, consultant report--RSE Geotechnical, July 20, 1979.

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HAZEN RESEARCH, INC.

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TELEPHONE 303/279-4501

RETENTION OF RADIOISOTOPES AND OTHER SOLUBLE SPECIES ON CLAY AND SAND SAMPLES

for

Rocky Mountain Energy Company
4704 Harlan Street
Denver, CO 80212

August 30, 1979

OFFICIAL DOCKET COPY

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HRI Project No. 4740
Copy No. 2

RETENTION OF RADIOISOTOPES AND OTHER SOLUBLE SPECIES ON CLAY AND SAND SAMPLES

Prepared by:

D E Hyatt
D. E. Hyatt, Ph.D.
Project Engineer

Approved by:

D N Goens
D. N. Goens
Project Manager

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INTRODUCTION

Work reported here was performed for Rocky Mountain Energy Company under Professional Services Agreement dated June 14, 1979.

The primary objective of this project was to evaluate the sorptive capacity of several substrates (clay and sand) for Ra^{226}, Th^{230}, Pb^{210}, As, Ba, Se, V, U, Ca, and sulfate. The design considerations for the construction of containment ponds to hold solutions containing radioisotopes and other constituents include consideration of the sorptive capacity of contacting clays, sand, soil, etc., for solution components. Evaluation of sorptive properties of these materials allows projections of sealing capabilities of the containment area to be made.

The specific laboratory program followed diverges from the original proposal (Hazen Research Proposal 79-92, June 6, 1979) in two particulars, both at the request of Rocky Mountain Energy Company. First, test solution was prepared by blending solutions designated as Bear Creek and Nine Mile; the original proposal anticipated the availability of a single feed solution not requiring blending. Second, a pH regime of 6, 9, and 12 was specified to be of interest rather than the originally proposed 4, 6, and 8.

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SUMMARY

The removal of radioisotopes (Ra^{226}, Th^{230}, and Pb^{210}) and of other scluble species in a blended pH adjusted combination of Nine Mile and Bear Creek solutions has been studied.

Removal of Th^{230}, Pb^{210}, As, V, U_3O_8, and Se by coprecipitation-scavenging upon pH adjustment to 6, 9, and 12 was observed. Removal efficiencies by this route exceeded 95% for Th^{230}, Pb^{210}, As, and V.

Sorption of radioisotopes on clay (TP-1) and sand (S-8 and HS-5/S-12) substrates was significant at all pH levels evaluated. Concentration factors for Th^{230} and Pb^{210} were generally higher than for Ra^{226}; Ra^{226} was most concentrated by clay TP-1 while sand S-8 provided highest concentration factors for Th^{230} and Pb^{210}.

All three substrates evaluated contribute little leachable components to contacting solutions in the pH range of 6 to 12. Sand HS-5/S-12 provides some leachable Se (increasing with increasing pH); sand S-8 and clay TP-1 exhibit similar but less marked behavior relative to Se release.

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EXPERIMENTAL

Samples of the following substrates were provided in glass bottles by Rocky Mountain Energy Company:

Clay	No. TP-1
Sand	No. S-8
Sand	No. HS-5 and S-12

The clay TP-1 represents the proposed clay material which could be used to line the commercial evaporation reservoir at Nine Mile Lake. Sand S-8 is a sample of a clayey sand which would be directly below the reservoir. The remaining sands, HS-5 and S-12, are sandier type sands which lie beneath S-8.

All samples were dried in an air oven at 110°C for 24 hours. Clay TP-1 and sand S-8 exhibited 17% weight loss and clay HS-5/S-12 exhibited 14% weight loss under these conditions. The dried materials were stored in closed polyethylene bottles for use in the sorptive tests described in this report.

Two solution samples designated Nine Mile solution (approximately 5 gallons) and Bear Creek solution (approximately 1/2 gallon) were supplied by Rocky Mountain Energy Company for use in blending a test solution for the sorption tests. These solutions were analyzed for components of interest prior to blending and pH adjustment required for the sorption tests. Analytical data on the component solution is shown in Table 1.

Feed solutions for sorption tests at pH levels of 6, 9, and 12 were prepared by blending one part of Bear Creek tailings solution with five parts of Nine Mile solution to yield a solution containing an appropriate level (about 200 pCi/L) of Ra^{226}. This was necessary because Nine Mile Lake solution of appropriate strength was not available. The pH of this initial mixture was 2.9; mixing resulted in no appreciable formation of solids. Equal portions of the blended solution (approximately 2 liters each) were then pH-adjusted by the addition of 10 M NaOH with vigorous stirring. Subsequent to attainment of the chosen pH levels, the solutions were allowed to stand for 48 hours (with infrequent stirring) and then filtered through 0.45-μ membrane filters under pressure to provide the final pH adjusted feed solutions for the sorption tests. Significant amounts of solids precipitated from all solutions upon the adjustment of pH. Analytical data for the pH adjusted sorptive capacity feed solutions are summarized in Table 2.

Equilibration of substrates and pH adjusted feed solutions was accomplished by mixing of varying weights (1, 10, and 40 grams) of each substrate with 200-ml aliquots of each pH adjusted solution. Mixing was performed in sealed polyethylene bottles on a roller mill for a period of 24 hours. Subsequent to the equilibration period, each slurry was filtered through a 0.45-μ membrane filter under pressure (approximately 100 psig). Filtrates were analyzed for components of interest,and solids were sealed in plastic containers for later analysis and studies aimed at eluting sorbed species.

Analytical data for filtrates from the 27 equilibration tests (three substrate addition levels at each of three pH levels) are summarized in Tables 3, 4, and 5 for pH levels of 6, 9, and 12, respectively.

Stripping experiments in which sorbed radioisotopes were subjected to elution by 0.2 M ammonium acetate (200 ml of solution; 24-hour equilibration on roller mill) were performed on solids from the pH 6 equilibration test with clay TP-1. Analytical data from this equilibrium test are presented in Table 6.

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Table 1

Component Solution Analytical Data

Component	Nine Mile Solution	Bear Creek Solution
Ra^{226}	45 ± 5 pCi/L	1120 ± 90 pCi/L
Th^{230}	13 ± 4 pCi/L	124,000 ± 1000 pCi/L
Pb^{210}	3.7 ± 3.0 pCi/L	20,000 ± 200 pCi/L
As	<0.1 mg/L	1.0 mg/L
Ba	<2 mg/L	<2 mg/L
Ca	453 mg/L	426 mg/L
Se	6 µg/L	80 µg/L
SO_4^{-2}	10.3 g/L	12.6 g/L
V	21 mg/L	42 mg/L
U_3O_8	1.5 mg/L	41.5 mg/L

Table 2

Analytical Data for pH Adjusted Solutions

Component	pH 6	pH 9	pH 12
Ra^{226}	170 pCi/L	25 pCi/L	85 pCi/L
Th^{230}	210 pCi/L	20 pCi/L	0 pCi/L
Pb^{210}	96 pCi/L	26 pCi/L	98 pCi/L
As	<0.01 mg/L	<0.01 mg/L	<0.01 mg/L
Ba	0.1 mg/L	<0.1 mg/L	<0.1 mg/L
Ca	410 mg/L	332 mg/L	7.14 mg/L
Se	<5 µg/L	<5 µg/L	<5 µg/L
SO_4^{-2}	11.0 g/L	6.96 g/L	10.3 g/L
V	<0.2 mg/L	<0.2 mg/L	<0.2 mg/L
U_3O_8	1.5 mg/L	-	1.9 mg/L

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Table 3

Analytical Data
Equilibration Test Filtrates - pH 6

		Grams of Substrate		
Component	Substrate	1	10	40
Ra^{226} (pCi/L)	Clay TP-1	99 ±29	6 ± 15	0 ± 12
Th^{230} (pCi/L)		98 ±55	0 ±32	0 ±32
Pb^{210} (pCi/L)		45 ±52	0 ±32	34 ±46
As (mg/L)		0.01	0.01	0.01
Ba (mg/L)		0.2	0.2	0.2
Ca (mg/L)		478	546	448
Se (µg/L)		<5	<5	<5
SO_4^{-2} (g/L)		12.6	12.3	10.8
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.2	0.1	0.2
Ra^{226} (pCi/L)	Sand S-8	110 ±30	0 ± 12	0 ± 12
Th^{230} (pCi/L)		66 ±48	11 ±34	5 ±32
Pb^{210} (pCi/L)		2 ±52	40 ± 52	0 ±48
As (mg/L)		<0.01	0.01	0.01
Ba (mg/L)		0.2	0.2	0.2
Ca (mg/L)		482	442	400
Se (µg/L)		52	60	45
SO_4^{-2} (g/L)		11.4	12.0	-
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.2	0.2	-
Ra^{226} (pCi/L)	Sand HS-5/S-12	160 ± 40	44 ±26	5 ± 17
Th^{230} (pCi/L)		200 ± 70	22 ±37	11 ±34
Pb^{210} (pCi/L)		59 ±48	31 ±49	16 ±49
As (mg/L)		0.02	0.01	0.02
Ba (mg/L)		0.1	0.1	0.2
Ca (mg/L)		478	514	478
Se (µg/L)		162	45	107
SO_4^{-2} (g/L)		11.6	12.5	12.5
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.2	0.3	0.2

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Table 4

Analytical Data
Equilibration Test Filtrates - pH 9

Component	Substrate	Grams of Substrate		
		1	10	40
Ra^{226} (pCi/L)	Clay TP-1	2 ± 11	0 ± 8	0 ± 8
Th^{230} (pCi/L)		11 ± 41	0 ± 33	0 ± 8
Pb^{210} (pCi/L)		53 ± 38	59 ± 41	10 ± 43
As (mg/L)		0.02	<0.01	0.02
Ba (mg/L)		<0.1	<0.1	0.2
Ca (mg/L)		380	461	525
Se (μg/L)		76	64	71
SO_4^{-2} (g/L)		12.4	11.8	16.5
V (mg/L)		-	-	<0.2
U_3O_8 (mg/L)		-	-	1.2
Ra^{226} (pCi/L)	Sand S-8	6 ± 10	6 ± 10	0 ± 6
Th^{230} (pCi/L)		130 ± 60	110 ± 60	-
Pb^{210} (pCi/L)		70 ± 40	36 ± 40	57 ± 39
As (mg/L)		0.02	0.01	0.01
Ba (mg/L)		0.2	0.2	0.1
Ca (mg/L)		407	401	403
Se (μg/L)		33	38	-
SO_4^{-2} (g/L)		10.9	11.3	13.1
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.13	1.30	0.39
Ra^{226} (pCi/L)	Sand HS-5/S-12	23 ± 15	0 ± 6	0 ± 9
Th^{230} (pCi/L)		11 ± 41	0 ± 35	6 ± 40
Pb^{210} (pCi/L)		2 ± 41	55 ± 38	83 ± 40
As (mg/L)		0.02	0.12	0.04
Ba (mg/L)		0.1	0.3	<0.1
Ca (mg/L)		370	353	391
Se (μg/L)		560	58	76
SO_4^{-2} (g/L)		11.4	12.2	-
V (mg/L)		-	-	-
U_3O_8 (mg/L)		3.53	0.70	-

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Table 5

Analytical Data
Equilibration Test Filtrates - pH 12

		Grams of Substrate		
Component	Substrate	1	10	40
Ra^{226} (pCi/L)	Clay TP-1	0 ± 6	0 ± 6	0 ± 6
Th^{230} (pCi/L)		0 ± 33	0 ± 6	0 ± 6
Pb^{210} (pCi/L)		19 ± 36	43 ± 37	10 ± 43
As (mg/L)		0.12	0.07	0.01
Ba (mg/L)		<0.1	0.2	0.2
Ca (mg/L)		4.71	4.96	-
Se (µg/L)		107	78	78
SO_4^{-2} (g/L)		12.6	12.2	17.5
V (mg/L)		-	<0.2	<0.2
U_3O_8 (mg/L)		-	-	0.04
Ra^{226} (pCi/L)	Sand S-8	0 ± 6	0 ± 6	0 ± 6
Th^{230} (pCi/L)		56 ± 51	78 ± 56	27 ± 33
Pb^{210} (pCi/L)		84 ± 40	49 ± 37	40 ± 37
As (mg/L)		0.03	0.04	0.06
Ba (mg/L)		<0.1	<0.1	0.1
Ca (mg/L)		9.69	5.42	4.47
Se (µg/L)		64	59	-
SO_4^{-2} (g/L)		10.8	12.4	16.1
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.46	-	4.05
Ra^{226} (pCi/L)	Sand HS-5/S-12	23 ± 10	0 ± 9	0 ± 6
Th^{230} (pCi/L)		0 ± 35	6 ± 40	0 ± 33
Pb^{210} (pCi/L)		63 ± 38	30 ± 37	4 ± 36
As (mg/L)		0.09	2.12	0.20
Ba (mg/L)		<0.1	<0.1	<0.1
Ca (mg/L)		13.0	8.66	9.65
Se (µg/L)		214	58	580
SO_4^{-2} (g/L)		11.0	12.0	12.6
V (mg/L)		-	-	-
U_3O_8 (mg/L)		0.71	3.74	-

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Table 6

Analytical Data
Ammonium Acetate Leach[1] of
Clay TP-1 (pH 6 Loading)

Component	Range of Recovery
Ra^{226}	49-257%
Th^{230}	2-45%

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[1] 200 ml of 2 M ammonium acetate contacted with solids on roller mill for 24 hours.

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RESULTS

In conducting the experimental program described above and reviewing the analytical data pertinent to blending, pH adjustment, and sorption segments, it is clear that various soluble species are removed by sorption on solids precipitating during pH adjustment as well as by sorption on the tested substrates. While the objective of this program was to evaluate component removal by substrate sorption on clays and sands, the observed removal (coprecipitation) during neutralization also deserves comment.

In the absence of coprecipitation or scavenging by precipitated solids, upon pH adjustment, component levels in the blended Nine Mile-Bear Creek test solution should be calculable by simple dilution calculations. Departures from these component levels in the blended, pH adjusted solution provides a qualitative measure of the binding capacity of the precipitate for species in solution. Tables 7, 8, and 9 summarize analytical data in terms of expected and observed component levels in the equilibration test solutions at pH 6, 9, and 12, respectively.

While the removal mechanism (sorption, formation of filterable solid phase, etc.) is not identifiable in these experiments, it is nevertheless apparent that a consequence of pH adjustment is the formation of nonfilterable (0.45 μ) associations for many of the components of interest. To the extent that similar neutralization reactions occur in a full scale pond, accumulation of some components in precipitated solids may be anticipated. These findings support the earlier findings and projections by In-Situ Consulting (1978) regarding scavenging of soluble species by $Fe(OH)_3$ formed during neutralization of tailings solution at the Bear Creek site.

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Table 7

Component Levels Expected and Observed in Test Solution at pH 6

Component	Expected Concentration 1/	Analytical Concentration	Removal, %
Ra^{226}	195 pCi/L	170 pCi/L	11
Th^{230}	20,678 pCi/L	210 pCi/L	99
Pb^{210}	3336 pCi/L	96 pCi/L	97
As	0.25 mg/L	<0.01 mg/L	>96
Ba	<2 mg/L	0.1 mg/L	-
Ca	449 mg/L	410 mg/L	9
Se	18 μg/L	<5 μg/L	>72
SO_4^{-2}	10.7 g/L	11.0 g/L	-
V	24.5 mg/L	<0.2 mg/L	>99
U_3O_8	8.2 mg/L	1.5 mg/L	82

1/ Based on 5:1 dilution.

Table 8

Component Levels Expected and Observed in Test Solution at pH 9

Component	Expected Concentration 1/	Analytical Concentration	Removal, %
Ra^{226}	195 pCi/L	25 pCi/L	87
Th^{230}	20,678 pCi/L	20 pCi/L	>99
Pb^{210}	3336 pCi/L	26 pCi/L	>99
As	0.25 mg/L	<0.01 mg/L	>96
Ba	<2 mg/L	<0.1 mg/L	-
Ca	449 mg/L	332 mg/L	26
Se	18 μg/L	<5 μg/L	>72
SO_4^{-2}	10.7 g/L	-	-
V	24.5 mg/L	<0.2 mg/L	>99
U_3O_8	8.2 mg/L	-	-

1/ Based on 5:1 dilution.

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Table 9

Component Levels Expected and Observed in Test Solution at pH 12

Component	Expected Concentration[1]	Analytical Concentration	Removal, %
Ra^{226}	195 pCi/L	85 pCi/L	56
Th^{230}	20,678 pCi/L	0 pCi/L	>99
Pb^{210}	3336 pCi/L	98 pCi/L	97
As	0.25 mg/L	<0.01 mg/L	>96
Ba	<2 mg/L	<0.1 mg/L	-
Ca	449 mg/L	7.14 mg/L	98
Se	18 µg/L	<5 µg/L	>72
SO_4^{-2}	10.7 g/L	10.3 g/L	4
V	24.5 mg/L	<0.2 mg/L	>99
U_3O_8	8.2 mg/L	1.9 mg/L	77

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[1] Based on 5:1 dilution.

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A review of the analytical data on component levels remaining in the test solutions after equilibration with varying amounts of each substrate may be augmented by graphic data display. Residual levels of Ra^{226} and Th^{230} are plotted with respect to calculated solids uptake of these components on the three substrates at pH 6 (Figures 1 and 2). Similar curves are not presented for pH 9 and pH 12 systems or for Pb^{210} due to the overall low level of radioisotopes in these feed solutions and the large error bar associated with analyses in small solution volumes at these ultratrace levels. Estimated maximum radioisotope sorptive capacities of the three substrates at pH 6 are summarized in Table 10.

The radioisotope removal curves at pH 6 and the analytical data on all substrates at pH 6, 9, and 12 suggest that clay (TP-1) and sand (S-8) substrates have significantly more capacity than the (lower) clay designated HS-5/S-12. Significant interaction of all substrates at all pH levels with U_3O_8 was noted. No substantial contribution to levels of any analyzed components was noted by the substrates tested at the pH levels of 6, 9, and 12 with the exception of Se. Low levels of Se appear in solutions equilibrated with all substrates and increase with pH.

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Ra^{226} UPTAKE FROM pH 6 TEST SOLUTION

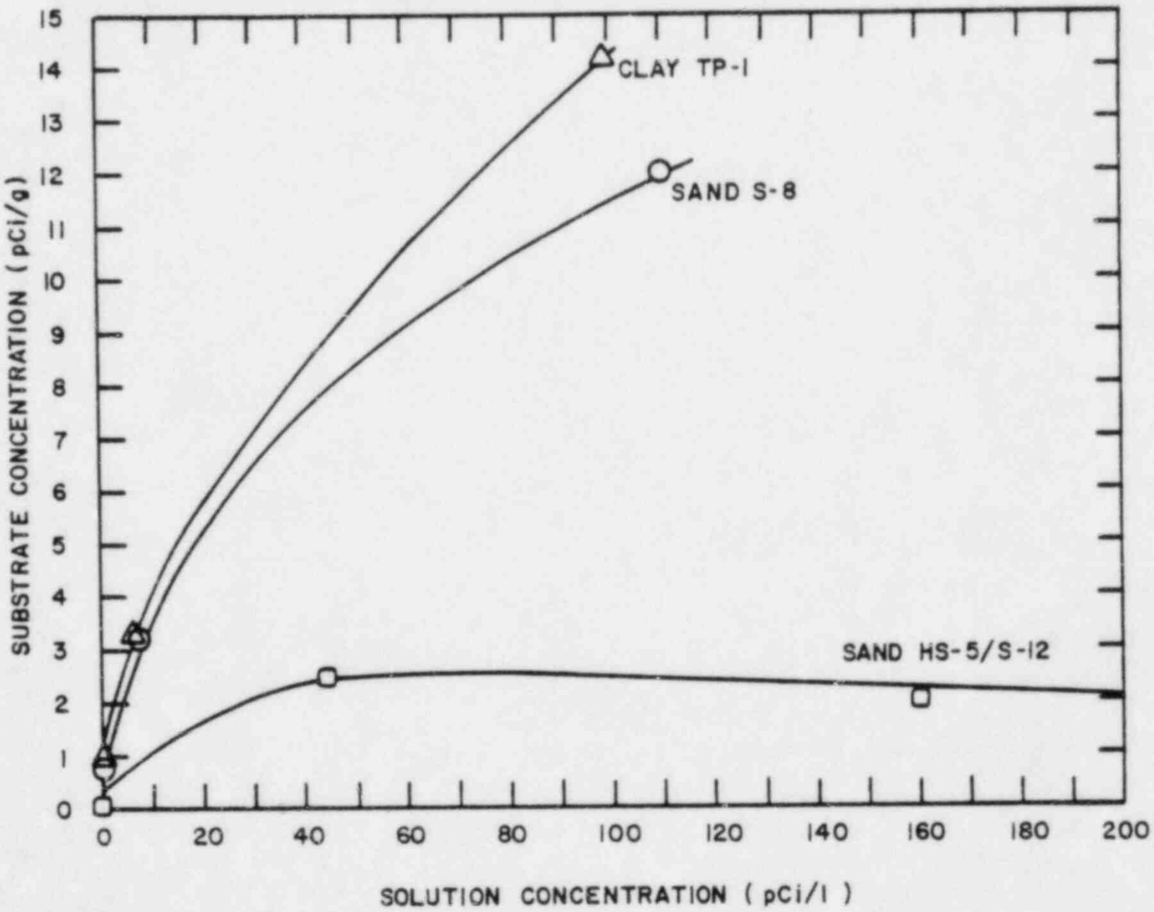

FIGURE 1

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Th^{230} UPTAKE FROM pH 6 TEST SOLUTION

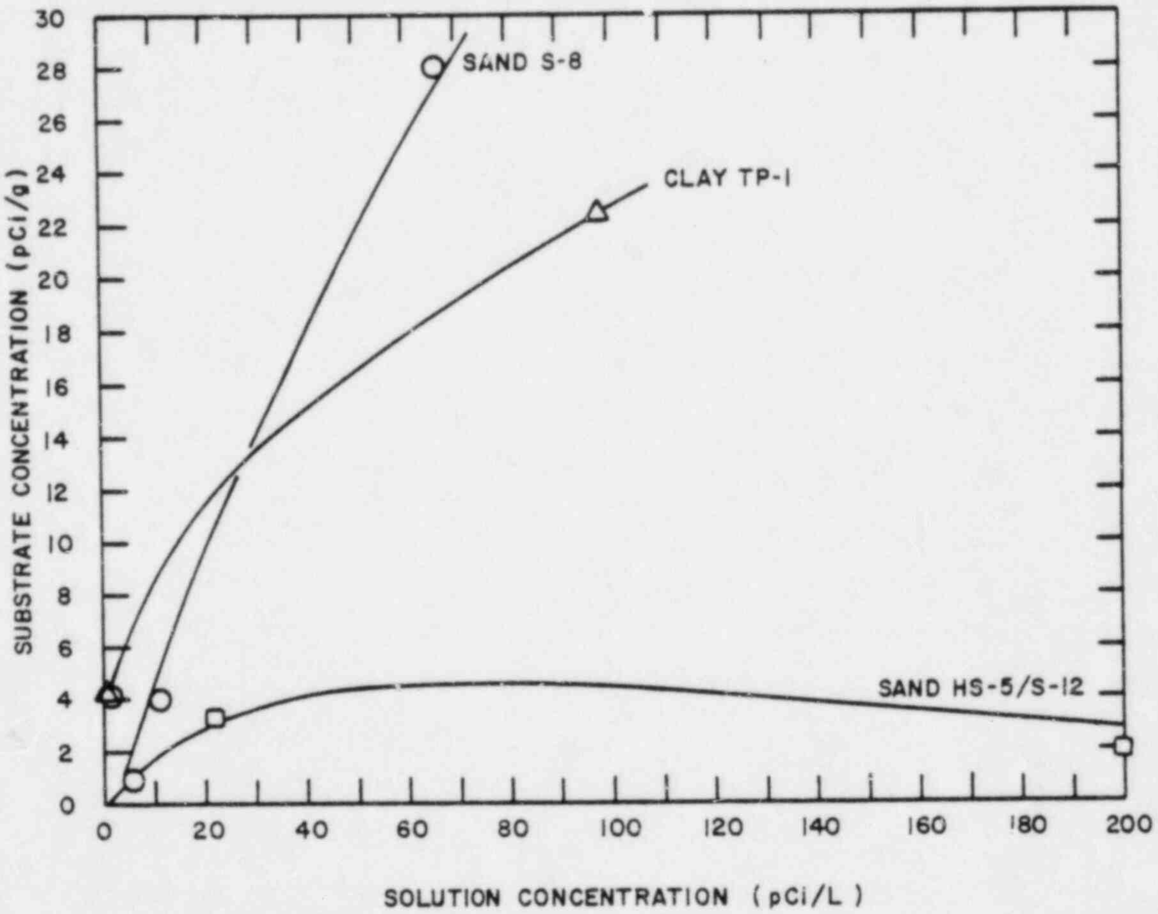

FIGURE 2

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Table 10

Estimated[1] Substrate Sorptive Capacity
for Ra^{226}, Th^{230}, and Pb^{210}

Substrate	pH	Ra^{226} pCi/kg	Ra^{226} CF[2]	Th^{230} pCi/kg	Th^{230} CF	Pb^{210} pCi/kg	Pb^{210} CF
Clay TP-1	6	14,200	143	22,400	229	10,200	226
Sand S-8	6	12,000	109	28,800	436	18,800	>361
Sand HS-5/S-12	6	2,000	13	2,000	10	7,400	125

1/ Maximum based on sorptive level of 1 gram of substrate exposed to 200 ml of solution.

2/ CF = concentration factor = $\frac{\text{pCi/kg of radioisotope in solids}}{\text{pCi/L of radioisotope in equilibrated solution}}$

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CONCLUSIONS

Based on the test program described above and upon the data presented, the following conclusions are offered:

1. pH adjustment of the test solution prepared by blending Nine Mile and Bear Creek samples results in significant reduction in the levels of Th^{230}, Pb^{210}, and other low level components of the solution in the pH range 6-12.
2. Clay TP-1 and sand S-8 exhibit marked capacity for radioisotope and U_3O_8 removal from solutions at pH 6-12. Sand S-12 exhibits measurable but lower capacity
3. Efforts to strip sorbed Ra^{226} and Th^{230} from clay TP-1 (loaded at pH 6) resulted in radioisotope recovery levels of 49-257% for Ra^{226} and 3-45% for Th^{230}. This indicates that the clay TP-1 binds Th^{230} more strongly than Ra^{226} and may even contain low levels of exchangeable (soluble) Ra^{226} in 2 M ammonium acetate. Quantitative data and conclusions based upon data at the ultratrace analytical levels involved here must be viewed with reserve.
4. Sand HS-5/S-12 and, to a lesser degree, sand S-8 and clay TP-1 contribute increasing amounts of Se upon increasing pH of contacting solutions.

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APPENDIX B-3

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Potential Migration of Ground Water Constituents from Patterns 1, 2, and 3 at the Rocky Mountain Energy Co. Nine Mile Lake Test Site

Prepared for:

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P.O. Box 2000
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May 28, 1982

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Potential Migration of Ground Water Constituents from Patterns 1, 2, and 3 at the Rocky Mountain Energy Co. Nine Mile Lake Test Site

Introduction

At the request of Rocky Mountain Energy Company, an analysis was undertaken of the potential distance and rate of migration of several ground water constituents present at the Nine Mile Lake test site. Specifically, the fate of radium (Ra-226), uranium (U_3O_8), vanadium (V), iron (Fe), and lead (Pb) were investigated. The analysis was conducted for the three acid patterns at the site, patterns 1, 2, and 3.

Migration of the ground water constituents was described using a mass transport and dispersion equation. Where a distribution coefficient could be calculated from available on-site test data, the retardation of constituent movement due to adsorption was included in the analysis. Where a site-specific distribution coefficient could not be obtained, the ion was assumed to migrate at the same rate as the ground water.

For each parameter and test pattern, the distance to the ion front, the distance to the peak concentration, and the value of the peak concentration were calculated over time. These values are considered to represent a worst case due to several assumptions underlying the migration calculations. A major assumption of the mass transport equation is that the adsorption reaction is completely reversible. This is probably not the case for all of the ions of interest. Secondly, the equation does not take into account other geochemical reactions which may be occurring, such as

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coprecipitation of these ions with other chemical species in the ground water. Therefore the presence of any geochemical activity in the aquifer would reduce the migration distances given in this report. The data taken from Hazen Research, Inc. (1979) represent conditions of pH 6 and a sandy substrate. These seemed most representative of the Nine Mile Lake site; however any elevation in aquifer pH or clay content of the substrate would further reduce migration distance.

Finally, an evaluation was made of existing Rocky Mountain Energy Company predictions of radium migration. Conclusions were based on comparison with the mass transport/dispersion results and on examination of the assumptions and input parameters of the analysis.

Mass Transport Equation

The mass transport equation used to describe the movement of ground water constituents at the Nine Mile Lake site was originally described by Baetsle (1969) and presented in Freeze and Cherry (1979). As a contaminant mass is transported through a flow system, the concentration distribution within that mass at any time t is given by:

$$C(x,y,z,t) = \frac{M}{8(\pi t)^{3/2}\sqrt{DxDyDz}} \exp\left(-\frac{X^2}{4Dxt} - \frac{Y^2}{4Dyt} - \frac{Z^2}{4Dzt}\right)$$

where M is the mass of contaminant introduced at a point source; Dx, Dy, and Dz are the coefficients of dispersion in the x, y, and z directions; and X, Y, and Z are the distances from the center of gravity of the contaminant mass in the x, y, and z

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directions. $X = x - \bar{v}t$, $Y = y$, and $Z = z$. Theoretically, the contaminant input occurs at a point and therefore has mass but no volume. In practice, the mass M is approximated by C_oV_o, where C_o is the initial concentration and V_o is the initial volume.

This equation assumes no retardation of ion movement due to adsorption; that is, the ion is assumed to migrate at the same rate as the ground water flow. Testing conducted by Hazen Research, Inc. (1979) on Nine Mile Lake site materials showed that radium and uranium are adsorbed onto the aquifer materials. Data were not presented for the other ions of interest to the present study. In order to account for the effects of adsorption in the mass transport equation, the parameter t was replaced by $\tau = t(\bar{v}_c/\bar{v})$, where $\bar{v}$ is the rate of ground water movement and $\bar{v}_c$ is the rate of ion movement (Freeze and Cherry, 1979).

The retardation factor for ion migration is given by:

$$\frac{\bar{v}}{\bar{v}_c} = 1 + \frac{\rho_b}{n} . K_d$$

where ρ_b is the bulk mass density, n is the porosity, and K_d is the distribution coefficient.

Input Parameters

The parameters $\bar{v}$, n, ρ_b, Dx, Dy, and Dz in the above equations are properties of the aquifer and can therefore be treated as constants throughout the mass transport analysis. The parameters K_d and $\bar{v}_c$ depend on the ion as well as the aquifer characteristics and therefore will vary with the ground water constituent.

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Finally, the parameters C_o and V_o are specific to each ion and test pattern combination.

The natural ground water flow velocity in the vicinity of the Nine Mile Lake site was provided by Rocky Mountain Energy Company as approximately 20 ft/yr in an E25°S direction. The value of 6.10 m/yr was used in the calculations. Rocky Mountain Energy Company also provided a local porosity of 28%.

The bulk mass density was approximated from the average mass density of minerals that constitute unconsolidated deposits, taken as 2.65 g/cm^3. The average mass density was multiplied by the percentage of solid materials in the aquifer (1 - 0.28) to yield a bulk density of 1.91 g/cm^3.

The coefficients of dispersion, Dx, Dy, and Dz, were taken from a plot of flow velocity versus dispersion for a sand of 22% porosity (Freeze and Cherry, 1979). The resulting values were $Dx = 2.84\ m^2/yr$, $Dy = Dz = 0.22\ m^2/yr$, and $\sqrt{DxDyDz} = 370\ L/yr^{3/2}$. The 22% porosity curves were the most representative dispersion data readily available. Because these reflect a slightly lower porosity than is found at the Nine Mile Lake site, longitudinal dispersion may be slightly underestimated while transverse dispersion may be overestimated. With all other factors held constant, this would result in a slight underprediction of concentrations and migration distances. The 6% difference in porosity is probably not significant. A sample calculation using radium data for pattern 1 shows that even if the longitudinal dispersion is doubled and the transverse dispersion is halved, a change much greater than that expected, after 500 years the

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peak concentration would be 483 pCi/L rather than 478 pCi/L and the distance to the front would be 200 feet rather than 177 feet.

Distribution coefficients, K_d, were calculated for radium and uranium from on-site data collected by Hazen Research, Inc. (1979). By definition, the distribution coefficient is the mass of solute adsorbed onto solid materials per unit mass of solids divided by the concentration of solute in solution. The mass of solute on the solid phase was computed from the Hazen study by simply subtracting the final solute concentration and multiplying by the solute volume. The concentration of solute in solution was the final solute concentration. Data were taken from the Hazen study for the case where the pH of the initial solution was equal to 6 and the substrate was sand HS-5/S-12. For radium:

initial solute concentration = 170 pCi/L
final solute concentration = 160 pCi/L
volume of solute = 0.2 L
mass of solute on solid phase = 260 mg/kg
K_d = 12.5 L/kg

For uranium:

initial solute concentration = 1.5 mg/L
final solute concentration = 0.2 mg/L
volume of solute = 0.2 L
mass of solute on solid phase = 260 mg/kg
K_d = 1300 L/kg

The clay content of sand HS-5/S-12 was not provided in the Hazen report. The ore sand at the Nine Mile Lake site contains up to 15% clay, which may indicate slightly higher K_d values than used here.

The velocity of the ions, $\bar{v}_c$, was calculated for radium and uranium using the retardation equation given above. For radium,

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$\bar{v}_c$ = 7.01 x 10^{-2} m/yr, and for uranium, $\bar{v}_c$ = 6.87 x 10^{-4} m/yr.

The initial ion concentration, C_o, and volume, V_o, were determined for each ion and test pattern combination. Water quality data for February 1982 were examined for each pattern, and the region within which each ion remained above baseline was delineated to the extent possible, by interpolation between wells. The affected area was then multiplied by the aquifer thickness and porosity to obtain the initial volume of contamination. The present ion concentration was taken as the average of the reported concentrations within the affected area. The initial concentration, C_o, was then obtained by subtracting the baseline concentration from the present concentration. Table 1 gives the affected area, aquifer thickness, baseline concentration, C_o, and V_o for each ion and test pattern combination. Analysis of the water quality data indicated that uranium and lead concentrations were not elevated above baseline in pattern 2 and that uranium was not elevated in pattern 3.

Analysis of Ion Migration

Once the input parameters were identified, the migration of each ion away from the three test patterns was characterized. The peak concentration within the contaminant plume at any time t can be obtained from the mass transport equation by setting X, Y, and Z equal to 0. The resulting equation is:

$$C_{max} = \frac{C_o V_o}{V_o + 8(\pi t)^{3/2} \sqrt{DxDyDz}}$$

The term V_o has been added to the denominator in this form of the

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equation. This is necessary due to the very large initial ion volumes used in this application. The volumes are so large that they cannot be considered negligible, as required in theory. The equation divides the initial mass by the incremental increase in volume due to dispersion at time t to obtain the peak concentration. Because of the large volumes used, the increase in volume is much less than the initial volume for most values of t, resulting in peak concentration values much larger than the initial concentration. The addition of V_o to the denominator simply adds the increase in volume to the initial volume to give a realistic peak concentration.

This equation can be rearranged to determine the time it will take for the plume to disperse to any given peak concentration C (i.e: baseline):

$$t = \left(\frac{\frac{C_oV_o}{C} - V_o}{8\sqrt{DxDyDz}}\right)^{2/3} \cdot \frac{1}{\pi}$$

The distance which the plume will move before dispersing to baseline is [illegible]:

$$d = \bar{v}t$$

Again, when an ion is known to move more slowly than the ground water flow, t is replaced by $\tau = t(\bar{v}_c/\bar{v})$ in the above equations.

For each ion and test pattern, the above equations were used to determine the time it would take for the contaminant to disperse to baseline and the distance the concentration peak would travel before dispersing. To gain a broader picture of the character of ion migration is each case, the peak concentration and distance to the peak were computed for several selected times during

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migration. The mass transport equation was then used, in a rearranged form, to compute the distance to the ion front at the same time intervals. In all of these calculations dispersion to baseline was considered to be complete when the contaminant had been reduced to a concentration less than 10% of the baseline reported for the pattern.

Results

Tables 2 through 13 present the peak concentration, distance to the peak, and distance to the ion front at intervals during plume migration for each ion and test pattern combination. Table 14 summarizes the times and distances required for complete dispersal.

Table 14 shows that all constituents, with the exception of vanadium in pattern 2, can be expected to disperse to baseline within one mile of their origin. Radium in pattern 2 will disperse within 350 feet. Vanadium, however, is expected to travel nearly 8 miles from pattern 2 before dispersing to baseline. (Vanadium dispersal will occur over much shorter distances from patterns 1 and 3). The reason that such a large distance is required for vanadium dispersal from pattern 2 is the low baseline level (0.05 mg/L) reported for this pattern. Dispersal to the most stringent Wyoming ground water quality standard for vanadium (0.1 mg/L) will occur within approximately 2 miles.

The time required for dispersal to baseline varies widely, from 30 years for lead in pattern 1 to 1.8 million years for

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uranium. The time frame is partially dependent on the baseline and present concentrations of each constituent in the three patterns. The most significant factor, however, is the level of retardation due to adsorption. The very large time frames for radium and uranium are due to the retardation factor included in the mass transport equation for these ions; while the other ions were assumed to migrate at the same velocity as the water. The time frames given for vanadium, iron, and lead should be considered minimum values. Any retardation of these constituents due to adsorption would significantly increase travel times. To put the movement of radium and uranium in perspective, at the end of ten human generations, or 1000 years, radium will have migrated 308 feet from pattern 1, 260 feet from pattern 2, and 310 feet from pattern 3 and uranium will have migrated about 2 feet from pattern 1.

It should also be noted that each test pattern is treated as an instantaneous contaminant source. That is, over time each constituent will move away from the pattern as a slug which expands slowly in the up- and down-gradient directions. The result of this type of movement is that the pattern area can be expected to restore itself to baseline at some point before the contaminant mass has completely dispersed. Because the peak concentration is always located at the center of mass of the contaminant plume, the distance from the pattern to the back end of the migrating plume can easily be calculated from the distance to the peak and the distance to the front at any time. For example, after 1000 years of migration, the distance to the peak radium concentration

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from pattern 1 is 230 feet, and the distance to the front is 308 feet. The distance from pattern 1 to the back of the radium plume is 230 - (308 - 230) = 152 feet.

Evaluation of RME Radium Analysis

The Rocky Mountain Energy Company analysis of radium migration, based on cation exchange capacities, predicted a migration distance of 93 feet for pattern 1 and 37 feet for pattern 3. These results are significantly less than those obtained using the mass transport method for the same initial conditions.

The difference can be explained by examination of one major assumption. The cation exchange capacity method assumes that once the radium is adsorbed onto the aquifer materials, it will not go back into solution. The mass transport method assumes that all adsorbed radium will eventually go back into solution. Therefore the cation exchange capacity method predicts much shorter migration distances than the mass transport method. The mass transport method clearly produces worst-case results. Because the radium is being adsorbed within a dynamic flow system, some degree of desorption would be expected when baseline quality water re-enters the region and changes the chemical equilibrium of the system. Whether or not the adsorption reaction would be completely reversible at Nine Mile Lake requires further study.

Conclusions

The distances which radium, uranium, vanadium, iron, and lead can be expected to travel from patterns 1, 2, and 3 before

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dispersing to baseline concentrations have been calculated under worst-case conditions. All constituents, except for vanadium in pattern 2, will disperse to baseline within one mile of travel. Vanadium in pattern 2 will require nearly 8 miles. Where retardation due to adsorption was taken into account, for radium and vanadium, travel times are extremely long. Travel times for vanadium, iron, and lead should be considered minimum values.

The nearest water well completed in the Mesa Verde Formation down-gradient is located approximately 20,500 feet (3.9 miles) from the boundary. Therefore, under worst-case predictions, all constituents except vanadium are expected to be reduced to baseline concentrations before reaching this well. The peak increase in vanadium concentration expected in this well is 0.016 mg/L. If the baseline concentration in this well is 0.05 mg/L as it is in pattern 2, then the maximum expected vanadium level would be 0.066 mg/L. This is within the 0.1 mg/L standard for vanadium.

These worst-case travel distances may be significant over-predictions due to the assumption of complete reversibility of adsorption reactions. Further definition of distribution coefficients and reversibility of adsorption reactions for the five constituents could provide more realistic travel distances.

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References

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TABLE 1

Initial Ion Concentration and Volume

Ion	Pattern	Affected Area (m^2)	Aquifer Thickness (m)	Baseline Concentration	Present Concentration	Initial Concentration*	Initial Volume (L)
Radium	1	2919	6.10	500 pCi/L	1000 pCi/L	500 pCi/L	4.92×10^6
	2	183	6.10	700	974	274	3.12×10^5
	3	1051	18.29	270	600	330	4.66×10^6
Uranium	1	1140	6.10	0.2 mg/L	0.77 mg/L	0.57 mg/L	1.95×10^6
Vanadium	1	285	6.10	0.1 mg/L	0.17 mg/L	0.07 mg/L	4.87×10^6
	2	7127	6.10	0.05	0.79	0.74	1.22×10^7
	3	1051	18.29	0.45	0.79	0.34	5.38×10^6
Iron	1	1140	6.10	1.42 mg/L	2.89 mg/L	1.47 mg/L	1.95×10^6
	2	730	6.10	1.11	4.17	3.06	6.23×10^5
	3	730	18.29	4.10	4.89	0.79	3.74×10^6
Lead	1	570	6.10	0.1 mg/L	0.14 mg/L	0.04 mg/L	9.75×10^5
	3	526	18.29	0.05	0.10	0.05	2.69×10^6

*Initial Concentration (C_o) = Present Concentration - Baseline Concentration

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TABLE 2

Radium Migration, Pattern 1

Time (yrs)	Peak Concentration (pCi/L)	Distance to Peak (ft)	Distance to Front (ft)
10	499	2	15
100	498	23	56
150	496	35	74
250	492	58	105
500	478	115	177
1,000	442	230	308
5,000	202	1150	1266
10,000	97	2300	2411
16,500	50	3795	3848

Site Baseline Range 1.5 - 717

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TABLE 3

Radium Migration, Pattern 2

Time (yrs)	Peak Concentration (pCi/L)	Distance to Peak (ft)	Distance to Front (ft)
10	273	2	13
20	272	5	18
50	268	12	31
100	257	23	47
150	244	35	62
250	217	58	89
500	158	115	149
1000	89	230	260
1460	59	336	347

Site Baseline Range 1.5 - 717

Pattern 2 Range 19 - 717

TABLE 4

Radium Migration, Pattern 3

Time (yrs)	Peak Concentration (pCi/L)	Distance to Peak (ft)	Distance to Front (ft)
10	330	2	15
100	329	23	57
150	328	35	74
250	325	58	106
500	315	115	178
1,000	290	230	310
5,000	129	1150	1271
10,000	61	2300	2420
15,000	36	3450	3544
18,500	27	4255	4305

Pattern 3
High = 274 pCi,

Site Baseline Range 1.5 - 717

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TABLE 5

Uranium Migration, Pattern 1

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
10	0.57	0.03	2
10,000	0.56	23	56
20,000	0.55	45	89
100,000	0.43	225	304
500,000	0.12	1127	1247
1,000,000	0.05	2254	2373
1,800,000	0.02	4057	4119

Site Baseline Range 0.002 - 0.750

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TABLE 6

Vanadium Migration, Pattern 1

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	0.16	20	48
5	0.12	100	148
10	0.08	200	258
20	0.04	400	465
30	0.03	600	664
50	0.01	1001	1047
60	0.01	1201	1225

Site Baseline Range ND-0.45

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TABLE 7

Vanadium Migration, Pattern 2

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)	
1	0.74	20	58	
3	0.73	60	121	
10	0.71	200	300	
20	0.66	400	532	
50	0.50	1001	1188	
100	0.31	2001	2241	SITE RANGE
150	0.21	3002	3276	
250	0.12	5003	5322	
500	0.05	10,007	10,380	
1000	0.02	20,013	20,403	
2000	0.006	40,026	40,248	
2200	0.005	44,209	44,155	

Site Baseline Range ND-0.45

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TABLE 8

Vanadium Migration, Pattern 3

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	0.34	20	51
3	0.33	60	108
10	0.31	200	273
20	0.27	400	490
50	0.16	1001	1110
100	0.08	2001	2106
120	0.07	2402	2498
140	0.06	2802	2884
150	0.05	3002	3075
160	0.047	3202	3264
170	0.044	3402	3449

Site Baseline Range ND-0.45

Pattern 3 Baseline Range 0.01 - 0.45

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TABLE 9

Iron Migration, Pattern 1

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	1.46	20	50
3	1.41	60	105
5	1.34	100	154
10	1.16	200	267
20	0.84	400	480
50	0.37	1001	1088
70	0.25	1401	1481
100	0.16	2001	2053
110	0.14	2201	2233

Site Baseline Range ND-4.10

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TABLE 10

Iron Migration, Pattern 2

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	2.98	20	49
3	2.69	60	104
5	2.36	100	153
10	1.67	200	266
20	0.91	400	478
50	0.30	1001	1082
70	0.19	1401	1472
95	0.12	1901	1940
100	0.11	2001	2026

Pattern 2
High = 1.11 m

Site Baseline Range ND-4.10

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TABLE 11

Iron Migration, Pattern 3

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	0.79	20	47
3	0.77	60	100
5	0.75	100	147
10	0.69	200	257
20	0.57	400	463
30	0.46	600	660
35	0.41	700	757

Site Baseline Range ND-4.10

Pattern 3 Baseline Range 0.01 - 4.10

TABLE 12

Lead Migration, Pattern 1

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
1	0.04	60	97
5	0.03	100	143
20	0.02	400	449
30	0.01	600	637

Site Baseline Range ND-0.140

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TABLE 13

Lead Migration, Pattern 3

Time (yrs)	Peak Concentration (mg/L)	Distance to Peak (ft)	Distance to Front (ft)
5	0.05	100	155
10	0.04	200	270
20	0.03	400	485
50	0.02	1001	1097
75	0.01	1501	1593
100	0.007	2001	2079
110	0.006	2201	2270
130	0.005	2602	2641

Pattern 3
High=0.05 mg/

Site Baseline Range ND-0.140

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TABLE 14

Summary of Ion Dispersal

Ion	Pattern	Time to Disperse (yrs)	Travel Distance (ft)	Concentration
Radium	1	16,500	3,800	50 pCi/l
	2	1,460	350	59 pCi/l
	3	18,500	4,300	27 pCi/l
Uranium	1	1.8×10^6	4,100	0.02 mg/l
Vanadium	1	58	1,150	0.01 mg/l
	2	2,085	41,700	0.005 mg/l
	3	170	3,400	0.045 mg/l
Iron	1	110	2,200	0.15 mg/l
	2	100	2,000	0.12 mg/l
	3	35	700	0.43 mg/l
Lead	1	30	600	0.01 mg/l
	3	130	2,600	0.005 mg/l

Site Baseline Range	
Radium	1.5 - 717 pCi/l
Uranium	0.002 - 0.750 mg/l
Vanadium	ND - 0.45 mg/l
Iron	ND - 4.10 mg/l
Lead	ND - 0.140 mg/l

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APPENDIX C

PATTERN 3 EXCURSION REPORT

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APPENDIX C

PATTERN III EXCURSION DISCUSSION

One of the basic reasons for the operation of Test Pattern III was to test the principle of dual ore zone open injection wells. All six injection wells were perforated in the upper and lower ore zones with one flow and pressure monitoring system per injection well. The concept was: since upper and lower ore zone permeabilities were nearly identical, the injection flow should split evenly between upper and lower ore zones.

Vertical flow profile tests were planned before leaching and uranium recovery began, but could not be done because the highly specialized equipment was not ready. Full flow uranium recovery from Pattern III began in September of 1979.

The vertical flow profile equipment was not ready until late September and the profiles were not run until the end of the first week in October. Test results indicated that flows were not balanced between upper and lower ore zones in all injection wells, and that flow into the upper ore zone was significantly greater than that into the lower ore zone.

Plans were made to begin packing off and isolating the upper and lower ore zones and orders were placed for packers and flow measuring equipment. Meanwhile, Pattern III operation continued as before, that is, with dual zone injection. Packing efforts began on October 24, 1979, with a two inch, heavy-duty PVC string and packer for lower zone injection, and upper zone injection into the five inch, heavy-duty PVC casing annulus.

After initial packing, the upper and lower ore zone injection ports were plumbed together because the flow measuring devices had not yet arrived by late November. It was noted that the packed injection wells were pressuring up almost as soon as they were packed and brought on-line. After a few days' operation (in early November), the packers were pulled and the wells airlifted. Airlift product indicated that while inserting the packers, fungus sludge had been wiped off the casing walls and pushed to the lower ore zone. When the wells were started up, the loose sludge plugged off the lower ore zone, causing the wells to pressure up and probably almost all the flow to be directed to the upper ore zone perforations. These last few days of unbalanced injection flow probably reinforced the excursion flow nets, resulting in contamination of Monitor Wells M-40 and M-43. The excursion was detected during the monthly sampling of the wells on November 13th.

After analysis on November 15, 1979, injection rates into the three wells closest to the affected monitor wells were reduced while production contined at 42 gpm. Sampling of all four monitor wells the following day again showed elevated levels of uranium, conductivity, and sulfate with low pH values for Monitor Wells M-40 and M-43. At this time, injection into all wells was discontinued, and production from the Pattern was increased to about 50 gpm.

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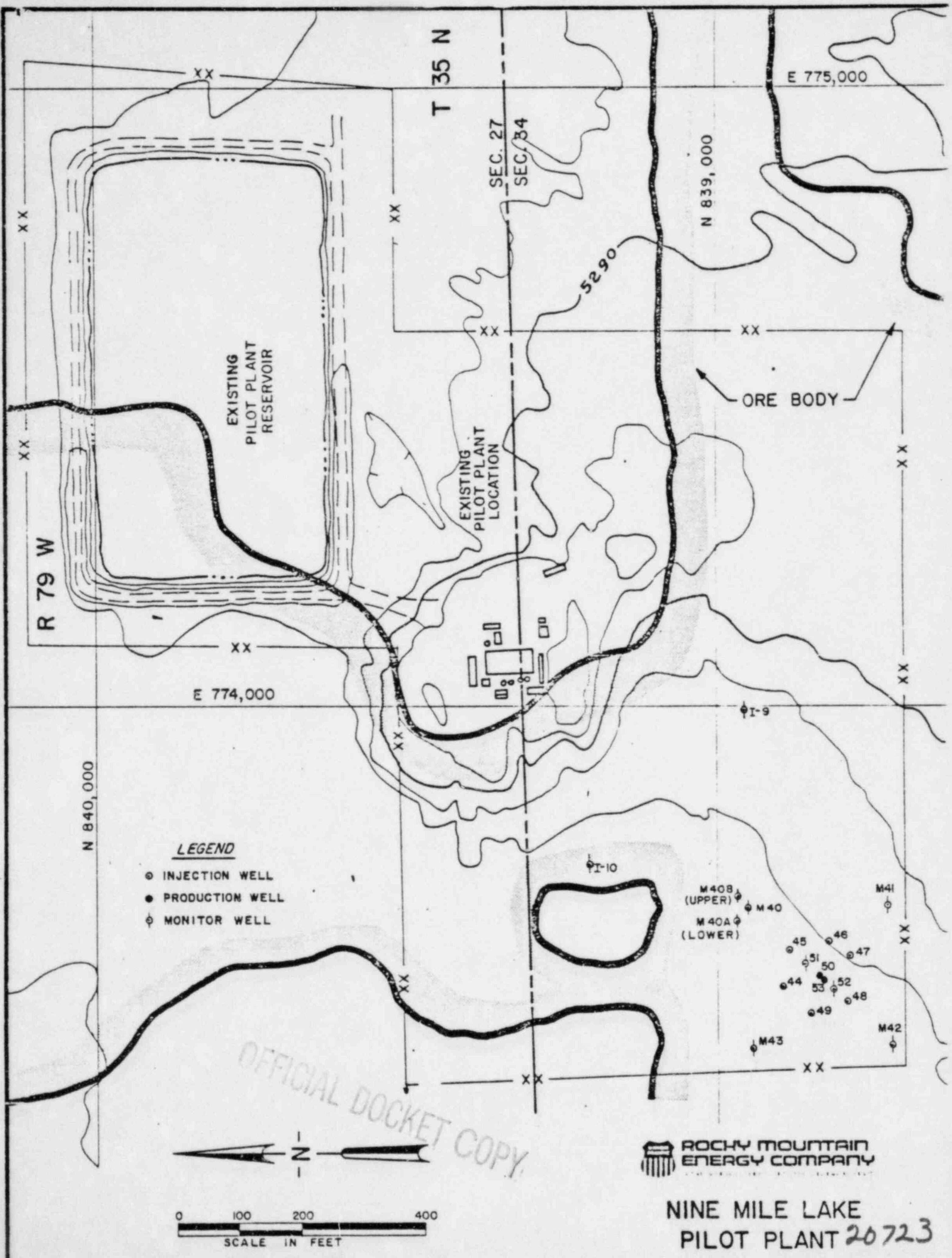

ROCKY MOUNTAIN ENERGY COMPANY

NINE MILE LAKE
PILOT PLANT 20723
PATTERN #3 LOCATION PLAN

On November 16th, all Pattern III monitor wells were sampled again, and excursion status was confirmed for Wells M-40 and M-43. Verbal notification of the confirmed excursion was given immediately to the proper NRC and Wyoming DEQ authorities. Monitor Wells M-41 and M-42 were found to be within upper control limits for excursion control parameters, and selective sampling of the upper and lower ore zones in Wells M-40 and M-43 indicated that the excursion was confined to the upper ore zone. Installation of the packers on all injection wells was completed in order to allow independent control of flows into the upper and lower ore zones. In addition, plans were made to install a packer in Well M-40 for the purpose of determining which ore zone(s) was in excursion status.

As of November 17th, the production rate from Well M-50 (lower ore zone) was reduced to 5 gpm, and installation of two new monitor wells began. It was decided to install the wells about 25 feet out from Well M-40, with one well to be completed in the upper ore zone and one in the lower ore zone. Two days later, production from the upper ore zone (Well P-53) was also cut back to 5 gpm after a six day period of over-production.

Sampling of Well M-40 on November 21, 1979, indicated that the Pattern was responsive to the period of over-production, as values for pH, conductivity, sulfate, and uranium were beginning to return toward baseline (background) levels.

The following week, installation of the new monitor wells continued, as did production from the upper and lower ore zones at 5 gpm each, for a total production rate of 10 gpm. During the week, Well M-43 was again sampled and found to be within baseline ranges for pH, conductivity, and sulfate, although uranium and other metals remained at slightly elevated levels. This confirmed that the net withdrawal of 10 gpm was effectively drawing lixiviant back to the pattern interior. By November 27, 1979, a packer had been installed in Well M-40 to allow selective sampling of the upper and lower ore zones, and the new lower ore zone monitor well (M-40A) had been completed. Sampling of Well M-40 indicated that the excursion was confined to the upper ore zone, which was confirmed by sampling of the new lower zone monitor well (M-40A) on November 29, 1979. Results of the M-40A sampling showed essentially background levels for pH, conductivity, sulfate, uranium, and vanadium. Figure II shows the location of Pattern III monitor wells.

On December 4, 1979, all Pattern III monitor wells were sampled, and Wells M-41, M-42, and M-40A showed values within baseline ranges. Well M-43 was also back to baseline ranges with the exception of slightly elevated values for metals, including uranium. Well M-43 showed considerable improvement with the excursion parameters beginning to return to the upper control limits (UCL).

The following day, selective injection into the lower ore zone was resumed at a rate of 20 gpm, while production was maintained at 21 gpm for an injection/production ratio of 1:1.05. Production from the upper ore zone continued at 5 gpm with no injection.

On December 7th, the new upper ore zone monitor well (M-40B) was completed and sampled. Sample results revealed slightly elevated (with respect to Pattern background ranges) values for conductivity, sulfate, and metals which, again, indicated that the excursion was confined to the upper ore zone. All M-40B parameters were below upper control levels.

Sampling of the monitor wells on December 10th showed an appreciable deterioration of water quality in Well M-40. In order to increase the water withdrawal ratio from the M-40 side of the Pattern, Injection Well I-45 was put into production. The intent was to sweep M-40 with unaffected water drawn toward the Pattern interior. Problems with pump failures hindered these efforts, but, by December 31st, this action was showing positive results. M-40 was sampled and revealed significant improvement for all excursion parameters with values again approaching baseline ranges. The January 2nd sampling confirmed that M-40 was greatly improved. Values for pH, conductivity, and sulfate had returned to baseline ranges for all wells, including M-40.

Believing that the upper zone excursion had been effectively retrieved and stabilized, production from Well I-45 was terminated and injection into the lower ore zone resumed on January 4th. Sampling of Well M-40 the following week (January 11, 1980) again showed substantial deterioration of water quality, indicating that hydraulic communication between the upper and lower ore zones was occurring. The "pressuring up" of the lower ore zone probably caused recontamination of M-40. Injection into Well I-45 was curtailed. A potassium chloride solution was injected into Well M-40B (upper ore zone) in order to prepare a tracer test.

The following day, injection of process water into Well M-40B at 5 gpm was initiated, and I-45 was put back into production at 18 gpm. This action was taken to introduce "clean" water into the affected area, while simultaneously producing from the nearest injection well. The purpose of this action was to force the affected groundwater in the vicinity of M-40 toward the Pattern interior. Sampling of M-40 two days later (January 14th), indicated that the corrective action was producing the desired effect, as considerable improvement for the M-40 excursion parameters were noted.

Throughout the rest of January and February, this mode of operation, with occasional modification, continued. The basic strategy was to maintain production from the lower ore zone while producing, without any injection, from the upper ore zone to maintain a hydraulic gradient toward the Pattern interior. Repeated sampling of all monitor wells during January confirmed the effectiveness of this approach. On January 21st, sampling of Well M-40 resulted in baseline range values for all excursion parameters except uranium, which was less than 0.5 mg/l. This was the fourth consecutive sampling

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indicating improvement, and the excursion was officially termed controlled. The attached graphs display excursion parameter values for the Pattern III monitor wells during the period prior to excursion confirmation through June, 1980.

Production from the lower ore zone continued until the end of March, at which time all injection into the Pattern was halted. On March 31, 1980, both the upper (P-53) and lower (P-50) ore zone production wells were set to produce at 5 gpm for a net production of 10 gpm from the Pattern. This mode of operation is continuing, and will be maintained until restoration of the Pattern begins.

Summary and Conclusions

As was stated earlier, one of the primary goals of the Pattern III test program was to evaluate the feasibility of dual ore zone production by means of open injection wells and selectively completed recovery wells. Because of a difference in ore sand permeabilities and well completion efficiencies, injection rates into the upper and lower ore zones became unbalanced, resulting in an upper zone horizontal excursion.

A factor which indirectly, but strongly, contributed to the excursion problem was the placement of monitor wells only 100 feet from the Pattern perimeter. Balanced flow in a 60-foot radius pattern would have produced normal flow nets closely approaching the monitor wells. A slight injection imbalance was apparently enough to push lixiviant an extra few feet and cause the excursion.

The excursion proved to be a valuable learning experience, as the situation presented an opportunity to evaluate theoretical corrective procedures in an operational environment. The following conclusions can be drawn as a direct result of Pattern III experience.

1. The principle of open well, dual zone injection may still be valid; however, injection/production ratios should be closely monitored for both ore zones.

2. Monitor wells located at 100-feet with a 60-foot radius pattern are too close to serve as valid monitor wells, and should be more properly described as trend wells. For a 60-foot radius test facility pattern, monitor wells should be a minimum of 200-feet from the injection wells.

3. The method of determining upper control limits (UCL) for excursion parameters used at Nine Mile Lake ($\text{UCL} = \bar{x} + 2(s) + 10\%$) effectively allows detection of a pattern excursion. Although this method may need some refinement for commercial scale operations, it has been proven to be simple and effective to use for major groundwater constituents.

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4. When using an acid lixiviant, vanadium and iron are good early indicators of an excursion, and should be considered as potential excursion control parameters.

5. Over-production and selective conversion of injection wells to production wells can be considered demonstrated corrective procedures for controlling an excursion.

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APPENDIX D

GROUNDWATER CLASSIFICATION ANALYSIS

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APPENDIX D

ROCKY MOUNTAIN
ENERGY

A Subsidiary of
Union Pacific Corporation

February 11, 1982

Mrs. Kathy Ogle
DEQ Land Qyality Division
401 W. 19th Street
Cheyenne, WY 82002

Dear Kathy:

Re: TFN 1 5/186
Nine Mile Lake Project

Enclosed are materials intended to facilitate the Department's assessment of groundwater quality at RME's Nine Mile Lake R and D project. Copies are also being provided to the Water Quality Division with the expectation that a joint determination of baseline water quality use category can be resolved for this project.

A parameter by parameter comparison of baseline water quality with the quality standard for Wyoming groundwaters (DEQ Water Quality Rules and Regulations, Chapter VIII) clearly demonstrates the proper classification for these groundwaters is Class IV-A, industrial use.

Table 1 summarizes baseline data for Patterns 2, 3, and 4. Pattern 1 baseline data was not included, as "baseline" was originally established on the basis of one round of bailed samples taken by a consultant and is therefor of questionable validity. The table illustrates that twelve (12) Class I standards were exceeded by at least one sample from one well; ten (10) Class II standards exceeded and seven (7) Class III standards by at least one sample from one well.

Reading down the columns on Table 1, it is evident that a minimum of 138 sample analyses exceeded Class I quality standards, 110 analyses exceeded Class II standards, and at least 64 samples exceeded Class III standards. Tables 2,3, and 4 provide a detailed breakdown of these data by pattern, representing at least three samples from 18 production and monitor wells. Figure 1 shows pattern and well locations.

Also included are final baseline data for patterns 2,3, and 4 giving the mean and range for each parameter both for individual wells and for the pattern. These data are presented in Appendices A-2, A-3, and A-4.

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Presumably, all of the constituents which exceed

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Box 2000
Broomfield, Colorado 80020

respective classification standards are toxic, potentially toxic, or hazardous to either plants, animals, or man at baseline concentrations. The overwhelming conclusion is that ambient baseline water quality of the Teapot Sandstone within the project area is suitable only for industrial use.

Should you have any questions concerning this data or the conclusion drawn, please call at the earliest opportunity.

Sincerely,

Michael R. Neumann

M.R. Neumann
Licensing Specialist

/sje

cc: W. Ackerman (LQD)
A. Mancini (WQD)
R. Chancellor (LQD)
F. Ross (NRC)
E.C. Gibbs
J.A. Yellich
J.A. Yopps

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TABLE 1
NINE MILE LAKE
BASELINE WATER QUALITY
CLASSIFICATION SUMMARY

No. of Wells with at least one assay $\geq$ Class Standard

Parameter	Class I	Class II	Class III	Class IV-A	No. Assays $\geq$ Std.
As	1	1	0	0	2
B	2	2	0	0	4
Cl	0	2	0	0	2
Cr	3	2	3	0	8
Cu	0	2	0		2
Fe	17	0	-	0	17
Pb	6	0	3	0	9
Mn	18	11	-	0	29
Se	10	10	3	0	23
SO_4	18	18	0	0	36
TDS	18	16	0	0	36
V	-	10	10	0	20
pH	9	0	9	0	18
Ra-226	18	18	18	0	54
Gross	18	18	18	0	54
No. of Parameters Exceeding Standard	12	10	7	0	310
No. of Wells Exceeding Standard	138	110	64	0	

Note: Data represents samples from 18 wells (minimum of 3 samples per well) in Patterns 2,3, and 4. Individual wells may have several sample assays exceeding standard, but only one per well recorded.

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NDWA[illegible] CLAS[illegible]ATIO[illegible]ALYS
NINE MILE LAKE

PATTERN 2 (Wells P-15, M-20, M-21, M-22, M-23, M-24) BASELINE

Table 2

USE CATEGORY	I (DOMESTIC)			II (AGRICULTURE)			III (LIVESTOCK)			IV (INDUSTRIAL)		
PARAMETER	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells Above Standard
Aluminum (Al)	-	-	-	5.0		0	5.0		0	-		
Ammonia (NH)	0.5		0	-	-	-	-	-	-	-		
Arsenic (As)	0.05		0	0.1		0	0.2		0	-		
Barium (Ba)	1.0		0	-	-	-	-	-	-	-		
Boron (B)	0.75		2	0.75		2	5.0		0	-		
Cadmium (Cd)	0.01	ND (0.02)	?	0.01	ND (0.02)	?	0.05		0	-		
Chloride (Cl)	250		0	100.0		2	2000		0	-		
Chromium (Cr)	0.05		0	0.1		0	0.05		0	-		
Cobalt (Co)	-	-	-	0.05	NA	NA	1.0	NA	NA	-		
Copper (Cu)	1.0		0	0.2		2	0.5		0	-		
Fluoride (F)	2.4		0	-	-	-	-	-	-	-		
Iron (Fe)	0.3	x	6	5.0		0	-	-	-	-		
Lead (Pb)	0.05		0	5.0		0	0.1		0	-		
Manganese (Mn)	0.05	x	6	0.2		5	-	-	-	-		
Mercury (Hg)	0.002		0	-	-	-	0.00005		?	-		
Nickel (Ni)	-	-	-	0.2	NA	NA	-	ND (.0001)		-		
Nitrate (NO_3)	10.0		0	-	-	-	-	-	-	-		
Nitrite (NO_2)	1.0		0	-	-	-	10.0		0	-		
Selenium (Se)	0.01		0	0.02		0	0.05		0	-		
Sulfate (SO_4)	250	x	6	200	x	6	3000		0	-		
Total Dissolved Solids (TDS)	500	x	6	2000	x	6	5000		0	-		
Uranium (U)	5.0		0	5.0		0	5.0		0	-		
Vanadium (V)	-	-	-	0.1		0	0.1		0	-		
Zinc (Zn)	5.0		0	2.0		0	25.0		0	-		
pH	6.5-9.0*		5	6.5-9.0*		0	6.5-8.5*		5	-		
Radium 226 + 228	5*	x	6	5*	x	6	5*	x	6	-		
Gross Alpha	15*	x	6	15*	x	6	15*	x	6	-		
Total No. of Parameters Exceeding Criteria	-	6	≥ 43	-	4	≥ 35	-	2	≥ 17	-	0	0

*All units in mg/l except pH (std. units), Ra (pCi/l) and Gross Alpha (pCi/l) NA=Not Assayed ND=Non Detectable

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GR[illegible]ATER [illegible]SSIF[illegible]ON A[illegible]SIS

NINE MILE LAKE

PATTERN 3 (Wells M-40, M-41, M-42, M-43, P-50, P-53, HSM-52) BASELINE

USE CATEGORY	I (DOMESTIC)			II (AGRICULTURE)			III (LIVESTOCK)			IV (INDUSTRIAL)		
PARAMETER	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells Above Standard
Aluminum (Al)	-	-	-	5.0		0	5.0		0	-		
Ammonia (NH)	0.5		0	-	-	-	-	-	-	-		
Arsenic (As)	0.05		0	0.1		0	0.2		0	-		
Barium (Ba)	1.0		0	-	-	-	-	-	-	-		
Boron (B)	0.75		0	0.75		0	5.0		0	-		
Cadmium (Cd)	0.01		0	0.01		0	0.05		0	-		
Chloride (Cl)	250		0	100.0		0	2000		0	-		
Chromium (Cr)	0.05		0	0.1		0	0.05		0	-		
Cobalt (Co)	-	-	-	0.05	NA	NA	1.0	NA	NA	-		
Copper (Cu)	1.0		0	0.2		0	0.5		0	-		
Flouride (F)	2.4		0	-	-	-	-	-	-	-		
Iron (Fe)	0.3	x	7	5.0		0	-	-	-	-		
Lead (Pb)	0.05		1	5.0		0	0.1		0	-		
Manganese (Mn)	0.05	x	7	0.2	x	5	-	-	-	-		
Mercury (Hg)	0.002		0	-	-	-	0.00005	ND (.0005)	?	-		
Nickel (Ni)	-	-	-	0.2		0	-	-	-	-		
Nitrate (NO_3)	10.0		0	-	-	-	-	-	-	-		
Nitrite (NO_2)	1.0		0	-	-	-	10.0		0	-		
Selenium (Se)	0.01	x	5	0.02	x	5	0.05		0	-		
Sulfate (SO_4)	250	x	7	200	x	7	3000		0	-		
Total Dissolved Solids (TDS)	500	x	7	2000	x	5	5000		0	-		
Uranium (U)	5.0		0	5.0		0	5.0		0	-		
Vanadium (V)	-	-	-	0.1	x	6	0.1	x	6	-		
Zinc (Zn)	5.0		0	2.0		0	25.0		0	-		
pH	6.5-9.0*		2	6.5-9.0*		0	6.5-8.5*		2	-		
Radium 226 + 228	5*	x	7	5*	x	7	5*	x	7	-		
Gross Alpha	15*	x	7	15*	x	7	15*	x	7	-		
Total No. of Parameters Exceeding Criteria	-	7	≥ 50	-	7	≥ 42	-	3	≥22	-	0	0

*All units in mg/l except pH (std. units), Ra (pCi/l) and Gross Alpha (pCi/l)   NA=Not Assayed   ND=Non Detectable

Table 3

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GROUNDWATER CLASSIFICATION ANALYSIS

NINE MILE LAKE

PATTERN 4 (Wells P-62, M-55, M-56, M-57, OB-67) BASELINE

USE CATEGORY	I (DOMESTIC)			II (AGRICULTURE)			III (LIVESTOCK)			IV (INDUSTRIAL)		
PARAMETER	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells with Assays ≥ Standard	DEQ Std.	Pattern $\bar{x}$ Exceeds Standard	No. of Wells Above Standard
Aluminum (Al)	-	-	-	5.0		0	5.0		0	-		
Ammonia (NH)	0.5		0	-	-	-	-	-	-	-		
Arsenic (As)	0.05		1	0.[illegible]		1	0.2		0	-		
Barium (Ba)	1.0		0	-	-	-	-	-	-	-		
Boron (B)	0.75		0	0[illegible]		0	5.0		0	-		
Cadmium (Cd)	0.01		0	0[illegible]		0	0.05		0	-		
Chloride (Cl)	250		0	100.0		0	2000		0	-		
Chromium (Cr)	0.05	x	3	0.1		2	0.05	x	3	-		
Cobalt (Co)	-	-	-	0.05	NA	NA	1.0	NA	NA	-		
Copper (Cu)	1.0		0	0.2		0	0.5		0	-		
Flouride	2.4		0	-	-	-	-	-	-	-		
Ir[illegible]	0.3	x	4	5.0		0	-	-	-	-		
Lead (Pb)	0.05	x	5	5.0		0	0.1		3	-		
Manganese (Mn)	0.05	x	5	0.2		1	-	-	-	-		
Mercury (Hg)	0.002		0	-	-	-	0.00005	<0.0001	?	-		
Nickel (Ni)	-	-	-	0.2		-	-	-	-	-		
Nitrate (NO_3)	10.0		0	-	-	-	-	-	-	-		
Nitrite (NO_2)	1.0		0	-	-	-	10.0		0	-		
Selenium (Se)	0.01	x	5	0.02	x	5	0.05		3	-		
Sulfate (SO_4)	250	x	5	200	x	5	3000		0	-		
Total Dissolved Solids (TDS)	500	x	5	2000	x x	5	5000		0 0	-		
Uranium (U)	5.0		0	5.0		0	5.0		0	-		
Vanadium (V)	-	-	-	0.1	x	4	0.1	x	4	-		
Zinc (Zn)	5.0		0	2.0		0	25.0		0	-		
pH	6.5-9.0*		2	6.5-9.0*		0	6.5-8.5*		2	-		
Radium 226 + 228	5*	x	5	5*	x	5	5*	x	5	-		
Gross Alpha	15*	x	5	15*	x	5	15*	x	5	-		
Total No. of Parameters Exceeding Criteria	-	9	> 45	-	6	≥33	-	4	≥ 25	-	0	0

*All units in mg/l except pH (std. units), Ra (pCi/l) and Gross Alpha (pCi/l)

Table 4

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APPENDIX E

Regulatory Agency Correspondence

reference

Groundwater Restoration of Patterns

1, 2, and 3 at Nine Mile Lake

Section	Content
E-1	Letter; 5/9/78 from DEQ to RME
E-2	Memo; DEQ Note to the File
E-3	Letter; 9/7/79 from RME to DEQ
E-4	Letter; 9/21/79 from DEQ to RME
E-5	Letter; 10/11/79 from RME to DEQ

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File 96.6.2.12
cc J Shaw
D McCready

APPENDIX E-1

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Department of Environmental Quality

LAND QUALITY DIVISION
DISTRICT IV OFFICE

30 EAST GRINNELL STREET **TELEPHONE 307-672-6488** **SHERIDAN, WYOMING 82801**

May 9, 1978

Mr. A.D. Luck
Project Environmental Specialist
Rocky Mountain Energy Company
4704 Harlan
Denver, CO 80212

RE: Renewal of Exploration License No. 4-A1

Dear Mr. Luck:

Pursuant to your request of April 28, 1978, this license is renewed through May 6, 1979. Your renewal letter mentions a Well Pattern #3. No work is authorized on a third well pattern until restoration is demonstrated on Patterns 1 and 2 as we discussed by phone.

If you have any questions please do not hesitate to contact this office. We will be contacting you soon to arrange for a mutually convenient time for an inspection.

Sincerely,

Doyl Fritz

Doyl Fritz
District IV Engineer

DF/sh

cc: W.C. Ackerman

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APPENDIX E-2

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THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Department of Environmental Quality

LAND QUALITY DIVISION

DISTRICT IV OFFICE

30 EAST GRINNELL STREET
TELEPHONE 307-672-6488
SHERIDAN, WYOMING 82801

NOTE TO THE FILE

TO: File, Rocky Mountain Energy, Nine Mile Lake ISL Site, LE #31

FROM: Dennis Morrow, District IV Engineer DM

DATE: August 8, 1979

SUBJECT: Request for Permission to Initiate Third Test Site

Al Luck called this afternoon to request permission to initiate testing at Site #3. Reasons are as follows:

1. Pattern #1 is restored.
2. Pattern #2 is almost restored; final data write-up will take approximately two months.
3. Pattern #3 is drilled and ready to go.

The present approved plan for this license specifies that testing of Pattern #3 will follow restoration of Pattern #2. Al is requesting to bring in the current data from Pattern #2 to show that restoration is close. This would support his request to start testing at the third site.

cc: Al Luck

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APPENDIX E-3

ROCKY MOUNTAIN
ENERGY COMPANY

ENVIRONMENTAL SERVICES
CLARK M BOLSER
MANAGER

September 7, 1979

Department of Environmental Quality
Land Quality Division
District IV
30 East Grinnell
Sheridan, Wyoming 82801

ATTENTION: Mr. Dennis Morrow

Gentlemen:

Re: Nine Mile Lake ISL Pattern III Start-up
License to Explore 4-AL

Pursuant to discussions of September 6, 1979, between A. D. Luck and K. W. Loest of Rocky Mountain Energy Company (RMEC), and D. Morrow and M. A. Hulbert of Wyoming DEQ regarding the restoration status of Nine Mile Lake ISL well field Pattern II and the proposed production start-up of Pattern III, this letter is a request for written authorization to proceed with Pattern III activities. In conjunction with this request, RMEC will provide within the month a written summary of Pattern II restoration data; Pattern III baseline ranges of water quality; a well field map; and a monitoring, excursion control, and restoration summary for Pattern III.

As discussed, RMEC will proceed with Pattern III activities as verbally authorized. Your review in this matter is appreciated. If there are any questions or concerns, please advise.

Sincerely,

A D Luck

A. D. Luck
Environmental Specialist

ADL:sh

cc: M. A. Hulbert (DEQ) R. A. Shaffer (DEQ)
K. W. Loest, R. D. Andrews, R. E. Hynes
File: 86.6.2.12

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4704 HARLAN STREET, DENVER, COLORADO 80212 (303) 433-6841

RECEIVED SEP 24 1979

APPENDIX E-4

THE STATE OF WYOMING

ED HERSCHLER
GOVERNOR

Department of Environmental Quality

LAND QUALITY DIVISION
DISTRICT IV OFFICE

30 EAST GRINNELL STREET TELEPHONE 307-672-6488 SHERIDAN, WYOMING 82801

OK
86.6.2.12

September 21, 1979

Mr. Al Luck
Project Environmental Specialist
Rocky Mountain Energy Company
4704 Harlan
Denver, Colorado 80212

RE: Nine Mile Lake ISL Test, LE4

Dear Mr. Luck:

In response to your letter of September 7, 1979, permission is granted to proceed with the Pattern III Test. We will expect to receive the written reports we discussed in our September 6, 1979, meeting by the end of the month.

If you should have any questions, please do not hesitate to contact this office.

Sincerely,

Dennis Morrow

Dennis Morrow
District IV Engineer

DM/ls

cc: Margie Hulburt

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APPENDIX E-5 ESD 7 934

ROCKY MOUNTAIN
ENERGY COMPANY

ENVIRONMENTAL SERVICES
CLARK M BOLSER
MANAGER

October 11, 1979

Department of Environmental Quality
Land Quality Division
District IV
30 East Grinnell
Sheridan, Wyoming 82801

Attention: Mr. Dennis Morrow

Gentlemen:

Re: Nine Mile Lake; Pattern II Restoration,
Pattern III Description

Please pardon the delay in forwarding to you the information promised in Mr. A.D. Luck's letter of September 7, 1979 (ESD 79-790) to the DEQ. As you probably know, Mr. Luck is no longer with Rocky Mountain Energy Company (RMEC). I am presently pursuing the tasks related to RMEC's Nine Mile Lake Project in which Mr. Luck was engaged.

Enclosed with this letter are descriptions of: Demonstrated Restoration of Pattern II (Attachment A), Well Field Map (Attachment B), Pattern III Baseline Water Quality (Attachment C), and a Summary of Pattern III (Attachment D).

Should you have any questions upon review of this material, please don't hesitate to give me a call.

Sincerely,

Michael R. Neumann

M.R. Neumann
Reclamation Specialist

Attachment

cc: M.A. Hulbert (DEQ)
R.A. Shaffer (DEQ)
K.W. Loest
R.D. Andrews
R.E. Hynes
File 86.6.2.12

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4704 HARLAN STREET DENVER COLORADO 80212 (303) 433-6841

Attachment A

Demonstrated Restoration - Pattern 2

As part of the Nine Mile Lake (NML) pilot testing program, the test programs were restored after leaching. Test pattern 1 was restored with a clean Teapot formation water sweep. This restoration method, which was water intensive, resulted in a significant amount of formation water lost to the evaporation pond. In order to evaluate alternatives to the groundwater sweep method, pattern 2 was restored by producing, treating and reinjecting a high percentage of affected water.

The leaching phase of pattern 2 lasted from December, 1977 through September, 1978. Since demonstration of restoration was an important part of the test program, pattern 2 leaching was shut down in mid-September (1978) so that restoration efforts could begin. Tables A and B summarize important parameters at the close of pattern 2 leaching.

The initial sweep of pattern 2 was made by injection of local well water (process). Concurrent with the process water sweep, construction began on a pilot restoration circuit. The restoration circuit was designed to treat affected water from pattern 2 and produce a clean water suitable for reinjection. The test restoration circuit was designed from bench scale test results to serve as a prototype for the proposed commercial restoration circuit. The basic circuit flowsheet calls for:

1) production of affected water from pattern production well;
2) addition of lime to neutralize acid and precipitate heavy metals and radionuclides;
3) a liquid/solids separation, with solids going to the evaporation reservoir and the liquor advancing to a calcium removal step;

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PATTERN 2 INTERIOR WELL DATA

	pH	TDS	Ca	SO_4	Fe	V	U_3O_8	Al	As	Se	Mn	Mo	Zn	Cu	pCi/l	
															230 Th	226 Ra
Pattern 2 Production Well Baseline	6.9-7.7	2890-3300	90-130	1760-2120	.39-.83	.01	.18-.36	.03-.11	<.01	<.01	.12-.32	<.01	.01-.02	.01-.02	18.2±28.6	440±114
Pattern 2 Production Well Early Stage Restoration in Nov. 1978	1.52	6750	200	5745	154	430	58	81	2.6	.08	1.3	0.01	40	1.6	18400±600	1000±300
Pattern 2 Production Well at Termination of Restoration Phase September 1979	6.3	2360	60	1380	3.6	10	0.3	1.6	0.35	0.02	0.05	0.02	0.54	0.01	1±.8[1]	76±.20[2]
Observation Well 1 On 9/3/79 Restoration	6.2	2200	54	1410	1.32	4	<0.1	0.2	0.05	0.02	0.12	0.02	0.42	0.01	-----	230±10
Observation Well 3 On 9/3/79 Restoration	5.9	2150	48	1480	5.15	9	<0.1	3.6	0.1	0.01	0.13	0.02	1.57	0.01	-----	190±10
Proposed Guidelines For Stockwater	6.0-9.0	5000		3000	.5-20	.1	5	5.0	0.2-1.0	0.5	10.0		25.0	0.5	-----	5

1) Data from June 1979 Sampling

2) Data from 8/14/79 Sampling

Table A

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Table B

PATTERN 2 MONITOR WELL DATA

Description	pH	TDS	Ca	SO_4	Fe	V	U_3O_8	As	Se	Th 230	Ra 226
Monitor Well #20											
Baseline	7.3	3844	130	2081	0.31	0.01	0.51	0.01	0.01	1.8±1.6	178±83
Sept. 1978	6.8	3200	115	1960	1.4	0.06	0.30	0.02	0.01	<1	184±5
Aug. 1979	6.7	3000	72	1310	0.38	0.06	0.20	0.01	0.01	2.9±1	135±15
Monitor Well #21											
Baseline	7.1	2238	82	1295	0.43	0.02	0.13	0.01	0.01	6.2±9.7	161±123
Sept. 1978	6.5	2258	89	1250	0.95	0.06	0.11	0.01	0.01	<1	131±6
Aug. 1979	6.7	2280	65	1379	0.26	0.06	0.11	0.01	0.01	1.2±.5	165±15
Monitor Well #22											
Baseline	7.0	2679	114	1649	0.48	0.02	0.02	0.01	0.01	1.1±.6	182±27
Sept. 1978	7.1	4262	334	2930	0.92	0.06	<0.02	0.01	0.01	<1	27±4
Aug. 1979	6.6	2520	88	1340	1.09	0.08	<0.02	0.01	0.01	8.9±1.6	185±20
Monitor Well #23											
Baseline	7.1	2308	96	1348	0.24	0.02	0.12	0.01	0.01	1.4±1.5	221±71
Sept. 1978	6.4	2130	79	1150	1.0	0.06	0.08	0.01	0.01	<1	176±7
Aug. 1979	6.6	2120	64	1156	0.24	0.13	0.18	0.01	0.01	2.7±1	210±20
Monitor Well #24											
Baseline	7.1	2299	100	1391	0.32	0.01	0.07	0.01	0.01	.48±.32	342±291
Sept. 1978	6.5	2258	89	1250	0.45	0.06	0.10	0.01	0.01	<1	30±8
Aug. 1979	6.5	2000	73	998	2.5	<0.01	0.08	0.01	0.01	1.2±.7	210±20

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4) removal of calcium by precipitation with CO_2 and Na_2CO_3;
5) a liquid/solids separation with the liquor (at this point consisting mostly of sodium sulfate) going to reserve osmosis (R.O.); and
6) reverse osmosis to concentrate Na_2SO_4 into a brine stream for disposal in the evaporation reservoir and a clean water stream for reinjection. The pilot circuit was constructed at the NML test facility and began operation in late November, 1978.

In order to limit the amount of discharge to the evaporation pond, the well water sweep of pattern 2 was operated at a reduced level until the restoration circuit could be functionally implemented. The restoration circuit began operation in mid-November, 1978, however, because of various equipment and operational problems, did not achieve full scale operation until the end of March.

During the interim period, pattern 2 restoration proceeded at reduced flow rates. By the middle of December, 19789, Ca and SO_4 has returned to near baseline conditions. The pH however, and parameters more dependent on pH for solubility (Fe, U_3O_8, etc.), plateaued, as shown in Plates 1 to 12. Analysis of bench scale tests performed at the University of Texas indicated that a high pH/TDS injection water actually speeded restoration by neutralizing and exchanging with H^+ ions absorbed on clay lattices. Therefore, an injection solution with a high pH and TDS content was used on pattern 2.

Injection of pH 9-10 Na_2CO_3 solutions at about 6,000 ppm TDS began at the end of March, 1979 and after five days, the pattern 2 production liquor showed a sharp increase in pH from 3.7 to 4.4. High pH/TDS injection was stopped after 41/2 days to allow pH to stabilize.

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High pH/TDS injection was resumed in mid-May, utilizing NaOH and continued through June, 1979. NaOH was used to avoid problems with uranium and vanadium mobilization which occured during Na_2CO_3 addition. Injection of near netural water, low in TDS, was resumed in late June as pattern 2 neared restoration.

The final stage of pattern 2 restoration began on 8/14/79 when Teaport formation water injection was resumed. By the first week of September, all parameters had returned to original use category and pattern 2 was shut down and restored.

Pattern 2 restoration was accomplished with about 7 million gallons of reinjection water versus about 13.8 million gallons used for mining. This corresponds well with bench test data indicating that about one half the leaching pore volumes are required to restore. The apparent long time period involved in pattern 2 restoration is a result of comparatively low flow rates from the restoration circuit equipment.

Table B presents restoration data for pattern 2 production well P-15 and surrounding monitoring wells. As noted, Ca, SO_4 and TDS levels are actually substantially below baseline ranges and well within the proposed values for stockwater use.

Pattern 2 water quality has been returned to its original use category with several parameters actually lower than baseline. The test program demonstrated that mining mode residual (affected) formation water could be successfully restored by the selected water treatment methods. The test program also served to generate design information for the projected commercial restoration circuit.

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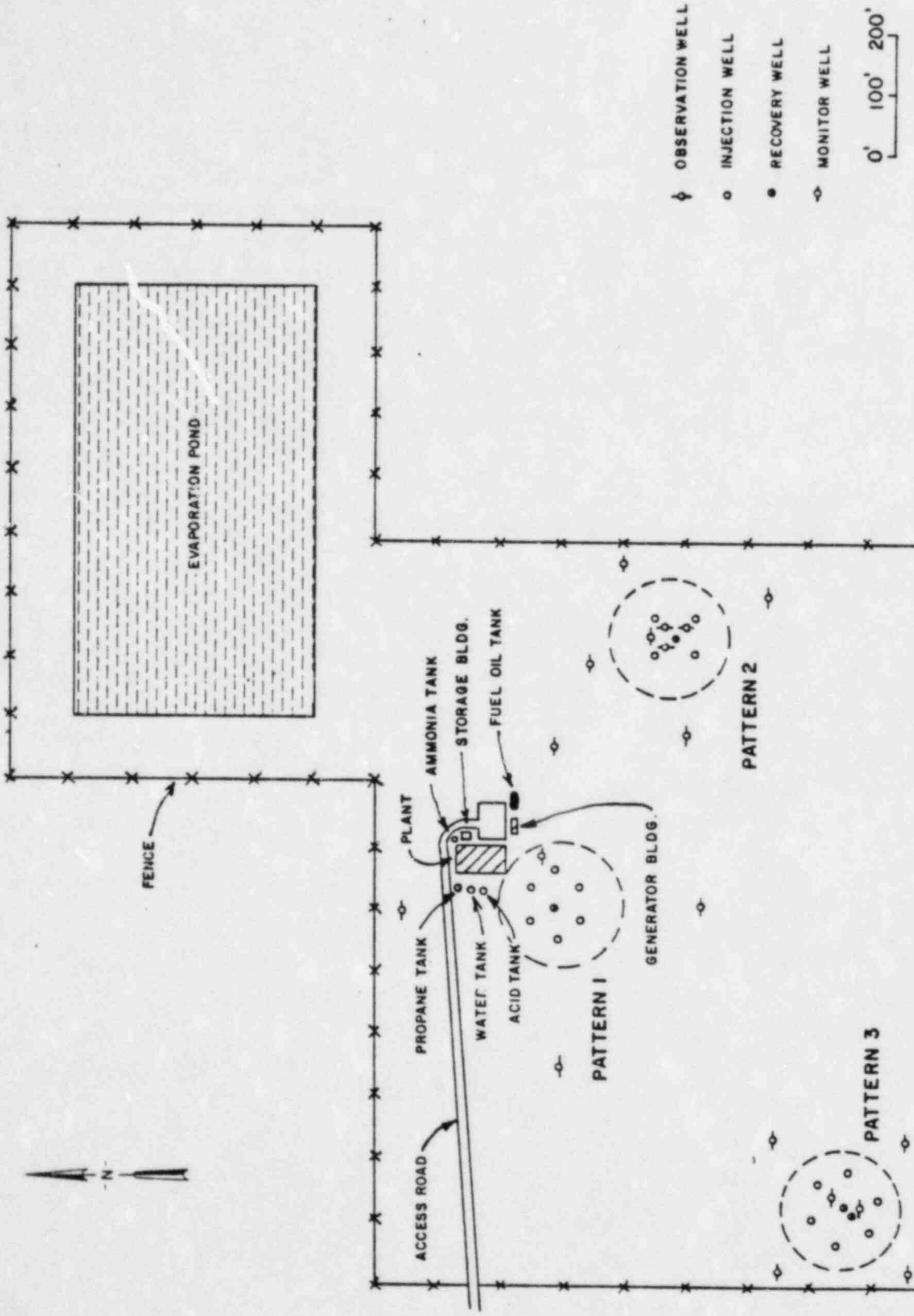
Attachment B



NINE MILE LAKE PILOT PLANT PLOT PLAN

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Attachment C

Pattern III Water Quality Baseline Ranges

Attached is the preliminary water quality data for Pattern III. Some results from recent samplings are pending. When all data has been received, a final report will be issued. From the available data, RMEC determined the range and calculated range for the pattern as a whole. The calculated range (x - 2 S.D. + 10%) serves as the upper and lower control limits.

The data presented in the report represents the average Pattern III water quality based upon analyses of individual wells. The values given in the Range column represent the highest and lowest values detected for an individual well within the pattern, therefore, actual data for any given well falls within the range denoted for that particular parameter.

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ROCKY MOUNTAIN ENERGY

NINE MILE LAKE

Pattern 3 Water Quality

Preliminary Report 9/14/79

Parameter	Range	Calculated Range ($\bar{x}$ ± 2 S. D. + 10%)
pH	6.40-7.64	5.96-7.90
Conductivity, µmhos/cm	1200-3500	554-4207
Alkalinity (as $CaCO_3$) mg/l	144-416	68-471
Bicarbonate, mg/l	176-507	83-573
Carbonate, mg/l	0	0
Calcium, mg/l	41-135	12-136
Chloride, mg/l	20-55	7-62
Magnesium, mg/l	13-71	0-75
Manganese, mg/l	0.03-0.87	0.0-0.72
Hardness (as $CaCO_3$), mg/l	253-550	175-544
Nitrate (as N), mg/l	0.10-0.93	0-0.74
Sodium mg/l	310-863	167-845
Potassium mg/l	5.9-16.0	2.4-18.4
Sulfate mg/l	628-2826	0-2522
Uranium (U_3O_8) mg/l	0.002-0.200	0-.190
TDS mg/l	880-3320	404-3664
Iron mg/l	0.01-4.10	0-3.98
Vanadium mg/l	0.01-0.45	0-0.59
Aluminum mg/l	0.05-0.88	0-0.77
Ammonia (as N) mg/l	0.10-0.33	0-0.38
Arsenic mg/l	0.01-0.04	0-0.04
Barium mg/l	0.05-0.10	0.0.09
Boron mg/l	0.05-0.49	0-0.61
Cadmium mg/l	0-0.002 (LLD)	0-0.002 (LLD)
Chromium mg/l	0.01-0.03	0-0.02
Copper mg/l	0-0.01 (LLD)	0-0.01 (LLD)
Fluoride mg/l	0.10-1.07	0-1.29
Lead mg/l	0.01-0.05	0-0.04
Mercury mg/l	0-0.0005 (LLD)	0-0.0005 (LLD)
Molybdenum mg/l	0-0.05 (LLD)	0-0.05 (LLD)
Nickel mg/l	0.01-0.19	0-0.13
Nitrite (as N) mg/l	0.02-0.06	0-0.13
Selenium mg/l	0.01-0.04	0-0.04
Silver mg/l	0-0.01 (LLD)	0-0.01 (LLD)
Silicon (SiO_2) mg/l	1.0-15.0	0-14.4
Zinc mg/l	0.01-0.04	0-0.04
Lead-210 pCi/l	0.5-41.0	0-40.5
Polonium-210 pCi/l	0.5-62.0	0-65.8
Radium-226 pCi/l	1.5-274.0	0-302.9
Thorium-230 pCi/l	0.5-41.9	0.0-33.8

LLD = lower limit of detection

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Attachment D

Pattern 3 Summary

Restoration

Pattern 3 restoration plans will be based on pattern 2 restoration experiences. Two main problems were encountered during pattern restoration re: 1) high initial vanadium levels in the recirculating liquor made it difficult to return to low vanadium levels at final restoration 2) pH levels plateaued because of adsorbed H^+ and improved slowly as ion exhcange/neutralization reactions took place. These problems hindered restoration efforts and resulted in a lengthy restoration process. In order to complete pattern 3 restoration in an efficient manner, there will be some changes from pattern 2 restoration philosophy.

Vanadium, in the recirculating liquor, will be removed to fairly low levels at the close of the uranium testwork and before restoration begins. This will simulate commercial plant vanadium removal plans and should result in much lower vanadium levels in the restored pattern.

After free acid has been flushed from pattern 3, high TDS/pH solutions will enhance H^+ ion exchange/neutralization reactions and should speed pH restoration. When pH has been returned to near baseline use category, low TDS/neutral pH solutions will be injected in order to return pattern 3 groundwater to baseline use category.

Pattern 3 restoration will utilize pattern 2 restoration experiences and parallel commercial restoration plans. The water treatment equipment used for pattern 3 will be similar to that used for pattern 2. Plans are now underway to modify the circuit to

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increase efficiency and flow rate which should shorten the time required to restore the pattern.

Monitoring

Monitor wells are designed to serve a two-fold function. They define an area of solution mining containment and also represent the surveillance mechanism to detect leachate migration. Monitor wells will be sampled monthly for pH, conductivity, water level, uranium and sulfate.

Excursion Verification Procedure

Each monitor well will have an Upper Control Limit (UCL) defined for those constituents considered most indicative of a well field excursion. For Pattern III, those parameters are; pH, conductivity, sulfate and uranium. UCL's for each parameter are determined by taking the average well field value (X) for the particular parameter, adding 2 S.D. (Standard Deviation) plus 10%. If a monthly monitor well analysis exceeds the UCL for any two of the three lead indicators, a second sample will be taken within 48 hours. Analysis of the second sample will be done within 24 hours of sampling. If the second analysis shows that two parameters exceeded the UCL, a third sample will be taken as above for that well. If UCLs are again exceeded, an excursion status for that well will be established. Appropriate corrective action, as outlined below, will be taken and the appropriate state and federal agency will be notified of the excursion by phone within 48 hours. A letter stating the time that corrective action was initiated will follow.

A monitor well in excursion status will be sampled every week. If a subsequent assay falls below the UCL, a second and then

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a third sample will be taken. If the analysis shows that the excursion indicator did not exceed the UCL, at the end of the third sampling, the excurison will be considered over. A letter declaring an end to the excursion, including assay results, will be sent to the appropriate state and federal agency. If an excursion persists beyond a reasonable time, additional monitor wells will be drilled, if deemed necessary, to identify the limits of the excursion. During an excursion, analysis will also be performed for arsenic, selenium and uranium.

Excursion Control and Correction Plan

Water Quality Parameters Necessary for Excursion

In the event of a confirmed excursion, the plant manager will take immediate action to halt the spread of lixiviant. This action could include balance of the well field, reducing or stopping injection, ceasing both injection and production pumping, or initiation of restoration. These methods may be applied locally to a few wells, parts of an entire production cell, or the entire well field as the situation dictates. At the discretion of the plant manager, several methods may be employed simultaneously if considered necessary. In no event will leaching continue in an area if an excursion persists for more than 120 days.

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