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1981 and 1982

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WATER QUALITY IN THE VICINITY OF FENTON HILL, 1981 AND 1982

by

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ABSTRACT

As part of a continuing program of environmental studies, water quality data have been collected from established surface and ground water stations and from ponds and pond discharges at Fenton Hill Site located in the Jemez Mountains. Most of these stations were established in 1973, and water quality data have been collected since that time. There have been slight variations in the chemical quality of water from the surface and ground water locations; however, these variations are within normal seasonal fluctuations. The discharge from ponds at Fenton Hill infiltrates into canyon alluvium within 400 m of the site. Monitoring surface and spring discharge downgradient from the ponds failed to detect any effects resulting from water released from the ponds. Total dissolved solids and calcium have increased in water from well FH-1, which furnishes the water supply for the site. This increase is caused by the decreasing water level in the well resulting in yield from beds with a slightly different quality than has been found in previous years.

I. INTRODUCTION

In 1973, a preliminary study was made of the Jemez River and Rio Guadalupe drainages to establish base line water quality data before experimental work started on the hot dry rock geothermal project by the Los Alamos National Laboratory at the Fenton Hill Site (TA-57).¹ Geologic and hydrologic investigations were made in the area and at TA-57 from 1972 through 1974.^{2,3} These

studies provided the basis for selecting locations for water quality monitoring stations. Water quality data from the permanently established stations have been published for 1974 through 1980.⁴⁻¹⁰ Late in 1980, a hydrologic study was made of the aquifer that furnishes the water supply to the Fenton Hill Site.¹¹ The present report interprets and evaluates the data for 1981 and 1982.

Fig. 1. Location of sampling stations.

Fenton Hill Site is located about 30 km west of Los Alamos on the western flank of the Valles Caldera (Fig. 1). Studies at the site are based on the concept of extracting heat from dry geothermal reservoirs by developing artificial hydrothermal systems. The site contains two deep holes (each 3000 m), completed in dry Precambrian granitic rock. The holes are connected by a large fracture, which was induced by hydraulic pressurization. Water is circulated under pressure

through this system to recover heat from fracture areas. The system is complete, and initial tests have been conducted.

A second system is now being developed to a depth of about 4500 m to test the system at a higher temperature and develop a commercial-sized reservoir. The drilling operations to complete the second system used chemical additives (drilling mud) and chlorides. Water from the

geothermal circulation loop contains moderate concentrations of silica, calcium, magnesium, sodium, sulfates, and chlorides, with moderate to high amounts of fluoride. At times, this water contained elevated concentrations of arsenic, boron, cadmium, and lithium, relative to those concentrations in natural waters. Drilling fluids and water from the circulation loop are stored in two ponds at the site. Periodically, these ponds are drained into the adjacent dry canyon when additional storage is needed. The water, under controlled discharge, is lost by evapotranspiration or infiltration into the alluvium and underlying tuff within 400 m of the outfall from the lower pond.

II. SURFACE AND GROUND WATER

Water samples for analyses were collected in June and November 1981 and June 1982 (Figs. 1 and 2), from the immediate area of the site and in the major drainage of the Jemez River and Rio Guadalupe downgradient from the site. Routine analyses were made for silica, calcium, magnesium, potassium, sodium, carbonate, bicarbonate, sulfate, chloride, fluoride, nitrates, total hardness, total dissolved solids (TDS), conductance, and pH. Samples were also analyzed for arsenic, boron, cadmium, and

lithium. These trace metals are often present in water in the storage ponds at Fenton Hill Site. All analyses were performed using methods described in a USEPA document.¹²

The discussion of water quality is organized around stations with common chemical properties and TDS.

A. Surface Water

Surface water discharge on the upper Jemez River and Rio Guadalupe, 1976 through 1980, was computed using regression equations and discharge records from a US Geological Survey record from a gaging station on the lower Jemez. Special water samples were collected and analyzed from three locations near where experimental drilling may be located in the future. Routine chemical quality monitoring was performed by collecting water samples from nine surface water stations.

1. Surface Water Discharge. Surface water discharge was measured by the US Geological Survey at three gaging stations in the Jemez area until June 1976. The stations were at Location J on the Jemez River near Location R (about 1.1 km downstream from the confluence with the Rio Guadalupe), and on the Rio Guadalupe near Location Q (about 7.7 km upstream from the confluence with the Jemez River). The gaging stations at Location J and near Location Q were abandoned, because regression analyses of the mean discharge from these stations versus the mean discharge at the station near Location R correlated well (Fig. 1). The regression provides a means of estimating the annual volume of water at Locations J and Q from the record of the gaging station near Location R.⁵

The drainage area above the station on the Jemez River near Location R is 1220 km². The discharge includes runoff passing through Stations J and Q. Partial records of the stream discharge and water volumes passing the station are available from 1936. The maximum discharge recorded at the station was 167 m³/s on April 21, 1958. The minimum discharge for the period 1960 to 1975 was 0.24 m³/s, and the maximum was 64 m³/s with annual water volumes ranging from 31.1 to 161.2 hm³ (cubic hectometers).

The mean annual discharge and water volumes passing through the gaging station near Location R from 1976 through 1981 were obtained from records of the US Geological Survey.¹³⁻¹⁸ The mean annual discharge

Fig. 2. Location of sampling stations at La Cueva.

ranged from 0.59 m³/s to 4.4 m³/s, whereas annual volumes ranged from 18.5 to 138 hm³. The average runoff for this 6-year period was 5 cm (runoff = average annual runoff volume, 62.9 hm³ ÷ drainage area, 1220 km²).

The drainage area above the gaging station at Location J on the Jemez River is 448 km². The discharge at the station includes runoff from the Valles Caldera as well as adjacent areas. Station operation began in 1949. Maximum discharge recorded was 71 m³/s occurring on April 21, 1958, for the period 1960 to 1975. The annual minimum discharge was 0.09 m³/s and maximum was 29.2 m³/s. The annual volumes of runoff passing through the station for the same period ranged from 13.9 to 58.2 hm³.

The mean annual discharge for the period 1976 to 1981 at Location J was computed using the regression equation $y = 3.38 + 0.37x$, where y = mean annual discharge at Location J and x = the mean annual discharge near Location R from US Geological Survey records. The mean annual discharge for the period 1976 to 1981 using the regression analyses ranged from 0.31 to 1.7 m³/s with volumes 9.9 to 52.9 hm³ (Table I). The average annual runoff for the period 1976 to 1981 was about 6 cm.

The drainage area above the station near Location Q on the Rio Guadalupe is 609 km². The discharge at the station includes drainage from the western rim of the caldera and flanks of the mountains to the west. Canyons with intermittent streams north and south of the Fenton Hill Site drain into the Rio Guadalupe. Station operation began in 1951. The maximum discharge recorded was 40.8 m³/s on April 21, 1958. The minimum annual discharge for the period 1960 to 1975 was 0.09 m³/s and maximum was 32.2 m³/s. The annual water volume passing through the station for the same period ranged from 12.8 to 89.9 hm³.

The mean annual discharge for the period 1976 to 1981 was computed using the regression equation $y = -5.46 + 0.62x$, where y = the mean annual discharge at Location Q and x = mean annual discharge from US Geological Survey records at Location R. The mean annual discharge for the period 1976 to 1981 using the regression ranged from 0.21 to 2.6 m³/s with volumes ranging from 6.7 to 80.9 hm³ (Table I). The average annual runoff for the period 1976 to 1981 was about 6 cm.

The wide variation in annual mean discharge as well as annual runoff volume that passed through each of the

TABLE I
SURFACE WATER RECORDS ON THE
JEMEZ RIVER AND RIO GUADALUPE
1976-1981

Location	Year	Mean Annual Discharge (m ³ /s)	Annual Volume (hm ³)
Jemez River near Loc. J	1976	0.46	14.4
	1977	0.31	9.9
	1978	0.80	25.4
	1979	1.7	52.9
	1980	1.2	36.7
	1981	0.54	17.0
Rio Guadalupe near Loc. Q	1976	0.45	14.3
	1977	0.21	6.7
	1978	1.0	32.6
	1979	2.6	80.9
	1980	1.6	51.5
	1981	0.59	18.6
Jemez River near Loc. R	1976	0.98	31.0
	1977	0.59	18.5
	1978	1.9	60.5
	1979	4.4	138
	1980	2.9	91.7
	1981	1.2	38.0

three gaging stations emphasizes the wide range in the chemical quality of surface water that can occur at each of the monitoring stations. Base flow in the streams is from ground water discharge (springs), which at times is highly mineralized (e.g., Sulphur Creek or thermal and mineral springs in Jemez Canyon). The water from the springs (base flow) is diluted by runoff from precipitation. The average annual runoff at Locations J and near Q is about 6 cm, decreasing to about 5 cm near Location R. The decrease in runoff indicates a loss of stream flow between Location J (upper) and near Location R (lower) gaging station on the Jemez River and between Location Q on the Rio Guadalupe and Location R on the Jemez River.

2. **Special Surface Water Quality.** Surface water samples were collected near areas considered for experimental drilling (spallation, where a hot flame is used as a bit to heat the rock, causing it to break off in flakes). These areas are underlain by different types of rocks. Granites and gneiss occur at the Rio Guadalupe; "red beds,"

mudstone, siltstones, and shale at Clear Creek; and limestone at the Rio de las Vacas. Three different rock types were chosen to test the drilling method.

Water from the Rio Guadalupe is the calcium bicarbonate type (Table II). The TDS is low at 151 mg/l. The water quality is quite similar to that found at

TABLE II
CHEMICAL QUALITY OF SURFACE WATER FROM RIO GUADALUPE,
CLEAR CREEK, AND RIO DE LAS VACAS
(August 12, 1982)

<u>Chemical Analyses</u>	<u>Rio Guadalupe above Tunnels</u>	<u>Clear Creek at State Road 126</u>	<u>Rio de las Vacas at State Road 126</u>
General (mg/l)			
SiO ₂	21	5	3
Ca	32	22	7
Mg	3.2	2.4	0.8
K	1.6	0.8	0.6
Na	9	3	2
CO ₂	13	0	0
HCO ₃	124	86	28
PO ₄	<0.05	<0.05	<0.05
SO ₄	4	5	6
Cl	2	<1	<1
F	0.4	0.2	<0.1
NO ₃	0.5	1.0	1.1
TDS	151	96	31
Hardness	94	67	22
Special (mg/l)			
Ag	<0.0005	<0.0005	<0.0005
As	<0.005	<0.005	<0.005
Ba	0.05	0.07	0.03
Cd	<0.0005	<0.0005	<0.0005
Cr	<0.001	<0.001	<0.001
Hg	<0.0002	<0.0002	<0.0002
Pb	<0.003	<0.003	<0.003
Se	<0.003	<0.003	<0.003
Total Uranium (µg/l)	1.3	2.7	<0.8
Conductance (µmho)	210	140	50
pH	8.6	8.0	8.1

Location Q on the Rio Guadalupe. The area is underlain by granites and gneiss.

Water from Clear Creek is also the calcium bicarbonate type. The TDS is quite low at 96 mg/l. The area is underlain by red beds.

Water from the Rio de las Vacas is also the calcium bicarbonate type. The TDS is very low at 31 mg/l. All chemical constituents in the water are quite low. The area is underlain by limestone.

The special analyses (metal ions) in all three samples are below analytical detection limits with the exception of barium (Table II). Barium is low, ranging from 0.03 to 0.07 mg/l. These levels are well below limits or standards set for domestic use or irrigation, which are 1.0 mg/l. Total uranium is low, ranging from <0.8 to 1.3 µg/l (Table II).

3. Routine Surface Water Quality. Surface water stations (nine on the Jemez River, the Rio Guadalupe, and their tributaries) are identified by capital letters in Figs. 1 and 2 and are keyed to detailed analyses presented in Appendix A (1981) and Appendix B (1982). There are four general groups of surface waters based on common chemical properties of predominant ions and

TDS. The predominant ions are (1) sodium and chloride, (2) calcium and bicarbonate, (3) calcium and sulfate, and (4) sodium and bicarbonate.

Each surface water station has a chemical characteristic reflecting the water source in the drainage area. The chemical concentrations at each individual station may be modified by snowmelt or rainfall precipitation. Thus, the chemical quality of water at each station can vary widely with changes in discharge.

Sodium and chloride water are found in base flow at Locations U, R, and S (Fig. 3). Location U is on Redondo Creek, which drains the interbasins of the Valles Caldera, the site of former hydrothermal (wet geothermal) development. Locations R and S are on the lower end of the Jemez River. Location R is below the confluence of the Rio Guadalupe and Location S is above the confluence (Fig. 1). Sodium, chloride, and TDS decreased slightly in 1981 and 1982 at Location U and increased at Locations R and S. The concentrations are within the range that has occurred from 1974 to 1981.

Calcium and bicarbonate waters are at Locations N, T, and Q (Fig. 4). Location N is on San Antonio Creek, which drains the northern part of the Valles Caldera, and

Fig. 3. Sodium, chloride, and TDS in surface water at locations U, R, and S, 1974-1982.

Fig. 4. Calcium, bicarbonate, and TDS in surface water at locations N, T, and Q, 1974-1982.

Location T is located on the Rio Cebolla below the Fenton Hill Site. The Rio Cebolla is a tributary to the Rio Guadalupe at Location Q (Fig. 1). Calcium and bicarbonate are also the predominant ions in surface water in Lake Fork Canyon (Table III). The four surface water stations, LF-1, -2, -3, and -4, are located downgradient from the Fenton Hill Site (Fig. 1). Surface water at these Lake Fork Canyon stations has been sampled and analyzed periodically since 1978 to determine if any chemical changes have occurred from the release of water from the ponds at the site. No significant changes in chemical quality have occurred in the period 1978 to 1981. Chemical quality of surface water at Locations N, T, and Q has varied within the range of 1974 to 1981 showing no significant changes in chemical quality.

Calcium and sulfate waters are found in base flow at Locations V and F (Fig. 5). Location V is on Sulphur Creek, and Location F is also on Sulphur Creek below the junction with Redondo Creek (Fig. 1). The discharge from thermal and mineral springs along upper Sulphur Creek in the Valles Caldera determines the chemical quality of water at these locations. The dilution of the surface flow by water from Redondo Creek at Location F reduces the chemical concentrations when compared to those concentrations at Location V (Fig. 5). Chemical

quality varied each year since 1974 but showed no significant change, in 1981 and 1982, from previous analyses.

Sodium and bicarbonate waters are found at Location J (Fig. 6). Location J is on the Jemez River below the confluence of the San Antonio Creek and the East Fork of the Jemez. These two streams drain the interior and outer portions of the Valles Caldera. There is no significant change in chemical quality of water in 1981 and 1982 when compared to the chemical quality from 1974 to 1980.

The mineral and thermal springs along the Jemez Fault discharge into the Jemez River below Location J. The springs contain excessive amounts of naturally occurring arsenic, boron, and lithium, which are responsible for the downstream water quality in the Jemez River (Table IV). Other stations contain little or no arsenic, boron, and lithium. Cadmium is low, at or near the detection limits, at all surface water stations.

In summary, the comparison of the chemical quality of surface water from 1974 through 1982 shows some variation in quality. However, as previously stated, changes in surface water discharge can account for these variations in the chemical quality and are not considered significant.

TABLE III
PREDOMINANT IONS OF CALCIUM AND BICARBONATE IN
SURFACE WATER IN LAKE FORK CANYON
(analyses in mg/l)

Station	Year	Number of Analyses	Ca	HCO ₃	TDS
LF-1	1978-1981	6	15 ± 3	49 ± 19	151 ± 39
	1981	1	10	32	154
	1982	---	---	---	---
LF-2	1978-1981	6	19 ± 2	71 ± 25	191 ± 60
	1981	2	19 ± 0	97 ± 4	223 ± 86
	1982	1	20	84	200
LF-3	1978-1981	7	13 ± 2	59 ± 6	130 ± 27
	1981	2	13 ± 0	59 ± 1	119 ± 33
	1982	---	14	60	130
LF-4	1978-1981	8	17 ± 2	73 ± 7	146 ± 20
	1981	2	18 ± 4	77 ± 13	136 ± 14
	1982	1	17	72	146

Fig. 5. Calcium, sulfate, and TDS in surface water at locations V and F, 1974-1982.

B. Ground Water

Ground water locations sampled during 1981 and 1982 include five mineral and thermal springs, six natural springs, and seven wells. Each station location is shown by a capital letter followed by a number or by a number alone (Figs. 1 and 2) and are keyed to detailed analyses presented in Appendix C (1981) and Appendix D (1982). Three types of ground water categorized by predominant ions occur at the ground water stations. The principal types are (1) sodium and bicarbonate, (2) sodium and chloride, and (3) calcium and bicarbonate.

Sodium and bicarbonate waters are found at Locations JS-2,3, JS-4,5, 3, 4, 6, 31, and 47 in waters from thermal springs RV-2, RV-4, and RV-5 (Table V). Locations JS-2,3 and JS-4,5 are springs located in the wall of Jemez Canyon. These springs furnish the water

TABLE IV

ARSENIC, BORON, CADMIUM, AND LITHIUM IN SURFACE WATER, 1981 AND 1982
(analyses in mg/l)

Station	Location	Arsenic		Boron		Cadmium		Lithium	
		1981	1982	1981	1982	1981	1982	1981	1982
F	Sulphur Creek	<0.001	0.001	0.15	0.1	0.001	0.002	0.06	0.04
J	Jemez River	0.003	0.018	0.04	0.2	0.001	0.002	0.09	0.06
N	San Antonio Creek	<0.001	0.002	0.17	0.2	0.016	<0.001	0.05	0.03
Q	Rio Guadalupe	<0.001	0.010	0.03	0.1	0.001	<0.001	0.05	0.03
R	Jemez River	0.056	0.015	1.14	1.1	0.001	0.002	1.0	0.89
S	Jemez River	0.067	0.098	1.22	1.3	0.001	0.001	1.1	1.1
T	Rio Cebolla	0.001	0.010	0.04	0.1	<0.001	0.002	0.02	0.01
U	Redondo Creek	0.001	0.002	0.17	0.1	<0.001	<0.001	0.07	0.05
V	Sulphur Creek	<0.001	0.004	0.08	0.1	<0.001	<0.001	0.05	0.05
LF-1	Lake Fork Canyon	<0.001	---	0.10	---	0.004	---	0.02	---
LF-2	Lake Fork Canyon	0.002	0.016	0.18	0.3	<0.001	0.001	0.03	0.02
LF-3	Lake Fork Canyon	<0.001	0.012	0.04	0.3	<0.001	0.003	0.01	0.01
LF-4	Lake Fork Canyon	<0.001	0.008	0.04	0.3	<0.001	0.001	0.02	0.01

Note: In general, 1981 analyses are the average of two analyses (see Appendix A for individual results).

Fig. 6. Sodium, bicarbonate, and TDS in surface water at location J, 1974-1982.

supply for the village of Jemez Springs. Location 3 is a well at the United States Forest Service (USFS) Redondo Campground. Location 4 is a spring that supplies water to some residents of La Cueva; Location 6 is a spring at La Cueva; and Location 31 is a spring on the north wall of Lake Fork Canyon near the confluence with the Rio Cebolla (Fig. 1). Location 47 is a well in La Cueva. Thermal springs RV-2 (San Antonio Hot Springs), RV-4 (Spence Spring), and RV-5 (McCauley Hot Springs) discharge from recent volcanic rocks west and south of the Valles Caldera along San Antonio Creek and the East Fork of the Jemez River (Fig. 1).

Sodium and chloride waters are found at Locations JF-1 and JF-5 (Table VI). Location JF-1 and JF-5 are thermal and mineral springs that discharge along the Jemez Fault into the Jemez River. A series of thermal and hot springs in this reach of the Jemez Canyon affect the water quality of the river, changing it from sodium and bicarbonate water, as found at Location J, to a

TABLE V
PREDOMINANT IONS OF SODIUM AND BICARBONATE IN GROUND WATER
 (analyses in mg/l)

Station	Year	Number of Analyses	Na	HCO ₃	TDS
JS-2,3 (Springs)	1974-1981	20	15 ± 2	76 ± 11	179 ± 33
	1981	2	15 ± 3	83 ± 3	156 ± 17
	1982	1	18	84	194
JS-4,5 (Springs)	1974-1981	20	15 ± 2	76 ± 12	170 ± 19
	1981	2	16 ± 4	81 ± 1	172 ± 34
	1982	1	17	84	194
Loc. 3 (Well)	1981	1	54	146	306
	1982	1	48	160	260
Loc. 4 (Spring)	1974-1981	20	16 ± 2	66 ± 7	170 ± 23
	1981	2	17 ± 0	71 ± 13	179 ± 7
	1982	1	33	72	154
Loc. 6 (Spring)	1974-1981	7	17 ± 2	85 ± 6	192 ± 28
	1981	1	16	84	172
	1982	1	28	84	168
Loc. 31 (Spring)	1974-1981	20	13 ± 3	63 ± 6	145 ± 44
	1981	2	10 ± 2	65 ± 1	139 ± 10
	1982	1	16	64	154
Loc. 47 (Well)	1978-1981	8	217 ± 34	527 ± 21	652 ± 20
	1981	2	220 ± 7	542 ± 3	657 ± 7
	1982	1	200	520	628
RV-2 (Spring)	1975-1981	7	23 ± 2	49 ± 3	158 ± 20
	1981	1	23	48	150
	1982	1	25	48	130
RV-4 (Spring)	1975-1981	8	51 ± 5	116 ± 7	232 ± 36
	1981	1	50	116	228
	1982	1	53	112	218
RV-5 (Spring)	1975-1981	8	20 ± 2	73 ± 4	151 ± 25
	1981	1	19	72	132
	1982	1	19	72	142

TABLE VI

PREDOMINANT IONS OF SODIUM AND CHLORIDE IN GROUND WATER
(analyses in mg/l)

Station	Year	Number of Analyses	Na	Cl	TDS
JF-1 (Spring)	1974-1981	20	271 ± 77	404 ± 115	1288 ± 246
	1981	1	370	630	1920
	1982	1	345	540	1568
JF-5 (Spring)	1974-1981	21	819 ± 148	1458 ± 69	3736 ± 261
	1981	2	756 ± 97	1530 ± 15	3978 ± 17
	1982	1	855	1450	3964

TABLE VII

PREDOMINANT IONS OF CALCIUM AND BICARBONATE IN GROUND WATER
(analyses in mg/l)

Station	Year	Number of Analyses	Ca	HCO ₃	TDS
Loc. 2 (Well)	1981	1	30	202	334
	1982	1	50	148	252
Loc. 39 (Spring)	1978-1981	8	13 ± 2	41 ± 13	92 ± 15
	1981	2	14 ± 1	43 ± 1	95 ± 21
Loc. 42 (Well)	1978-1981	8	12 ± 1	73 ± 2	165 ± 14
	1981	2	13 ± 1	72 ± 0	168 ± 11
	1982	1	13	76	182
Loc. 48 (Well)	1978-1981	6	22 ± 1	93 ± 3	192 ± 22
	1981	2	22 ± 0	93 ± 4	209 ± 38
Loc. 53 (Well)	1980	2	45 ± 4	139 ± 2	331 ± 64
	1981	2	42 ± 5	145 ± 13	248 ± 17
	1982	1	46	156	272
Loc. 54 (Well)	1980	1	61	268	418
	1981	2	60 ± 2	247 ± 10	371 ± 10
	1982	1	55	228	322

sodium and chloride water, as found downgradient in the Jemez River at Locations R and S (Fig. 1).

Calcium and bicarbonate waters are found at Location 2, a well for the USFS San Antonio Campground; at Location 39, a stock tank in Lake Fork Canyon; and at two wells at Locations 42 and 48 in La Cueva. Locations 53 and 54 are wells located along Sulphur Creek that furnish domestic supply to two houses in the area (Table VII).

The thermal and mineral springs at JF-1 and JF-5 (Soda Dam) along the Jemez Fault contain arsenic concentrations that ranged from <0.001 to 2.7 mg/l, boron from 4.5 to 14 mg/l, and lithium from 3.5 to 11 mg/l (Table VIII). Water from these thermal and hot

springs discharges into the Jemez River and affects the chemical quality of water downstream at Locations R and S. Trace amounts of arsenic, boron, cadmium, and lithium occur at natural levels at other ground water locations.

The chemical quality of ground water from springs or wells reflects the type of rock and length of time the water has been in contact with it from recharge to discharge (spring or well). Seasonal fluctuations in the water quality occur as the result of changes in recharge rates to the ground water bodies. A comparison of data from 1974 through 1981 with the 1981 and 1982 data reflects normal chemical changes (Tables V through VII).

TABLE VIII

ARSENIC, BORON, CADMIUM, AND LITHIUM IN GROUND WATER, 1981 AND 1982
(analyses in mg/l)

Station	Location	Arsenic		Boron		Cadmium		Lithium	
		1981	1982	1981	1982	1981	1982	1981	1982
JS-2,3	Jemez Village	0.001	0.012	0.04	0.1	<0.001	0.003	0.03	0.02
JS-4,5	Jemez Village	0.001	0.013	0.03	0.1	<0.001	<0.001	0.02	0.02
JF-1	Jemez Canyon	<0.001	0.016	5.4	4.5	<0.001	<0.001	4.4	3.5
JF-5	Jemez Canyon	1.29	2.57	14.0	6.6	0.001	0.007	10.0	11.0
RV-2	San Antonio Hot Springs	0.007	0.006	<0.001	0.1	<0.001	<0.001	0.03	0.03
RV-4	Spence Hot Springs	0.053	0.064	0.06	0.3	<0.001	0.003	0.55	0.56
RV-5	McCauley Hot Springs	0.021	0.025	<0.01	0.2	<0.001	0.001	0.22	0.24
Loc. 2	Redondo Campground	0.009	0.010	0.28	0.1	<0.001	0.003	0.04	0.03
Loc. 3	San Antonio Campground	0.005	0.004	0.03	0.3	<0.001	0.003	0.06	0.04
Loc. 4	La Cueva	0.005	0.002	0.04	0.1	<0.001	0.003	0.02	0.02
Loc. 6	La Cueva	<0.001	0.027	0.10	0.1	0.001	0.002	0.02	0.02
Loc. 31	Lake Fork Canyon	<0.001	0.022	0.04	0.1	0.001	0.010	0.01	0.02
Loc. 39	Lake Fork Canyon	<0.001	0.009	0.05	0.2	0.002	0.002	0.01	0.01
Loc. 42	La Cueva	<0.001	0.004	0.10	0.1	0.001	<0.001	0.01	0.01
Loc. 47	La Cueva	0.003	0.008	0.56	0.4	<0.001	0.025	0.12	0.12
Loc. 48	La Cueva	0.002	0.002	0.01	0.1	<0.001	0.014	0.03	0.03
Loc. 53	Sulphur Canyon	0.004	0.010	0.05	0.1	0.003	0.003	0.03	0.03
Loc. 54	Sulphur Canyon	0.004	0.010	0.05	<0.1	0.001	0.003	0.05	0.05

Note: In general, the 1981 analyses are the average of two analyses (see Appendix B for individual results).

III. FENTON HILL SITE

The Fenton Hill site is located on a narrow mesa on the western flank of the Valles Caldera. It is a gently sloping southwest-trending mesa, which is bounded on the east by San Antonio Creek and on the west and northwest by the Rio Cebolla (Fig. 1). Lake Fork Canyon, to the south, drains the immediate area of the site and is tributary to the Rio Cebolla. Adjacent to the site, Lake Fork Canyon and the unnamed canyon north of the site contain intermittent streams. Only during periods of heavy precipitation or snowmelt does water reach the Rio Cebolla from these canyons. The lower 5 km of Lake Fork Canyon above the confluence with the Rio Cebolla contains perennial flow from springs and seeps (Fig. 1). Discharges from the ponds at the Fenton Hill site are regulated so that they do not commingle with perennial streams. By restricting the discharge, the water from the ponds infiltrates the alluvium of the dry canyon with 400 m of the pond outfall.

A. Fenton Hill Water Supply, FH-1

The water supply for Fenton Hill is furnished by a well completed at a depth of about 137 m into a perched aquifer. The aquifer is in the Abiquiu Tuff and is perched on clays and siltstones of the Abo Formation. The aquifer is of limited extent, being terminated to the east along the canyon cut by San Antonio Creek. The water movement in the aquifer is to the southwest, where a part is discharged through seeps and springs along the lower reaches of Lake Fork Canyon and the Rio Cebolla.

The supply well, FH-1, was completed in November 1976. Production for the last two months of 1976 was 1.8×10^6 l. Annual production from 1977 to 1982 has ranged from 9.4×10^6 l to 27.3×10^6 l (Fig. 7). The production in 1981 was 20.4×10^6 l and in 1982 it was 20.7×10^6 l. Cumulative production from the well from 1976 through 1982 has been 117.7×10^6 l (Fig. 7).

Monthly production during 1981 and 1982 has ranged from 0.31×10^6 l in January 1982 to about 4.9×10^6 l in December 1981 (Fig. 8). Water-level trends in FH-1 reflect months of heavy production (Fig. 9).

Average monthly water levels were compiled for supply well FH-1 and observation wells FH-2 and FH-3. All three wells are completed in the same aquifer in the Abiquiu Tuff. From 1976 through 1982 the water level in FH-1 has declined about 2.7 m owing to production to

supply the site. Pumpage has exceeded recharge to the aquifer. From January 1981 through December 1982 the water level in the well has declined about 1.1 m. Pumpage from FH-1 has caused a water-level decline in well FH-3 (located about 17 m southwest of FH-1) of about 0.9 m. Water levels in well FH-2 (located about 131 m west of FH-1) have varied slightly but have shown no particular trend as a result of pumpage from FH-1 (Fig. 9).

Calcium and bicarbonate are predominate ions in water from well FH-1 (Fig. 10). There has been little, if any, change in bicarbonate from 1976 through 1982. There has been some variation in calcium concentration from 1976 through 1980, but it has generally increased during this period. The calcium concentrations increased from about 34 mg/l in 1980 to over 50 mg/l in 1981 and 1982 (Fig. 10). Total dissolved solids have shown the same general trend as the calcium. The TDS increased slightly from 1976 through 1980. There was a large increase from about 240 mg/l in 1980 to over 300 mg/l in 1981 and 1982 (Fig. 10). The increase in calcium and TDS is probably caused from the water-level decline. Water of a slightly different quality is now being pumped from the aquifer. It is a natural variation from water usage.

Five water samples were collected from FH-1 from December 28, 1981, through January 8, 1982, as water from the well was used to fill pond GTP-1. The samples were analyzed for chloride, fluoride, nitrate, and TDS (Table IX). Chloride and TDS increased slightly during the 243 h of pumping from the well. Fluoride and nitrate concentrations showed no particular trends.

Water from well FH-1 was analyzed for chemical and radiochemical constituents for comparison with standards set for municipal or domestic use by the USEPA.^{19,20} A comparison of the analytical results of water from well FH-1 with federal and state standards shows that the constituents are below limits set for municipal use (Table X).

B. Storage Ponds

Two ponds at Fenton Hill site are used to store water from experimental operations in the circulation loop, from drilling, or from hydrofracturing operations. The ponds were sampled in July and November 1981 and June 1982. The results of the analyses are shown in Appendix A (1981) and Appendix B (1982).

Fig. 7. Annual and cumulative production from supply well FH-1, Fenton Hill (TA-57), 1976-1982.

Fig. 8. Monthly production from supply well FH-1, Fenton Hill (TA-57), 1981-1982.

Fig. 9. Average monthly water levels in supply well FH-1 and wells FH-2 and FH-3, Fenton Hill (TA-57), 1981-1982.

The concentrations of chloride, sulfate, fluoride, and TDS have varied for the period of record, reflecting the type of test or drilling operation in progress at the time the sample was collected. Chlorides and sulfate have varied widely during the period of record (1974-1982) in both ponds GTP-1 and GTP-3 (Fig. 11). Fluoride has generally remained below 5 mg/l. TDS concentration in both ponds has generally increased during the period of record (Fig. 11).

Total dissolved solid concentrations were higher in pond GTP-1 in 1981 and 1982 than in previous years. A high TDS concentration occurred in pond GTP-3 in 1981 when compared to similar data from 1974 through 1982.

Water from the ponds is released into a dry canyon that is a tributary to Lake Fork Canyon south of the site (Fig. 1). The water is released under controlled discharge (<6.5 l/s) and is lost to evapotranspiration and infiltration into alluvium and underlying tuff within 400 m of the outfall from the lower pond.

About 3.85×10^6 l of water was released from the pond in February through March and September through October 1981. Water quality is shown in Table XI. During 1982 about 2.29×10^6 l of water was released from the ponds in April and August through September. Water quality is shown in Table XII.

Fig. 10. Calcium, bicarbonate, and TDS from supply well FH-1, Fenton Hill (TA-57), 1976-1982.

In general, the 1982 release contained a lower concentration of chemical constituents than the 1981 release. The total dissolved solids decreased from an average of 3500 mg/l to 3200 mg/l. Chloride decreased from an average of 947 mg/l in 1981 to 393 mg/l in 1982, while sulfates decreased from 480 mg/l to 161 mg/l (Tables XI and XII).

Chemical concentrations in water locations 39 (Spr), LF-1, LF-2, LF-3, LF-4 (SW), 31 (Spr), and T (SW)

TABLE IX
QUALITY OF WATER FROM WELL FH-1 DURING PUMPING
(December 28, 1981, through January 8, 1982)

<u>Date</u>	<u>Hours Pumped (cumulative)</u>	<u>Cl (mg/l)</u>	<u>F (mg/l)</u>	<u>NO₃ (mg/l)</u>	<u>TDS (mg/l)</u>
12-28-81	5	45	<0.1	1.0	252
12-29-81	27	43	<0.1	0.3	266
12-30-81	51	47	<0.1	1.3	272
12-31-81	75	47	<0.1	1.0	258
01-08-82	243	47	<0.1	1.0	272

downgradient from the Fenton Hill site ponds in Lake Fork Canyon were in the normal range found in natural waters. The chemical quality of water from these locations showed no effects of water released from the site.

C. Vegetation and Soil Analyses

Samples of vegetation and soil from the channel bottom and the canyon bank below GTP-3 have been collected semiannually since 1978. The collected samples are analyzed for arsenic, boron, cadmium, fluorine, and lithium. The sampling locations are at distances of about 100, 200, 400, and 1000 m down-canyon from the GTP-3 discharge point. An additional sample is collected from the canyon bottom far down the canyon at its junction with Lake Fork Canyon. The data obtained to date from these samples are presented in Tables XIII through XVII.

The behavior in the environment of each of the five elements monitored reflects its varying soil physico-chemical and plant biophysiological properties. Each element is discussed separately in the following paragraphs.

The data indicate that there is a slight arsenic accumulation in plant roots (Table XIII). This agrees with published information,²¹ which notes that arsenic accumulates in much larger amounts in or on plant roots than in foliage. Foliar content is low (<0.5 ppm), which also agrees with the literature. Liebig²¹ notes that the effect of arsenic toxicity is such that plant growth is limited before large amounts of arsenic are absorbed and translocated to the foliage. The foliar arsenic level at

which toxicity occurs apparently varies widely, being reported at anywhere from 0.5 to 250 ppm,²² depending on plant species, arsenic source, soil type, etc. Natural foliar arsenic levels range up to about 10 ppm.²² The measured soil concentrations are well within the normal range of 0.3 to 38 ppm.²¹

Boron shows a definite accumulation pattern in soil, plant roots, and plant foliage (Table XIV), although the accumulation in plant foliage is, by far, the most pronounced. Excess foliar boron levels are generally considered to be anything above 200 ppm, although tissue levels may reach 1000 ppm without visible damage symptoms.²³ Recent foliar boron levels at Fenton Hill have exceeded 200 ppm in portions of the canyon within 200 m of GTP-3, although there is no visual evidence of foliar damage. Soil boron content is within the normal range of 2 to 100 ppm, although soils in the upper end of this range may cause plant damage under appropriate conditions.²³ There is evidence in the literature that plant damage may occur as a result of a boron-fluoride synergistic effect,²⁴ which is a consideration because fluoride is also present in the effluent discharged from GTP-3.

The data received to date on cadmium are scanty and insufficient to make any statements as to whether any accumulation is occurring (Table XV). The single set of foliage data from 1981 indicates that some foliar accumulation might be occurring. However, the levels are still well below critical levels of 10 to 15 ppm.²⁵ (Note that the data in Table XV are presented in parts per billion.)

TABLE X

**CHEMICAL AND RADIOCHEMICAL
CONCENTRATIONS IN WATER FROM
SUPPLY WELL FH-1,
MARCH 31, 1982**

	Water Supply Well FH-1	Standard ^a or Criteria
Chemical Standards (mg/l)		
Primary		
Ag	<0.0005	0.05
As	<0.005	0.05
Ba	0.02	1.0
Cd	<0.001	0.01
Cr	0.001	0.05
F	0.1	2.0
Hg	<0.0001	0.002
NO ₃	<0.5	45.0
Pb	<0.003	0.05
Se	<0.003	0.01
Secondary		
Cl	41.0	250.0
Cu	0.007	1.0
Fe	0.036	0.3
Mn	<0.002	0.05
SO ₄	8.0	250.0
Zn	0.91	5.0
TDS	274.0	500.0
pH (no units)	7.8	6.5 - 8.5
Radiochemical Standards (pCi/l)		
³ H	2.0	20 000
¹³⁷ Cs	5.0	200
²³⁸ Pu	<0.036	15
²³⁹ Pu	<0.024	15
Gross alpha	6.0	15

^aReferences 19 and 20.

The data for fluoride show some evidence that there is a slight accumulation in soils, but no trends are apparent in root and foliar analyses (Table XVI). Soil buildup is to be expected, because nearly all fluoride compounds are relatively insoluble. However, all measured soil concen-

Fig. 11. Sulfate, chloride, fluoride, and TDS at ponds GTP-1 and GTP-3, Fenton Hill (TA-57), 1974-1982.

trations are still within the normal range of 20 to 500 ppm.²⁶ With the exception of the fall 1981 root samples, the vegetation analyses all fall into the normal fluoride content range of up to 20 ppm.^{26,27} Toxic levels vary widely among species, ranging from about 30 to several hundred ppm.^{26,27,28} Also, as mentioned previously, there is the possibility of a detrimental fluoride-boron synergistic effect.²⁴

Lithium data also are rather scanty, but there does appear to be some accumulation in soils and roots, and there is a definite accumulation in plant foliage (Table XVII). Soil concentrations are well within the normal range of 10 to 100 ppm,²⁹ but foliage analyses of plants from that portion of the canyon affected by the GTP-3 effluent are considerably above the normal range of 0.5 to 1.5 ppm.²⁹ Lithium toxicity symptoms have been reported at as low as 13 ppm for sensitive species,²⁹ although critical levels for a grass (barley) were reported in the range of 22 to 60 ppm.³⁰ In spite of the fact that measured foliar lithium concentrations in the canyon are potentially in the toxic range, no apparent damage is evident on the grasses or aspen growing there.

TABLE XI

DETAILED ANALYSES OF WATER RELEASED FROM PONDS AT FENTON HILL, 1981

Chemical Analyses	Number of Analyses	Min (mg/l)	Max (mg/l)	Avg (mg/l)
TSS	60	4.0	876.0	61.0
SiO ₂	60	98.0	244.0	188.0
Na	60	385.0	1425.0	872.0
K	60	19.0	92.9	63.8
TDS	60	1575.0	6298.0	3500.4
TS	60	1658.0	6450.0	3561.5
Mg	60	2.2	26.8	6.5
Fe	60	1.9	75.5	33.9
Cl	60	55.0	1332.0	947.8
Ca	60	39.7	2030.0	246.0
Al	60	0.04	31.7	1.36
HCO ₃	60	256.0	700.0	55.9
P	60	0	2.93	0.37
Li	60	0.12	16.0	11.18
F	60	1.14	10.0	7.27
SO ₄	60	173.0	2563.0	480.2
CO ₃	60	0	200.0	9.3
B	60	2.6	14.6	11.2
Cd	60	0.00002	0.013	0.0009
As	60	0.002	0.23	0.05
NO ₃	60	0.20	4.44	2.32
Cr	2	1.25	1.35	1.3
Se	2	0.072	0.074	0.073
CN	2	0.008	0.008	0.008
Ag	2	0.005	0.015	0.01
Hg	2	0.0001	0.0001	0.0001
Cu	2	0.256	0.432	0.344
Pb	2	0.03	0.05	0.04
Phenols	2	0	0.0	
Ba	2	0.47	0.53	0.50
U	2	0.01	0.01	0.01
Mn	2	0.44	0.44	0.44
Zn	2	0.53	1.03	0.78

TABLE XII
DETAILED ANALYSES OF WATER RELEASED FROM PONDS
AT FENTON HILL, 1982

<u>Chemical Analyses</u>	<u>Number of Analyses</u>	<u>Min (mg/l)</u>	<u>Max (mg/l)</u>	<u>Avg (mg/l)</u>
TSS	14	45.0	388.0	161.1
SiO ₂	14	58.1	156.0	88.1
Na	14	490.0	850.0	696.6
K	14	15.0	108.0	45.4
TDS	14	2275.0	3670.0	3205.2
TS	14	2486.0	3722.0	3366.4
Mg	14	10.0	20.0	4.5
Fe	14	1.3	13.4	5.1
Cl	14	90.0	905.0	393.9
Ca	14	31.7	44.0	37.1
Al	14	2.4	25.3	8.4
HCO ₃	14	560.0	1000.0	845.7
P	14	0.3	2.4	1.6
Li	14	0.3	9.3	3.4
F	14	1.2	4.5	2.3
SO ₄	14	71.0	211.0	161.3
CO ₃	14	0	160.0	42.9
B	14	2.3	25.0	10.3
Cd	14	0.0002	23.3	1.7
As	14	0.012	2.5	0.88
NO ₃	14	0.08	0.90	0.31
Cr	14	0.005	0.06	0.026
Se	14	0.000002	0.011	0.003
CN	14	0.007	0.016	0.01
Ag	14	0	0.027	0.008
Hg	14	0.0001	0.0017	0.0005
Cu	14	0.02	0.27	0.08
Pb	14	0.002	0.08	0.04
Phenols	14	0.24	343.0	81.5
Ba	14	0.10	2.33	0.91
U	14	0	0	0
Mn	14	0.14	0.52	0.29
Zn	14	0.11	0.45	0.24
²²⁶ Ra ^a	6	0.05 ± 0.01	0.75 ± 1.00	0.20 ± 0.20

^apCi/l.

TABLE XIII
ARSENIC IN VEGETATION AND SOIL
(analyses in ppm)

Location	Fall 1978	Spring 1979	Fall 1979	Spring 1980	Fall 1980	Spring 1981	Fall 1981
Roots (bank)							
100 m	---	---	2.24	0.41	---	0.34	3.75
200 m	---	---	0.67	0.12	---	0.45	2.18
400 m	---	---	0.45	0.76	---	0.36	2.87
1000 m	---	---	0.78	0.35	---	0.10	5.72
Roots (channel)							
100 m	---	---	0.97	8.37	---	7.17	13.3
200 m	---	---	5.39	5.86	---	1.23	5.69
400 m	---	---	1.86	2.13	---	1.79	6.47
1000 m	---	---	1.60	0.31	---	0.16	1.93
Lower Canyon	---	---	0.41	0.27	---	0.09	1.06
Foliage (bank)							
100 m	0.13	<0.04	---	0.07	<0.08	0.26	0.11
200 m	0.14	<0.04	---	0.08	<0.04	<10.0	0.08
400 m	0.06	<0.02	---	<0.05	<0.06	26.3	0.35
1000 m	<0.05	<0.03	---	<0.04	<0.03	0.09	<0.06
Foliage (channel)							
100 m	0.22	0.44	---	<0.04	<0.06	<0.09	<0.11
200 m	<0.05	0.21	---	0.31	<0.06	<10.0	0.09
400 m	0.12	<0.04	---	0.12	<0.05	<0.09	0.45
1000 m	0.34	<0.06	---	<0.03	<0.04	---	0.24
Lower Canyon	0.08	<0.04	---	0.06	<0.04	1.8	0.30
Soil (bank)							
100 m	---	---	---	12	---	0.5	2.8
200 m	---	---	---	10	4.2	7.3	3.3
400 m	---	---	---	3	3.3	3.1	4.2
1000 m	---	---	---	5	4.8	3.3	3.6
Soil (channel)							
100 m	---	---	---	10	8.4	6.1	4.9
200 m	---	---	---	43	3.4	7.3	3.7
400 m	---	---	---	12	5.7	5.7	3.8
1000 m	---	---	---	2	2.4	3.2	2.5
Lower Canyon	---	---	---	3	3.2	4.9	3.4

TABLE XIV
BORON IN VEGETATION AND SOIL
(analyses in ppm)

<u>Location</u>	<u>Spring 1979</u>	<u>Fall 1979</u>	<u>Spring 1980</u>	<u>Fall 1980</u>	<u>Spring 1981</u>	<u>Fall 1981</u>	<u>Spring 1982</u>	<u>Fall 1982</u>
Roots (bank)								
100 m	---	14	9	---	22	42	7	29
200 m	---	<5	<5	---	18	29	12	37
400 m	---	9	13	---	19	28	17	30
1000 m	---	8	<5	---	15	35	10	34
Roots (channel)								
100 m	---	13	56	---	28	73	63	114
200 m	---	21	64	---	---	140	102	139
400 m	---	28	34	---	30	61	45	130
1000 m	---	20	9	---	14	36	7	30
Lower Canyon	---	<5	<5	---	10	21	11	32
Foliage (bank)								
100 m	<25	---	21	32	18	15	19	11
200 m	<25	---	14	30	24	14	18	13
400 m	<25	---	13	9	20	20	17	32
1000 m	<25	---	11	9	27	12	10	9
Foliage (channel)								
100 m	150	---	236	173	25	210	670	188
200 m	286	---	245	182	23	110	700	434
400 m	350	---	237	113	28	130	108	110
1000 m	26	---	21	18	28	13	33	12
Lower Canyon	<25	---	10	10	26	15	10	13
Soil (bank)								
100 m	---	---	16	10	15	16	14	14
200 m	---	---	19	13	16	16	16	23
400 m	---	---	15	19	20	15	19	17
1000 m	---	---	25	23	23	15	21	31
Soil (channel)								
100 m	---	---	22	31	33	38	38	49
200 m	---	---	44	42	150	51	42	104
400 m	---	---	25	36	11	17	18	54
1000 m	---	---	18	18	12	15	21	18
Lower Canyon	---	---	14	20	16	19	18	15

TABLE XV
CADMIUM IN VEGETATION AND SOIL
(analyses in ppb)

<u>Location</u>	<u>Fall 1978</u>	<u>Spring 1979</u>	<u>Fall 1980</u>	<u>Spring 1981</u>	<u>Fall 1981</u>	<u>Spring 1982</u>
Roots (bank)						
100 m	---	---	---	---	180	---
200 m	---	---	---	230	100	---
400 m	---	---	---	330	170	---
1000 m	---	---	---	660	---	---
Roots (channel)						
100 m	---	---	---	---	200	---
200 m	---	---	---	---	530	---
400 m	---	---	---	---	260	---
1000 m	---	---	---	320	330	---
Lower Canyon	---	---	---	---	320	---
Foliage (bank)						
100 m	<500	270	---	80	---	---
200 m	<500	190	---	280	---	---
400 m	<500	140	---	50	---	---
1000 m	<500	270	---	140	---	---
Foliage (channel)						
100 m	<500	170	---	450	---	---
200 m	<500	150	---	810	---	---
400 m	<500	150	---	100	---	---
1000 m	<500	190	---	---	---	---
Lower Canyon	<500	150	---	20	---	---
Soil (bank)						
100 m	---	---	170	240	130	120
200 m	---	---	170	160	170	170
400 m	---	---	110	110	110	160
1000 m	---	---	290	510	160	110
Soil (channel)						
100 m	---	---	250	220	160	280
200 m	---	---	220	250	170	180
400 m	---	---	290	560	150	110
1000 m	---	---	80	240	130	110
Lower Canyon	---	---	200	410	140	150

TABLE XVI
FLUORIDE IN VEGETATION AND SOIL
(analyses in ppm)

<u>Location</u>	<u>Spring 1979</u>	<u>Fall 1979</u>	<u>Spring 1980</u>	<u>Fall 1980</u>	<u>Spring 1981</u>	<u>Fall 1981</u>	<u>Spring 1982</u>
Roots (bank)							
100 m	---	66	---	---	19	45	7.5
200 m	---	28	---	---	21	28	12.0
400 m	---	25	---	---	22	59	2.5
1000 m	---	23	---	---	11.2	46	10.1
Roots (channel)							
100 m	---	50	---	---	39	92	10.9
200 m	---	34	---	---	32	96	15.4
400 m	---	78	---	---	6.4	70	15.0
1000 m	---	47	---	---	6.3	52	7.1
Lower Canyon	---	14	---	---	9	34	28.9
Foliage (bank)							
100 m	2.4	---	---	---	2.9	6.7	2.1
200 m	13.0	---	---	---	2.3	1.8	1.6
400 m	0.6	---	---	---	7.8	6.0	1.9
1000 m	1.2	---	---	---	13	3.8	2.0
Foliage (channel)							
100 m	3.3	---	---	---	5	19.0	2.1
200 m	1.2	---	---	---	1.8	2.7	2.1
400 m	8.8	---	---	---	3.2	11.0	2.6
1000 m	0.8	---	---	---	---	6.0	1.2
Lower Canyon	0.3	---	---	---	10.5	5.2	1.1
Soil (bank)							
100 m	---	---	100	---	100	90	80
200 m	---	---	110	80	160	150	130
400 m	---	---	100	95	130	130	200
1000 m	---	---	200	160	170	140	220
Soil (channel)							
100 m	---	---	380	420	360	350	240
200 m	---	---	290	140	320	250	200
400 m	---	---	160	180	120	170	150
1000 m	---	---	110	105	90	160	190
Lower Canyon	---	---	220	210	250	180	200

TABLE XVII
LITHIUM IN VEGETATION AND SOIL
(analyses in ppm)

<u>Location</u>	<u>Fall 1978</u>	<u>Spring 1979</u>	<u>Spring 1980</u>	<u>Fall 1980</u>	<u>Spring 1981</u>	<u>Fall 1981</u>
Roots (bank)						
100 m	---	---	---	---	2.63	23.4
200 m	---	---	---	---	2.67	19.1
400 m	---	---	---	---	1.10	19.9
1000 m	---	---	---	---	6.92	3.7
Roots (channel)						
100 m	---	---	---	---	---	43.0
200 m	---	---	---	---	---	15.8
400 m	---	---	---	---	---	6.0
1000 m	---	---	---	---	1.25	4.5
Lower Canyon	---	---	---	---	---	3.6
Foliage (bank)						
100 m	1.93	0.8	---	---	0.37	1.22
200 m	1.93	0.8	---	---	1.50	0.86
400 m	0.69	3.3	---	---	0.92	2.10
1000 m	1.00	0.8	---	---	0.75	0.75
Foliage (channel)						
100 m	3.5	46	---	---	71.8	51.7
200 m	9.1	109	---	---	154.0	32.0
400 m	12.9	239	---	---	31.5	19.2
1000 m	1.93	2.6	---	---	---	---
Lower Canyon	1.00	2.6	---	---	1.0	4.3
Soil (bank)						
100 m	---	---	29.9	---	28.4	29.7
200 m	---	---	30.0	32.1	29.1	30.3
400 m	---	---	33.6	29.2	30.6	29.3
1000 m	---	---	29.7	33.1	30.1	25.9
Soil (channel)						
100 m	---	---	52.4	57.7	46.6	44.5
200 m	---	---	46.3	35.9	88.0	35.3
400 m	---	---	38.9	38.9	35.9	31.6
1000 m	---	---	37.6	29.2	31.6	30.6
Lower Canyon	---	---	53.9	39.9	40.4	39.7

IV. SUMMARY

During 1981 and 1982 the chemical quality of surface and ground water within the drainage of Fenton Hill site varied slightly, which was attributed to normal seasonal fluctuations. The concentrations of the chemical constituents were within the range of previously measured concentrations with the exception of water from supply well FH-1. In water from supply well FH-1 at Fenton Hill, the TDS increased slightly from 1976 through 1980. There was an increase from about 240 mg/l in 1980 to over 300 mg/l in 1981. Calcium concentrations increased slightly from about 35 mg/l in 1980 to over 50 mg/l in 1982. The increase in TDS and calcium may be because of a decline in the water level in the well, resulting in yield from different beds within the aquifer.

Water in the ponds is highly mineralized because of its use as drilling fluid or use in the experimental loop. During 1981, about 3.85×10^6 l and in 1982 about 2.24×10^6 l of water were released from the ponds into the dry canyon of the site. All surface flow from the release was lost within 400 m of the lower pond. Monitoring of surface waters and spring discharge downgradient (6025 to 9420 m) from the site failed to detect any effect of those or previous releases from the pond.

Results from vegetation and soil analyses from the canyon below GTP-3 indicate that some elements are accumulating in the soil or vegetation. Only boron and lithium have reached potentially toxic levels in the vegetation. Visually, the vegetation (grass and aspen) appears to be healthy, although there are traces of sticky or greasy matter discharged with the water from the holding ponds.

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APPENDIX A
SURFACE WATER QUALITY, 1981

Station	Location	Date 1981	(mg/L)																Spec Cond (µmho)	pH	Temp (°C)
			SiO ₂	Ca	Mg	Na	CO ₃	HCO ₃	SO ₄	Cl	F	NO ₃	TDS	Total Hard	As	B	Cd	Li			
F	Sulphur Creek	6-18	40	24	4	18	0	22	50	20	0.5	0.4	168	76	<0.001	0.09	0.001	0.07	260	6.5	13
		11-19	30	30	5	12	0	32	76	30	0.4	0.3	212	96	<0.001	0.20	0.002	0.06	305	7.1	1
J	Jemez River	6-18	65	14	3	40	0	74	7	3	1.1	0.2	146	47	0.006	0.03	0.002	0.08	160	7.6	12
		11-19	48	14	3	16	0	72	8	8	1.1	0.4	138	50	<0.001	0.05	0.001	0.11	170	7.8	2
N	San Antonio Creek	11-19	30	30	6	12	0	24	75	29	0.7	0.1	222	100	<0.001	0.17	0.016	0.05	290	7.2	1
Q	Rio Guadalupe	6-18	39	52	7	19	0	176	8	3	0.9	0.4	242	159	<0.001	0.03	0.001	0.05	385	7.4	18
R	Jemez River	6-15	58	46	8	93	0	194	13	128	1.5	0.4	512	147	0.100	1.17	<0.001	1.0	780	7.6	17
		11-19	52	49	5	86	12	188	8	110	2.2	0.1	464	142	0.012	1.10	0.002	0.99	710	8.3	3
S	Jemez River	6-18	58	42	9	101	0	196	14	129	1.6	0.4	536	144	0.121	1.35	<0.001	1.2	960	7.4	16
		11-19	50	49	5	79	12	180	81	118	2.1	0.1	436	144	0.012	1.10	0.011	1.0	710	8.3	3
T	Rio Cebolla	6-18	54	20	2	22	0	82	3	<1	0.9	0.4	146	60	0.001	0.02	<0.001	0.02	165	7.3	12
		11-23	39	18	4	10	0	76	6	3	0.7	0.6	126	62	<0.001	0.07	<0.001	0.02	165	8.2	3
U	Redondo Creek	6-18	39	16	1	22	0	36	6	21	0.4	0.4	112	47	0.002	0.13	<0.001	0.08	150	6.7	13
		11-19	31	23	3	11	0	40	10	37	0.5	0.1	160	72	<0.001	0.21	<0.001	0.05	210	7.3	1
V	Sulphur Creek	6-18	59	66	15	40	0	0	304	2	0.7	0.4	528	225	<0.001	0.04	<0.001	0.03	700	3.2	12
		11-19	47	76	13	22	0	0	328	7	1.3	0.1	580	242	<0.001	0.13	0.001	0.07	720	3.8	1
LF-1	Lake Fork (6085) ^a	11-23	14	10	1	10	0	32	20	7	0.7	0.4	154	32	<0.001	0.10	0.004	0.02	140	6.3	2
LF-2	Lake Fork (7285) ^a	7-14	60	19	9	7	0	94	2	2	0.8	0.4	162	86	0.003	0.05	<0.001	0.03	180	6.2	---
		11-23	17	19	5	25	0	100	4	6	1.5	<0.1	284	68	<0.001	0.31	<0.001	0.03	230	6.9	1
LF-3	Lake Fork (8500) ^a	7-13	51	13	3	7	0	58	4	3	1.0	1.2	96	44	<0.001	0.01	<0.001	0.01	150	7.1	---
		11-23	56	13	3	9	0	60	3	4	1.0	1.8	142	44	<0.001	0.06	0.001	0.02	140	6.9	2
LF-4	Lake Fork (9420) ^a	7-13	53	20	3	11	0	86	3	4	1.0	0.4	126	64	<0.001	<0.01	<0.001	0.02	200	7.6	---
		11-23	51	15	3	12	0	68	5	4	1.3	1.0	146	52	<0.001	0.07	0.001	0.02	160	7.7	2
GTP-1	Pond Fenton Hill ^b	7-14	208	<1	2	1588	1240	2540	857	72	1.3	<0.4	6470	9	0.026	2.5	0.001	0.19	7300	11.1	---
GTP-3	Pond Fenton Hill ^b	7-14	43	24	3	1300	80	900	1770	240	1.2	0.4	5268	73	<0.001	3.1	<0.001	1.0	6300	8.3	---
		11-23	99	50	2	1275	200	2100	62	160	1.4	<0.4	5804	135	<0.001	0.25	0.013	0.42	5200	9.5	4

^aNumber represents meters below Lower Pond (GTP-3) in Lake Fork Canyon.

^bPond used for drilling fluids and water used in experimental loop.

APPENDIX B
SURFACE WATER QUALITY, 1982

Station	Location	Date 1982	(mg/L)																	Spec Cond (umho)	pH	Temp °C
			SiO ₂	Ca	Mg	K	Na	CO ₃	HCO ₃	SO ₃	Cl	F	NO ₃	TDS	Total Hard	As	B	Cd	Li			
F	Sulphur Creek	6-25	26	16	3	3	11	0	28	31	14	0.3	0.5	106	52	0.001	0.1	0.002	0.04	160	7.1	16
J	Jemez River	6-25	47	14	3	3	16	0	68	8	6	0.9	0.7	140	48	0.018	0.2	0.002	0.06	150	7.9	20
N	San Antonio Creek	6-15	51	18	3	2	21	0	72	10	3	0.9	0.6	130	56	0.002	0.2	<0.001	0.03	170	8.3	---
Q	Rio Guadalupe	6-28	26	50	6	4	14	0	156	9	4	0.8	0.7	216	152	0.010	0.1	<0.001	0.03	315	7.6	20
R	Jemez River	6-28	42	45	6	13	88	0	172	15	110	1.4	0.7	464	138	0.015	1.1	0.002	0.89	730	7.9	27
S	Jemez River	6-28	47	44	6	14	97	0	180	17	135	1.7	0.9	514	136	0.098	1.3	0.001	1.1	810	8.0	25
T	Rio Cebolla	6-28	39	18	3	2	13	0	68	5	2	0.8	1.1	138	58	0.010	0.1	0.002	0.01	145	7.0	20
U	Redondo Creek	6-28	18	14	2	1	11	0	32	8	13	0.3	0.7	86	44	0.002	0.1	<0.001	0.05	120	7.7	15
V	Sulphur Creek	6-28	42	59	10	8	22	0	0	280	3	0.6	0.9	430	190	0.004	0.1	<0.001	0.05	620	3.6	13
LF-2	Lake Fork (7285) ^a	6-28	13	20	3	2	26	0	84	3	6	1.8	0.5	200	62	0.016	0.3	0.001	0.02	195	6.7	24
LF-3	Lake Fork (8500) ^a	6-28	46	14	3	2	14	0	60	5	4	1.5	1.5	130	50	0.012	0.3	0.003	0.01	135	6.6	10
LF-4	Lake Fork (9420) ^a	6-28	46	17	3	2	17	0	72	5	7	1.4	0.8	146	54	0.008	0.3	0.001	0.01	155	7.1	10
GTP-1	Pond Fenton Hill ^b	6-28	130	25	6	216	1395	0	2200	112	1188	4.7	2.2	5430	88	6.56	40.0	0.003	9.6	7300	8.2	36
GTP-3	Pond Fenton Hill ^b	6-28	144	47	13	92	495	0	600	89	520	3.9	0.3	2238	172	3.13	13.0	0.003	4.0	2800	7.7	20

APPENDIX C
GROUND WATER QUALITY, 1981

			(mg/L)																	Spec		
Station	Location	Date	SiO ₂	Ca	Mg	Na	CO ₃	HCO ₃	SO ₄	Cl	F	NO ₃	TDS	Total Hard	As	B	Cd	Li	Cond	pH	Temp	
		1981																	(µmho)		°C	
JS-2,3	Jemez Village (Spr)	6-18	78	18	3	17	0	82	3	2	0.9	1.2	144	58	0.002	<0.01	<0.001	0.03	190	6.7	16	
		11-19	62	19	4	13	0	84	6	4	1.0	1.2	168	64	<0.001	0.09	0.001	0.03	180	7.6	2	
JS-4,5	Jemez Village (Spr)	6-18	78	17	3	19	0	82	3	3	0.8	1.2	148	57	0.001	<0.01	0.001	0.03	190	6.7	18	
		11-19	62	17	4	14	0	80	14	4	0.7	1.2	196	60	<0.001	0.05	<0.001	0.02	180	7.4	2	
FH-1	Fenton Hill (Well)	11-23	65	55	6	11	0	124	1	50	0.3	1.2	312	162	<0.001	0.48	<0.001	0.03	430	7.6	8	
JF-1	Jemez Canyon (Hot Spr)	11-19	46	114	19	370	0	656	21	630	3.6	3.2	1920	365	<0.001	5.4	<0.001	4.4	3000	7.0	14	
JF-5	Jemez Canyon (Hot Spr)	6-18	57	332	24	688	0	1230	33	1540	4.1	0.8	3990	930	2.57	13	<0.001	8.8	6210	6.2	43	
		11-19	43	242	22	825	0	1220	126	1520	3.8	0.5	3966	695	0.017	14	0.002	12	6200	6.4	44	
RV-2	San Antonio (Hot Spr)	6-30	84	4	1	23	0	48	6	1	1.2	1.6	150	13	0.007	<0.01	<0.001	0.03	110	7.2	---	
RV-4	Spence (Hot Spr)	6-30	78	7	2	50	0	116	16	7	1.1	6.0	228	27	0.053	0.06	<0.001	0.55	260	7.5	---	
RV-5	McCauley (Hot Spr)	6-30	68	9	5	19	0	72	6	3	1.5	1.6	132	42	0.021	<0.01	<0.001	0.22	150	8.0	---	
Loc. 2	Redondo Campground	6-15	50	30	7	12	0	202	16	19	0.9	<0.4	334	102	0.009	0.28	<0.001	0.04	410	6.9	13	
Loc. 3	San Antonio Campground	6-15	65	48	12	54	0	146	14	6	0.6	<0.4	306	167	0.005	0.03	<0.001	0.06	360	7.4	10	
Loc. 4	La Cueva (Well)	6-15	84	10	2	17	0	62	3	3	0.5	1.6	184	36	0.010	<0.01	<0.001	0.02	140	7.4	12	
		11-16	70	14	4	17	0	80	4	4	0.6	2.0	174	52	<0.001	0.08	0.001	0.02	190	6.9	14	
Loc. 6	La Cueva (Spr)	11-16	64	15	6	16	0	84	3	3	0.7	2.4	172	62	<0.001	0.10	0.001	0.02	195	6.9	13	
Loc. 31	Lake Fork (Spr)	6-15	64	14	3	12	0	66	4	<1	1.5	1.6	132	47	<0.001	<0.01	<0.001	0.01	160	6.7	13	
		11-23	47	14	3	9	0	64	3	3	1.3	1.6	146	48	<0.001	0.08	0.002	0.02	150	6.8	4	
Loc. 39	Lake Fork (Tank)	7-14	25	14	2	11	0	46	10	5	0.3	0.4	80	44	<0.001	<0.01	<0.001	0.01	130	6.3	---	
		11-23	26	13	4	3	0	40	14	3	0.3	4.9	110	48	<0.001	0.10	0.004	0.02	110	6.7	2	
Loc. 42	La Cueva (Well)	6-15	78	12	6	12	0	72	4	1	0.5	<0.4	176	55	0.001	0.08	0.002	0.02	160	6.7	10	
		11-16	68	14	7	13	0	72	5	2	0.6	6.2	160	62	<0.001	0.12	0.001	<0.01	170	6.5	14	
Loc. 47	La Cueva (Well)	6-15	30	6	3	225	0	550	19	1	3.3	<0.4	666	27	0.006	0.51	<0.001	0.12	920	8.2	11	
		11-16	21	6	4	215	0	544	21	3	3.2	1.2	652	32	<0.001	0.62	<0.001	0.12	1040	7.8	16	
Loc. 48	La Cueva (Well)	6-15	69	22	4	19	0	90	12	2	1.1	0.4	182	71	0.002	0.01	<0.001	0.03	200	6.8	10	
Loc. 53	Sulphur (Well)	6-15	72	38	7	17	0	136	12	1	0.8	3.2	236	122	0.009	<0.01	<0.001	0.04	280	6.8	12	
		11-16	62	45	6	18	0	154	13	3	0.9	2.6	260	138	<0.001	0.10	0.006	0.02	340	6.7	19	
Loc. 54	Sulphur (Well)	6-15	68	61	9	46	0	254	21	4	0.7	13	378	192	0.008	<0.01	0.001	0.06	550	6.8	16	
		11-16	56	58	8	39	0	240	20	5	0.8	23	364	180	<0.001	0.11	0.001	0.04	525	6.8	19	

APPENDIX D
GROUND WATER QUALITY, 1982

Station	Location	Date 1982	(mg/l)													Total Hard	As	B	Cd	Li	Spec	pH	Temp
			SiO ₂	Ca	Mg	K	Na	CO ₃	HCO ₃	SO ₄	Cl	F	NO ₃	TDS	Cond (μmho)						°C		
JS-2,3	Jemez Village (Spr)	6-28	66	20	4	3	18	0	84	9	5	0.6	1.9	194	66	0.012	0.1	0.003	0.02	180	7.0	21	
JS-4,5	Jemez Village (Spr)	6-28	69	21	3	4	17	0	84	8	5	0.3	2.1	194	66	0.013	0.1	<0.001	0.02	190	7.0	21	
FH-1	Fenton Hill (Well)	6-28	66	52	5	3	16	0	120	12	40	0.3	1.1	326	152	0.020	0.5	0.002	0.03	360	7.2	22	
JF-1	Jemez Canyon (Hot Spr)	6-28	40	90	16	48	345	0	360	33	540	1.9	1.2	1568	292	0.016	4.5	<0.001	3.5	2540	6.9	20	
JF-5	Jemez Canyon (Hot Spr)	6-28	37	324	29	200	855	0	736	49	1450	4.1	1.0	3964	930	2.57	6.6	0.007	10.8	6140	6.2	46	
RV-2	San Antonio (Hot Spr)	6-28	70	5	1	2	25	0	48	7	4	0.9	2.6	130	16	0.006	0.1	<0.001	0.03	125	7.4	41	
RV-4	Spence (Hot Spr)	6-29	60	7	2	<1	53	0	112	22	8	0.9	5.7	218	28	0.064	0.3	0.003	0.56	270	7.4	42	
RV-5	McCauley (Hot Spr)	6-29	43	10	6	<1	19	0	72	7	4	1.0	1.4	142	48	0.025	0.2	0.001	0.24	165	7.5	33	
Loc. 2	Redondo Campground (Well)	6-28	56	50	11	3	14	0	148	18	25	0.5	0.6	252	170	0.010	0.1	0.003	0.03	400	7.3	14	
Loc. 3	San Antonio Campground (Well)	6-28	51	34	4	7	48	0	160	21	8	0.6	0.8	260	100	0.004	0.3	0.003	0.04	395	6.5	18	
Loc. 4	La Cueva (Well)	6-28	70	13	2	<1	33	0	72	6	4	0.3	1.3	154	42	0.002	0.1	0.003	0.02	160	7.0	25	
Loc. 6	La Cueva (Spr)	6-28	62	16	4	2	28	0	84	6	4	0.6	1.6	168	58	0.027	0.1	0.002	0.02	205	6.7	22	
Loc. 31	Lake Fork (Spr)	6-28	42	16	3	2	16	0	64	4	4	1.5	1.3	154	52	0.022	0.1	0.010	0.02	160	6.9	10	
Loc. 39	Lake Fork (Tank)	6-28	18	13	3	2	6	0	40	15	2	0.3	1.1	66	46	0.009	0.2	0.002	0.01	95	6.1	6	
Loc. 42	La Cueva (Well)	6-28	68	13	7	1	18	0	76	5	4	0.4	<0.2	182	60	0.004	0.1	<0.001	0.01	170	6.2	20	
Loc. 47	La Cueva (Well)	6-28	22	7	3	4	200	0	520	26	4	3.5	0.5	628	32	0.008	0.4	0.025	0.12	1070	8.0	20	
Loc. 48	La Cueva (Well)	6-28	55	23	5	2	21	0	88	16	8	0.9	1.4	174	78	0.002	0.1	0.014	0.03	230	6.5	19	
Loc. 53	Sulphur (Well)	6-28	62	46	6	3	25	0	156	12	4	0.6	2.4	272	140	0.010	0.1	0.003	0.03	340	6.6	20	
Loc. 54	Sulphur (Well)	6-28	59	55	7	3	48	0	228	21	5	0.5	3.2	322	166	0.010	<0.1	0.003	0.05	490	6.6	15	