

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHEMICAL AND ISOTOPIC DATA FOR WATER FROM
THERMAL SPRINGS AND WELLS OF OREGON

Open-File Report 80-737

Menlo Park, California

January 1980

CONTENTS

	Page
Abstract-----	1
Introduction-----	2
Data-----	7
Geothermometry-----	34
Summary-----	45
Acknowledgment-----	45
References-----	45

ILLUSTRATIONS

	Page
Figure 1. Example of a complete Geotherm record-----	3
2. Physiographic divisions, Known Geothermal Resource Areas, and other features of possible geothermal importance-----	4

TABLES

	Page
Table 1. Chemical composition of thermal spring and well waters-----	8
2. References for analyses-----	24
3. Gas and isotopic composition of thermal spring and well discharges-----	32
4. Geothermometer calculations ($^{\circ}\text{C}$)-----	37

CHEMICAL AND ISOTOPIC DATA FOR WATER FROM THERMAL SPRINGS
AND WELLS OF OREGON

By R. H. Mariner, J. R. Swanson, G. J. Orris,
T. S. Presser, and W. C. Evans

ABSTRACT

The thermal springs of Oregon range in composition from dilute NaHCO_3 waters to moderately saline CO_2 -charged NaCl - NaHCO_3 waters. Most of the thermal springs are located in southeastern or south-central Oregon, with a few in northeastern Oregon and near the contact of the Western Cascades with the High Cascades. Thermal springs in the central and northern parts of the Cascades generally issue moderately saline NaCl waters. Farther south in the Cascades, the thermal waters are high in CO_2 as well as chloride. Most thermal springs in northeastern Oregon issue dilute NaHCO_3 waters of high pH (>8.5). These waters are similar to the thermal waters which issue from the Idaho batholith, farther east. Most of the remaining thermal waters are Na mixed-anion waters. Based on the chemical geothermometers, Mickey Springs, Hot Borax Lake, Alvord Hot Springs, Neal Hot Springs, Vale Hot Springs, Crump Well, Hunters (Lakeview) Hot Springs, and perhaps some of the springs in the Cascades are associated with the highest temperature systems ($>150^\circ\text{C}$).

INTRODUCTION

Data presented in this paper are stored in the U.S. Geological Survey Geotherm file. Geotherm is a computerized file created and maintained as part of the Geological Survey's Geothermal Research program (Teshin and others, 1979). Geotherm contains information on the physical characteristics, geology, geochemistry, and hydrology of national and some international geothermal resources. The data include published information, data from other computer files, personal communications, and compilations of various government and private organizations. Retrievals are available to the public in a variety of formats: tape, punched cards, listings, or tables. Requests should be sent to: Geotherm Project, Mail Stop 84, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025.

Geotherm is currently composed of three subfiles: geothermal fields/areas, chemistry and physical properties of thermal wells and springs (sample file), and geothermal drill holes. In addition to these subfiles, there is a file containing the references listed in each record. The data retrieved from the sample file were formatted and special programs were written to calculate temperatures using geothermometers and to create the tables. The records in Geotherm contain more data than are listed in the tables. An example of a complete record is illustrated in figure 1.

The physiographic provinces of Fenneman (1946), shown on figure 2, have differing geologic settings which, in large part, determine the chemical character of the thermal fluids. The Basin and Range province is characterized by a thick sequence of nonmarine volcanic and sedimentary rocks of Cenozoic age, broken by faults which bound the major topographic features (Walker and Peterson, 1969). The volcanics range from basalt to rhyolite and the sedimentary rocks contain considerable volcanic debris. The Owyhee Uplands of southeastern Oregon make up a relatively unbroken plateau consisting of basaltic, andesitic, and rhyolitic sheets and their associated pyroclastics of middle to late Cenozoic age (Corcoran and Walker, 1969). The High Lava Plains of southcentral Oregon also consist of basalt, andesite, and rhyolite flows and their associated sedimentary rocks (Walker, 1969). The Blue Mountains are generally made up of intrusive rock, Quaternary basalts, and older sediments and volcanics, some of which are highly metamorphosed. Intrusive rocks of two ages are present, an older Permian to Triassic suite

```

-----
GEOHEM SAMPLE FILE
NAME OF SAMPLE SOURCE... HOT LAKE
WARNING NUMBER..... 11
LOCATION
COUNTRY..... UNITED STATES
COUNTY..... OREGON
STATE..... OREGON
COUNTY..... UNION
MAP REFERENCE..... CRAIG MTN. 1124000, GRANGEVILLE 11250000
SAMPLE DESCRIPTION AND CONDITIONS
DATE/COLLECTOR..... 1972/00/00 BARNES GROUP
TEMPERATURE (C)..... 80.0
DISCHARGE..... 1500. L/MIN
WATER TREATMENT..... PRESSURE-FILTERED THROUGH A .45 MICROMETRE MEMBRANE. PORTION ACIDIFIED, DILUTED.
DEPOSITS OR ALTERATION..... TRAVERTINE
PERTINENT LITHOLOGY..... BASALT AND MYLONITE
WATER ANALYSIS
DATE/ANALYST..... 1972/00/00 BARNES GROUP
PH..... 9.21
SPECIFIC CONDUCTANCE..... 688.
ANALYSIS IN MG/L
AG.... L 0.02
AL....
AS.... 0.01
AU.... L 0.1
B.... 2.9
BA.... L 0.1
RE.... L 0.1
BR.... 0.4
CA.... 4.9
CA+MG.
CD.... L 0.01
CL.... 140.
CO.... L 0.05
GAS ANALYSIS
ANALYSIS IN VOLUME %
CH4.. 9.
C2H6.
CO2.. L 1.
OTHER ANALYTICAL DATA... 02*AR=2
REFERENCE AND IDENTIFICATION
COMPILED BY..... SANFORD, LINDA
COMPILER AFFILIATION... U.S. GEOLOGICAL SURVEY
COMPILER CROSS INDEX... 02
REFERENCE..... MARINER AND OTHERS, 1974; MARINER AND OTHERS, 1975; NEHRING AND OTHERS, 1979
-----
COORDINATES
LAT/LONG... 45-14.63 N 117-57.51 W
-----
GEOHEM FILE ID: 0000711

```

Figure 1. Example of a complete geotherm record

OREGON

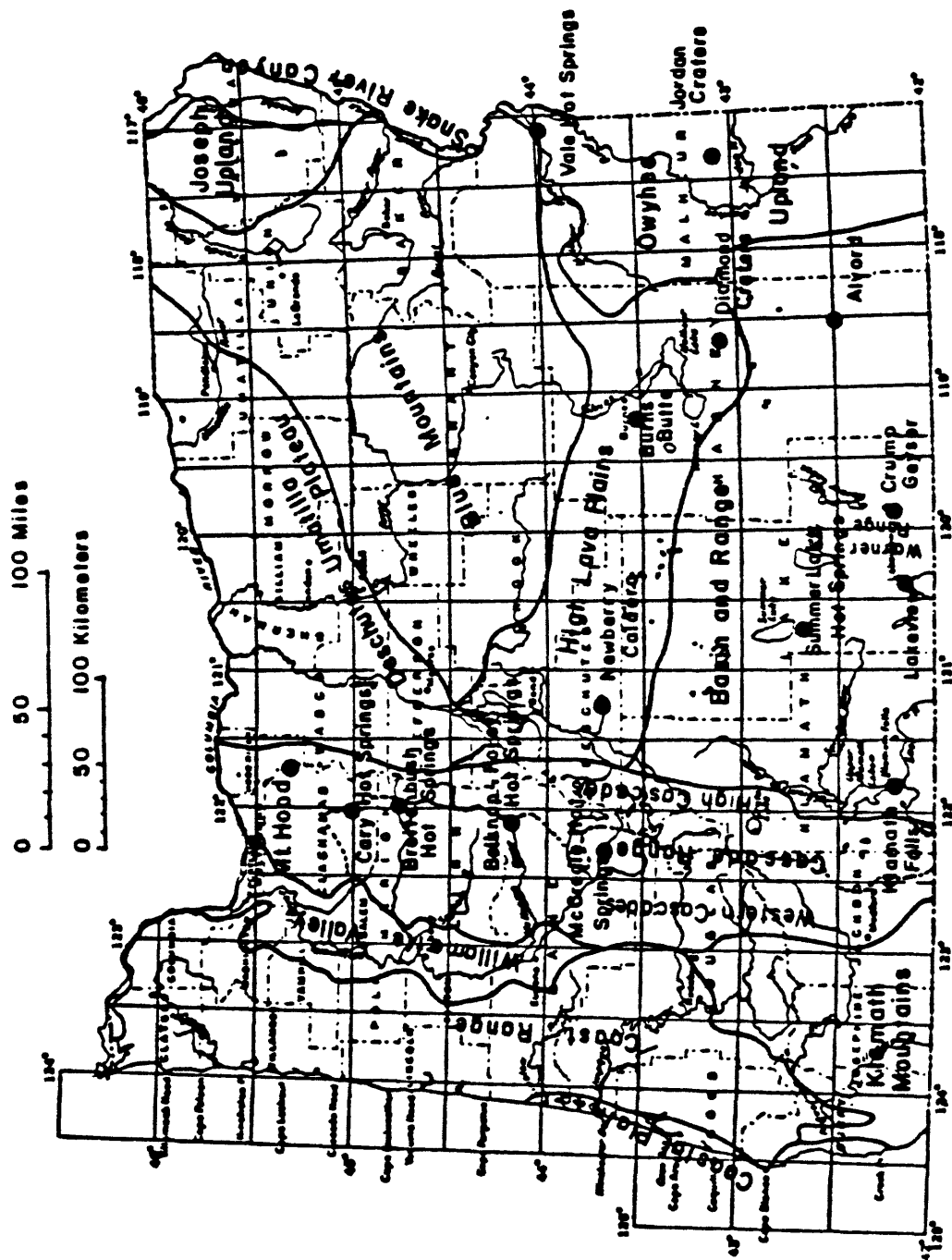


Figure 2. Physiographic Divisions, Known Geothermal Resource Areas, and other features of possible geothermal importance.

which ranges from peridotite to granite, and a Lower Cretaceous suite which ranges from gabbro to granodiorite (Thayer and Wagner, 1969). Several of the younger intrusives are outliers of the Idaho batholith. The Cascade province consists of two subdivisions, the High Cascades and the Western Cascades. The High Cascade Subprovince is a relatively narrow plateau of basalt and andesite flows of Pleistocene and Pliocene Age. The Western Cascade Subprovince is made up of slightly deformed and altered volcanic and pyroclastic rocks that range from late Eocene to late Miocene in age. A few small diorite intrusions also occur in the altered zones of the Western Cascades. The southern end of the Cascades is underlain by a complex of graywacke, siltstone, and interbedded volcanics of Triassic to Cretaceous age, some of which have been regionally metamorphosed. Intrusives associated with these rocks range from granite to peridotite (Griggs, 1969). This type of basement rock extends from the Klamath Mountains in southwestern Oregon to the Blue Mountains in northeastern Oregon. The northern part of the Cascades is underlain by marine and estuarine deposits of Eocene age which are exposed in the Coast Ranges to the west.

Thirteen KGRA's (Known Geothermal Resource Areas) have been designated in Oregon: Mt. Hood, Cary Hot Springs, Breitenbush Hot Springs, Belknap-Foley Hot Springs, and McCredie Hot Springs in the Cascades; Klamath Falls, Lakeview, Crump Geyser, Alvord, and Summer Lake Hot Springs in the Basin and Range province, Newberry Caldera and Burns Butte in the High Lava Plains; and Vale Hot Springs in the Owyhee Uplands. Groh (1966) pointed out several other areas of potential geothermal importance: Jordan Craters in the Owyhee Uplands; Diamond Craters in the Harney Basin; the area southeast of Newberry Caldera in the High Lava Plains; and the Warner Range in the southern part of the Basin and Range province.

Brook and others (1979) list eight areas which they believe have mean reservoir temperatures of more than 150°C: Newberry Caldera (230°C), Crump's Hot Spring (167°C), Mickey Hot Springs (207°C), Alvord Hot Springs (181°C), Hot (Borax) Lake (181°C), Trout Creek Area (154°C), Neal Hot Springs (188°C), and Vale Hot Springs (157°C). These areas are estimated to have an aggregate thermal energy of 90×10^{18} joules, most of which is in the Vale, Alvord, and Newberry areas. About 55×10^{18} joules are estimated to be present in 20 systems of lower temperature (90° to 150°C), with approximately 70 percent of this amount in the Klamath Falls and Lakeview areas. The temperatures used in the estimates are mean temperatures for the

respective systems and do not reflect the maximum and minimum temperatures of the reservoirs. Since volumes of the individual systems are more important in determining the amount of stored heat than the temperatures, and since the volume estimates may undergo considerable change as drillhole and geophysical data become available, changes in the estimated quantities of thermal heat available in Oregon are anticipated.

Chemical data exist for many of Oregon's thermal waters, but they are often scattered in the literature or in unpublished files. A compilation of the raw chemical data for Oregon, as it was entered into Geotherm, has recently been published by the Oregon Department of Geology and Mineral Industries as Open-File Report O-79-3. The data stored in Geotherm cannot be considered to be of uniform quality since they were collected for a myriad of purposes and by different techniques. Anyone considering a sampling program should consult the available literature on general water sampling, such as Brown and others (1970), and the special techniques described for handling geothermal waters such as those given by Presser and Barnes (1974).

The approximately 170 thermal springs and wells identified in Oregon are not distributed uniformly over the state (Bowen, Peterson and Riccio, 1979; Waring, 1965). The largest number of springs issue in the Basin and Range province of southeastern Oregon, with progressively fewer springs in the High Lava Plains, Owyhee Uplands, Blue Mountains, and Cascade Range. The Coastal Plain, Coast Range, Klamath Mountains, and Willamette Valley of western Oregon are devoid of thermal springs. Curiously, most hot springs do not occur in the areas of most recent volcanic activity. Crater Lake, formed some 7,000 years ago by a violent volcanic eruption, has no hot springs associated with it, and the smaller Newberry Caldera has only two areas of weak thermal springs. The springs at Newberry may be drowned fumaroles; they issue in or at the edges of the lakes and appear to be dominantly gas vents. Diamond Craters in the eastern High Lava Plains and Jordan Craters in the Owyhee Uplands are also of Holocene age, but neither has thermal springs nearby. With the exception of Mt. Hood, which has a fumarole on it and a weak thermal spring at its base, the prominent volcanoes of the High Cascades, which have all been formed in the last three million years, do not have thermal springs directly associated with them. Most of the thermal springs in the Cascades issue to the west of the crest, near the contact of the High Cascades and the older Western Cascades.

DATA

Chemical data for the springs and wells (table 1) are arranged by county and numbered to correspond to the thermal springs and wells on a map prepared by Bowen and others (1978). This compilation represents all of the chemical and isotopic data in Geotherm as of October, 1979. Entries for springs that have been analyzed several times are arranged chronologically. Sources of data, topographic map coverage, and year of collection are listed in table 2. Two of the chemical analyses have gross imbalances of ionic charge and hence are incomplete or otherwise inaccurate. Joaquin Miller Hot Springs in Grant County has 25.3 milliequivalents cations to 5.5 milliequivalents anions. A sample recently collected by us indicates that the reported alkalinity is low by more than a factor of 10. The sodium concentration of the sample from Camp Collins in Multnomah County seems to be excessively small. If the sodium concentration were greater by a factor of 10, the charge balance would be much better, 4.88 milliequivalents cations to 4.80 milliequivalents anions rather than the 0.95 to 4.80 as reported.

Waters from several geographic areas can be distinguished on the basis of their chemical composition. Thermal waters in the Western Cascades from Austin to Kitson and McCredie Hot Springs are high in chloride, but low in sulfate and bicarbonate. These sodium chloride waters may originate from the Eocene sediments which are thought to underlie this part of the Cascades. Ratios of B/Cl, Br/Cl, and HCO_3/Cl are similar to those reported for connate waters (White, 1960). Connate marine waters have been noted in springs and wells in the Coast Range, the Western Cascades, and at depths of as little as 30 meters in the Willamette Valley (Piper, 1942). Farther south in the Cascades, the water of Umpqua Hot Springs is similarly high in chloride, but is also high in CO_2 . Many CO_2 -charged mineral springs issue in Douglas County (Wagner, 1959). CO_2 -charged thermal waters also issue from Weberg Hot Springs in southwestern Grant County; this area also has many cold CO_2 -charged springs. The water issuing from Weberg Hot Springs differs from that of Umpqua Hot Springs in that it contains very little chloride. The rest of Grant County, and the southern part of Umatilla, Union, and western Baker counties, all in the north-eastern part of Oregon, have thermal springs which issue dilute, high-pH thermal water similar to waters from thermal springs in granitic rocks of the Idaho batholith. Bagby Hot Springs in the Cascades is another spring that yields the dilute, high-pH waters associated with granitic rock. These waters are high enough in pH to require corrections to the silica concentrations, as discussed in the section on

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/L; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
BAKER COUNTY															
01	RADIUM HOT SPRINGS	44-55.82 117-56.36 07S/039E -28 NE	55/05	290	57.2	9.7	80.	63.	2.0	1.6		101	31.	17.	1.0
01	RADIUM HOT SPRINGS	44-55.82 117-56.36 07S/039E -28 NE	72/00	290	58.	9.56	78.	58.	1.1	1.5	0.1	141	34.	17.	1.3
02	SAM-O SPRING	44-46.76 117-48.65 09S/040E -16 SE	77/02	891	27.0	8.1	67.6	171.	12.2	16.2	6.	519	3.7	15.9	1.2
05	KROPP HOT SPRING	45-00.8 117-53.1 06S/039E -25 NW		445	43.0	7.3	58.	93.	1.5	1.1	0.1	52	31.6	80.8	1.19
06	FISHER HOT SPRING	44-58.48 118-02.61 07S/038E -10 NW	72/06	197	37.0	9.8	38.9	40.		1.4	<0.1	83	12.	1.8	0.4
CLACKAMAS COUNTY															
01	ACID-SULFATE SPRING ON MT. HOOD	45-22.3 121-41.8 02S/009E -29	76/06	227		3.8	19.	5.	0.2	13.	2.8		77.	1.	
02	SWIM WARM SPRINGS	45-17.7 121-44.3 03S/8.5E -24 SW	76/12	1300	26.0	7.3	72.3	136.	11.7	60.	48.	218	205.	161.	0.23
03	AUSTIN HOT SPRINGS (CAREY)	45-01.30 122-00.50 06S/007E -30 NW	72/00	1720	86.0	7.63	81.	300.	7.1	35.	0.1	58	140.	430.	1.4
04	BAGBY HOT SPRINGS	44-56.15 122-10.35 07S/005E -26 NW	70/03	290	57.2	9.7	81.5	54.	0.8	3.7	0.1	68	33.7	14.6	0.68
04	BAGBY HOT SPRINGS	44-56.15 122-10.35 07S/005E -26 NW	77/09		58.	9.37	74.	53.	0.74	3.3	<0.05	69	42.	14.	0.66
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	45-01.65 121-57.80 06S/007E -21 SW	76/08	282	35.6	7.6	36.	48.	2.8	12.	2.6	162	3.6	2.	0.71
DESCHUTES COUNTY															
01	EAST LAKE HOT SPRINGS	43-43.1 121-12.2 21S/013E -29 SW	73/00	396	62.0	6.49	36.	32.	3.8	38.	16.	184	58.	0.4	0.2
01	EAST LAKE HOT SPRINGS	43-43.1 121-12.2 21S/013E -29 SW	75/08	767	49.	6.42	199.	53.		70.	34.	547	28.	1.7	0.16
02	PAULINA HOT SPRINGS	43-43.7 121-45.0 21S/012E -26 NE	77/07			6.82	205.	140.	17.	56.	60.	856	<1.	6.0	0.57
02	WARM WELL AT LITTLE CRATER CAMPGROUND	43-42.9 121-14.5 21S/012E -36 NW	75/08	900	35.5	6.46	161.	83.	10.	54.	48.	679	<1.	5.1	0.6
DOUGLAS COUNTY															
01	UMPQUA HOT SPRINGS	43-17.70 121-21.90 26S/004E -20 NE	77/09	11300	46.5	6.37	90.	2400.	63.	340.	41.	1380	193.	3500.	1.5
01	UMPQUA HOT SPRINGS	43-17.70 121-21.90 26S/004E -20 NE	78/06	10920	46.	6.2	96.	2150.	62.	428.	42.4	1120	139.2	3340.	1.2
GRANT COUNTY															
01	RITTER HOT SPRINGS	44-53.60 119-08.50 08S/030E -08 NW	73/00	319	41.0	9.68	70.	72.	0.82	1.4	<0.05	143	9.	29.	4.3
04	BLUE MOUNTAIN HOT SPRINGS	44-21.30 118-34.40 14S/034E -13 S/2	72/00	610	58.0	7.96	47.	140.	3.3	2.2	0.2	329	11.	15.	10.6
05	JOAQUIN MILLER RESORT	44-16.81 118-57.36 15S/031E -11 SE	78/07	2194	40.	6.8		500.	11.2	45.2	12.1	103	1.6	121.	7.1

Table 1: (CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (Nf) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
BAKER COUNTY													
01	RADIUM HOT SPRINGS								0.2	ND	ND	ND	
01	RADIUM HOT SPRINGS	0.42	0.01	<0.02	<0.1	<0.05	0.01	0.007			<0.02	<0.02	0.0005
02	SAM-O SPRING	1.6	0.06							0.43	<0.1	0.05	
05	KROPP HOT SPRING	3.3	<0.1							0.04	<0.03	<0.03	
06	FISHER HOT SPRING	2.8	1.0							0.07	<0.03	<0.03	
CLACKAMAS COUNTY													
01	ACID-SULFATE SPRING ON MT. HOOD		<0.01										
02	SWIM WARM SPRINGS	0.32	0.13						<0.02	<0.02	<0.05	<0.05	
03	AUSTIN HOT SPRINGS (CAREY)	2.6	0.4	0.03	<0.1	0.33	2.	0.33			<0.02	<0.02	0.0302
04	BAGBY HOT SPRINGS	0.6								0.2			
04	BAGBY HOT SPRINGS	0.07	0.02										
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	0.42	0.01						0.38	<0.05	18.		
DESCHUTES COUNTY													
01	EAST LAKE HOT SPRINGS	0.93	0.01	<0.02	<0.1	0.14					<0.02	0.10	0.0033
01	EAST LAKE HOT SPRINGS	1.1	0.04	0.03	<0.1					0.008m	0.66	0.90	
02	PAULINA HOT SPRINGS	0.87	0.22	0.04	<0.1								
02	WARM WELL AT LITTLE CRATER (CAMPGROUND)	2.5	0.12	0.02	<0.1					0.002m	4.	0.25	<0.0001
DOUGLAS COUNTY													
01	UMPQUA HOT SPRINGS	41.	2.4	0.16	0.2					<0.002m	0.44		<0.0001
01	UMPQUA HOT SPRINGS	41.2	2.4							2.2	6.2		
GRANT COUNTY													
01	RITTER HOT SPRINGS	2.6	0.01	<0.02	<0.1	<0.05					<0.02	<0.02	0.0005
04	BLUE MOUNTAIN HOT SPRINGS	1.6	0.07	<0.02	<0.1	<0.05	0.04	0.31			<0.02	<0.02	0.0004
05	JOAQUIN MILLER RESORT	12.7	0.25						3.02	0.08	0.1	1.8	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements															
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
GRANT COUNTY															
07	WEBERG HOT SPRING	44-00.1 119-38.8 18S/026E -18	72/00	2570	46.0	6.53	82.	610.	36.	38.	7.8	1712	13.	50.	3.9
HARNEY COUNTY															
01	UNNAMED SPRING	43-39.76 118-44.30 22S/32.5E-14 SW	31/09		22.					16.		86	4.	1.9	
02	O. J. THOMAS	43-37.65 118-51.75 22S/032E -34 NE	68/09	716	72.0	9.5	89.	157.	1.8	1.0	0.2	236	89.	38.	2.8
04	MILLPOND SPRING	43-32.43 119-04.86 23S/030E -35 NE	31/08		26.					14.		109	11.	8.	
05	HARNEY VALLEY DEV CO. OIL TEST WELL	43-30.25 118-54.30 24S/032E -08 SE	68/09	602	46.0	9.6	72.	135.	1.6	0.8	0.2	265	29.	11.	12.
08	ISLAND RANCH WELL	43-25.40 118-55.95 25S/032E -07 NW	69/08	1450	41.0	9.3	54.	386.	4.4	0.5	0.2	967	8.	9.	19.
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	31/08		49.					2.		218	80.	82.	
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	68/09	814	80.0	8.3	80.	170.	3.6	3.8	0.2	211	81.	78.	9.3
09	CRANE HOT SPRINGS	43-26.45 118-38.30 24S/033E -34 SW	72/00	810	78.0	8.1	83.	170.	3.9	3.7	0.1	208	86.	79.	9.0
10	WARM SPRING NEAR VENATOR	43-23.7 118-18.4 25S/036E -16 SW	77/06	650	41.0	9.1	370.	100.	1.0	2.7	0.1	134	51.	70.	1.1
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	43-10.6 119-03.6 27S/29.5E-36 SE	31/08		59.		92.	622.	12.	13.	3.0	601	140.	562.	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	43-10.6 119-03.6 27S/29.5E-36 SE	72/00	2970	68.0	7.26	92.	630.	13.	12.	1.8	568	143.	590.	3.3
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	70/07	2200	85.	8.5	167.	478.	20.	1.	1.2	205.	230.	230.	19.6
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	72/00	2490	73.0	8.05	200.	550.	35.	0.9	0.1	796	230.	240.	16.
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	76/09	2200	86.	8.31	214.	550.	31.	1.0	<1.	804	213.	240.	16.
22	MICKEY SPRINGS	42-40.6 118-20.7 33S/035E -13	76/09	2220	86.	8.31	214.	550.	30.	1.0	0.1	814	223.	240.	17.
22	MICKEY SPRINGS	42-40.54 118-20.67 33S/035E -13	76/09	2290			200.	560.	32.	0.6	<0.1	836	223.	245.	17.
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33 SE	55/11	4490	82.2	7.3	135.	1040.	66.	13.	1.0	1250	211.	760.	7.2
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33 NW	72/00	4590	76.0	6.73	120.	960.	69.	13.	2.2	1198	223.	780.	10.2
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33	76/09	4100	78.5	6.90	129.	990.	64.	12.	2.1	1225	183.	770.	9.6
23	ALVORD HOT SPRINGS	42-32.6 118-32.1 34S/034E -33	76/09	4070	78.5	6.89	128.	1000.	63.	12.	2.2	1230	183.	770.	11.
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	53/09	2227	29.4	7.7	184.	488.	23.	17.		424	343.	286.	8.
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	61/06	2410	31.1	7.8	193.	516.	27.	16.	0.5	450	367.	305.	9.7

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Map Code	Name	Minor and Trace Elements											
		Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
GRANT COUNTY													
07	WEBERG HOT SPRING	15.	0.7	0.09	<0.1	2.1	0.1	0.1		0.24	0.06	0.0003	
HARNEY COUNTY													
01	UNNAMED SPRING								1.0				
02	O. J. THOMAS	3.99							ND	0.03			
04	MILLPOND SPRING								1.1				
05	HARNEY VALLEY DEV CO. OIL TEST WELL	4.11							0.2	0.20			
08	ISLAND RANCH WELL								0.1				
09	CRANE HOT SPRINGS								1.4				
09	CRANE HOT SPRINGS	6.2							ND	0.02			
09	CRANE HOT SPRINGS	7.9	0.09	0.03	<0.1	0.06	0.1	0.02		<0.02	<0.02	0.0005	
10	WARM SPRING NEAR VENATOR	2.2								0.03 M			
15	UNNAMED HOT SPRING NEAR HARNEY LAKE								0.5	0.03			
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	11.3	0.45	0.08	<0.1	0.11	29.	0.2		0.005m	0.05	0.04	0.0001
22	MICKEY SPRINGS	9.2	<0.2						0.02	<0.01	0.05	0.02	
22	MICKEY SPRINGS	10.5	1.1	0.20	0.1	0.15	1.	0.09		0.058m	<0.02	<0.02	0.0001
22	MICKEY SPRINGS	11.	0.90	0.18	0.1								
22	MICKEY SPRINGS	11.	0.90	0.14	<0.1					0.068m	<0.02		
22	MICKEY SPRINGS	11.	0.85	0.15	<0.1								
23	ALVORD HOT SPRINGS	28.							1.1	0.09 M			
23	ALVORD HOT SPRINGS	30.	2.1	0.33	0.2	0.92	2.	0.09		0.003m	0.12	0.02	0.0001
23	ALVORD HOT SPRINGS	35.	1.9		0.1								
23	ALVORD HOT SPRINGS	36.	1.9	0.24	0.1								
24	HOT BORAX LAKE	17.9	<1.5						2.5				
24	HOT BORAX LAKE	18.											

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements																
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	
MARNEY COUNTY																
24	HOT BORAX LAKE	42-19.60 118-36.17 37S/033E -15 SW	72/00	2410	36.0	7.28	190.	500.	31.	16.	0.3	422	353.	300.	9.0	
27	UNNAMED HOT SPRING NEAR TROUT CREEK	42-11.3 118-23.0 39S/037E -16	70/08	1060		8.3	79.	230.	25.	18.4	0.9		177.	226.	12.0	
27	UNNAMED HOT SPRING NEAR TROUT CREEK	42-11.3 118-23.0 39S/037E -16	72/00	1168	52.0	6.77	105.	270.	10.8	18.	0.8	441	204.	24.	12.8	
39	GOODMAN SPRING (HOTCHKISS)	43-31.73 119-04.83 23S/030E -35 SE	68/09	210	22.0	7.5	46.	35.	3.2	8.2	1.4	92	15.	7.	0.6	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	53/09	2050	73.9	7.6	119.	430.	27.	15.		382	319.	255.	7.0	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	53/09	2160	79.4	8.1	173.	456.	30.	14.	0.3	414	339.	270.	7.0	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.08 118-36.11 37S/033E -11	57/05	2190	87.0	7.5	160.	426.	29.	9.6		425	329.	265.	6.5	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	73/06	2020	96.0	7.30	160.	450.	28.	14.	0.3	382	434.	250.	7.2	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	76/09	1990	91.	7.94	189.	460.	29.	15.	0.3	434	320.	270.	7.5	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.08 118-36.11 37S/033E -11	76/09	1840	97.	7.36	169.	435.	24.	13.	0.2	389	303.	250.	7.6	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	1910	90.5	7.04	154.	435.	26.	15.	0.3	420	303.	250.	7.0	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	2040	86.	8.67	157.	450.	26.	14.	0.3	423	303.	250.	7.7	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-20.17 118-36.08 37S/033E -11 SW	76/09	1840	97.	7.26	163.	425.	24.	12.	0.2	372	303.	250.	7.4	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	42-19.82 118-36.16 37S/033E -14 NW	76/09	1890	84.	7.48	164.	440.	25.	12.	0.2	386	313.	250.	7.5	
44	HOTCHKISS WELL	43-31.42 119-03.83 24S/030E -01 NE	31/08		27.		51.	30.	2.4	9.6	1.7	95	13.	5.2		
44	HOTCHKISS WELL	43-31.42 119-03.83 24S/030E -01 NE	68/09	194	27.	8.1	46.	31.	2.9	8.8	1.4	93	12.	5.	0.5	
45	HINES LUMBER CO. WELL	43-32.34 119-04.80 23S/030E -35 NE	68/07	222	25.0	7.8	55.	33.	4.	11.	2.	105	14.	7.	0.5	
46	CITY OF HINES WELL	43-33.57 119-05.31 23S/030E -23 SW	68/07	289	17.0	7.8	60.	35.	6.9	15.	5.7	128	18.	13.	0.5	
JACKSON COUNTY																
01	JACKSON HOT SPRING	42-13.30 122-44.65 38S/001E -48 SW	52/04	460	35.0	9.3	65.	95.	1.2	2.8	1.4	84	26.	80.	2.0	
KLAMATH COUNTY																
	ALFRED JACOBSEN	42-07.65 121-44.40 39S/009E -34 NE	74/05	290	30.0	7.6	65.	49.	12.	5.7	2.4	160	13.	7.9	0.1	
	BILL HILL	42-03.55 121-36.60 40S/010E -26 NW	74/06	245	20.0	7.7	26.	19.	6.4	9.1	13.	140	5.4	4.2		
	CLAUDE SHUCK	42-11.35 121-39.80 39S/010E -08 SE	74/05	220	24.	8.2	57.	25.	6.2	9.7	4.1	112	15.	2.8	0.2	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
HARNEY COUNTY													
24	HOT BORAX LAKE	16.6	0.65	0.23	0.1	0.42	2.	0.2			<0.02	0.03	0.0304
27	UNNAMED HOT SPRING NEAR TROUT CREEK	1.6	<0.5						0.05	<0.01	0.03		
27	UNNAMED HOT SPRING NEAR TROUT CREEK	0.89	0.68	0.10	0.1	0.30				0.002m	0.09	<0.02	0.0803
39	GOODMAN SPRING (HOTCHKISS)	0.23							2.1		0.02		
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	12.	<1.5						1.2				
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	<1.5						1.3				
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	ND			ND	1.8	0.2	ND	ND	ND	0.10	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.51	0.18	0.1	0.60				0.020m	<0.02	0.04	0.0008
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.50	0.23	0.2								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.50	0.17	0.1					0.028m	<0.02	0.05	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.5	0.18	0.2								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.55	0.18	0.1								
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	14.	0.45	0.17	0.1						<0.02		
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	15.	0.45	0.18	0.1								
44	HOTCHKISS WELL								1.2		0.01		
44	HOTCHKISS WELL	0.06							1.1				
45	HINES LUMBER CO. WELL	0.38							1.5		0.02		
46	CITY OF HINES WELL	0.53							3.8		0.05		
JACKSON COUNTY													
01	JACKSON HOT SPRING	2.9							0.2		0.07		
KLAMATH COUNTY													
	ALFRED JACOBSEN	0.05									0.12	0.050	
	BILL HILL	0.02									0.04	0.030	
	CLAUDE SHUCK	0.02									0.05	0.010	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements

Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)
KLAMATH COUNTY															
	CLYDE DEHILLINGER	42-06.75 121-39.65 40S/010E -05 SE	74/06	240	24.0	7.9	72.	40.	6.5	8.1	3.1	150	2.3	4.9	
	FALCON HEIGHTS SCHOOL	42-07.80 121-45.10 39S/009E -34 SW	74/05	350	37.0	7.8	80.	57.	7.1	7.7	4.5	170	24.	8.9	0.2
	GEORGE CARTER	42-00.55 121-36.90 41S/010E -14 NW	74/06	660	22.	8.2	41.	99.	7.9	29.	2.3	100	95.	98.	
	GEORGE STACY CO.	42-08.40 121-39.80 39S/010E -32 NE	74/06	170	25.0	8.3	34.	20.	4.0	13.	2.0	94	11.	2.0	
	JACK O'CONNER	42-02.00 121-42.95 41S/009E -01 NE	74/05	640	38.0	8.3	65.	130.	3.0	7.5	0.6	114	140.	50.	
	LEN DOBRY	42-08.90 121-38.65 39S/010E -28 SE	74/05	195	21.0	7.6	65.	32.	4.5	5.7	1.1	100	14.	3.4	
	LESTER BROOKSHIRE	42-08.70 121-39.70 39S/010E -29	74/05	175	25.0	8.1	35.	21.	3.4	13.	2.0	97	10.	2.8	0.1
	MELVIN MCCOLLUM	42-11.50 121-41.05 39S/010E -07 NE	74/05	300	25.0	7.5	52.	20.	4.0	24.	13.	120	53.	3.1	0.2
	MONTE DEHILLINGER	42-07.60 121-40.40 39S/010E -32 SW	74/06	260	26.0	7.6	54.	22.	6.7	17.	11.	160	7.1	3.6	
	O'CONNER LIVESTOCK CO.	42-01.00 121-41.00 41S/010E -07 SE	74/06	1300	30.0	7.8	80.	210.	7.0	58.	6.4	250	210.	160.	
	OREGON WATER CORP. (4)	42-12.10 121-41.40 39S/010E -06 SW	70/08		26.	8.6	63.	36.		8.5	5.8		5.5	3.0	0.32
	POPE'S MEAT CO.	42-01.95 121-37.50 41S/010E -03 NE	74/06	190	22.0	8.5	25.	30.	3.2	8.6	1.4	104	6.0	4.4	
	RAY BIXLER	42-11.55 121-37.95 39S/010E -10 NW	74/05	190	22.0	7.8	49.	16.	3.3	12.	8.4	110	7.9	1.9	0.2
	ROBERT LANGLEY	42-10.75 121-37.90 39S/010E -15 SE	74/05	200	23.	7.4	50.	22.	5.5	10.	6.3	112	14.	2.6	
	TOWN OF MERRILL	42-01.50 121-36.00 41S/010E -02 SE	55/02	316	21.0	8.3	39.	44.	3.8	11.	4.3	114	21.	27.	0.1
	U.S. AIR FORCE(1)	42-08.05 121-45.25 39S/009E -34 NW	72/10	240	31.0	7.0	53.	47.	9.0	3.8	1.2	128	8.	6.0	0.3
	U.S. AIR FORCE(2)	42-08.10 121-45.35 39S/009E -34 NW	72/10	255	30.		51.	48.	8.5	5.6	2.3	145	9.	6.3	0.2
	WEYERHAUSER WELL NO. 4	42-10.70 121-48.10 39S/009E -18 SW	72/08	200	22.	8.3	16.	32.	3.3	10.	1.9	124	4.	4.	0.11
	O1 EAGLE POINT SPRING	42-25.85 121-57.75 36S/007E -23 SE	72/08	305	35.	8.3	38.	62.	5.7	0.6	<0.1	136	<2.	16.	0.75
	O2 J. E. FRIESEN	42-13.75 121-46.15 38S/009E -28 SW	55/02	1230	73.0	8.7	87.	221.	4.4	25.		48	431.	56.	1.6
	O2 LOIS MERRYUYS	42-13.65 121-01.45 38S/009E -33 NW	54/12	1100	71.0	8.5	83.	207.	3.8	22.		51	393.	50.	1.4
	O2 MEDO-BELL DAIRY	42-13.8 121-46.4 38S/009E -28 SW	55/01	1160	81.0	8.8	81.	213.	4.2	23.		48	403.	54.	1.2
	O2 MILLS SCHOOL	42-13.45 121-45.90 38S/009E -33 NE		1200	89.0	8.3	78.	370.	3.0	27.	<0.2	46	462.	54.	1.2
	O2 MOYINA WATER CO.	42-12.60 121-42.45 39S/009E -01 NW	66/08	222	50.	7.4	64.	38.	5.0	7.9	2.3		5.6	1.8	0.22

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Concentrations in mg/L; (ND) not detected; (m) monomeric aluminum]

		Minor and Trace Elements												
Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)	
KLAMATH COUNTY														
	CLYDE DEHILINGER	0.04									0.02	ND		
	FALCON HEIGHTS SCHOOL	0.1									0.19	0.030		
	GEORGE CARTER	0.15									0.02	0.020		
	GEORGE STACY CO.	0.01									0.04	0.010		
	JACK O'CONNER													
	LEN DOBRY													
	LESTER BROOKSHIRE	0.006									0.02	0.02		
	MELVIN MCCOLLUM	0.02									1.4	0.07		
	MONTE DEHILINGER	0.02									0.02	ND		
	O'CONNER LIVESTOCK CO.	0.69									0.04	0.15		
	OREGON WATER CORP.(4)										0.33	<0.005		
	POPE'S MEAT CO.	0.02									0.02	ND		
	RAY BIXLER	0.02									0.15	1.4		
	ROBERT LANGLEY													
	TOWN OF MERRILL	0.01							ND		0.12			
	U.S. AIR FORCE(1)										0.04	<0.01		
	U.S. AIR FORCE(2)										0.03	<0.01		
	WEYERHAUSER WELL NO. 4	0.09												
01	EAGLE POINT SPRING	0.140												
02	J. E. FRIESEN	0.91						ND			ND			
02	LOIS MERRUYS	0.74						0.2			ND			
02	MEDO-BELL DAIRY	0.96						ND			0.04			
02	MILLS SCHOOL	0.96									0.03	0.03		
02	MOYINA WATER CO.										0.42	<0.05		

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements																
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potas- sium (K)	Cal- cium (Ca)	Mag- nesium (Mg)	Alka- linity (HCO3)	Sulfate (SO4)	Chlor- ide (Cl)	Fluor- ide (F)	
KLAMATH COUNTY																
02 O.I.T. NO. 5		42-13.85 121-46.40	67/00	1000	89.0	8.6	73.	331.	3.5	25.1	1.04	55	386.	48.	1.12	
		38S/009E -28 SW														
02 O.I.T. NO. 6		42-14.90 121-46.85	72/08		88.0	8.2	31.	195.	3.9	24.2	<0.1	44	400.	58.	1.45	
		38S/009E -20 NE														
02 O.I.T. NO. 6		42-14.90 121-46.85	75/03		79.		90.									
		38S/009E -20 NE														
02 OREGON WATER CORP.(1)		42-13.30 121-47.45	30/03	200	21.		46.	29.		10.	4.	117		8.		
		38S/009E -32 NW														
02 OREGON WATER CORP.(2)		42-13.30 121-47.45	71/09		21.0	8.3	24.	26.		11.2	6.8		1.2	5.3	0.01	
		38S/009E -32 NW														
02 OREGON WATER CORP.(3)		42-13.30 121-47.45	71/09	205	20.0	8.4	25.	26.		11.2	5.8		0.6	5.3	0.02	
		38S/009E -32 NW														
03 HOWARD HOLLIDAY		42-10.55 121-49.70	74/05	220	25.0	7.9	27.	27.	2.9	12.	3.1	122	5.4	5.1	0.1	
		39S/008E -13 SW														
04 MAZAMA SCHOOL		42-11.85 121-43.90														
		39S/009E -11 NW														
06 ABE BOEHM		42-04.05 121-45.40	74/05	895	61.0	8.3	92.	246.	6.0	5.4	1.0	120	256.	35.	1.0	
		40S/009E -28 NE														
06 ABE BOEHM		42-04.05 121-45.40	75/08		25.								308.	205.		
		40S/009E -28 NE														
06 DAN O'CONNER		42-04.85 121-43.85	74/05	260	24.0	7.6	42.	32.	8.1	12.	6.6	130	14.	9.1		
		40S/009E -23 NW														
06 JACK LISKEY		42-02.95 121-44.40	74/05	1030	93.0	8.9	90.	200.	4.0	15.	<0.1	52	363.	59.	1.5	
		40S/009E -34 NE														
06 JACK LISKEY		42-02.25 121-43.60	74/05	2400	22.0	7.6	100.	580.	12.	35.	16.	1550	13.	140.		
		41S/009E -02 NW														
06 JACK LISKEY		42-02.25 121-43.60	75/08		25.								5.	152.		
		41S/009E -02 NW														
06 O. H. OSBORN		42-03.30 121-44.70	74/05	920	90.0	9.5	90.	190.	4.1	15.		55	273.	56.	1.5	
		40S/009E -27 SW														
07 OLENE GAP HOT SPRINGS		42-10.45 121-36.90	67/00	1000	73.9	7.3	79.	294.	4.5	34.9	1.09	40	346.	58.	1.12	
		39S/010E -14 SW														
07 OLENE GAP HOT SPRINGS		42-10.45 121-36.90	72/00	1140	74.0	7.68	98.	190.	7.2	40.	0.2	55	400.	59.	1.2	
		39S/010E -14 SW														
07 OLENE GAP HOT SPRINGS		42-10.45 121-36.90	75/07		87.								385.	59.		
		39S/010E -14 SW														
08 ROENICKE HOT SPRING		42-10.40 121-37.05	72/10	1300	65.0	8.2	48.	217.	5.0	35.	0.1	50	430.	65.	1.5	
		39S/010E -14 SW														
16 MELVIN FEIGI		42-08.20 121-30.10	70/10	273	31.0	8.8	110.	66.	1.0	1.2		153	5.8	5.	0.4	
		40S/011E -03 NE														
22 RAY SMITH WELL		42-27.25 121-25.40	70/10	148	25.	8.4	50.	30.	1.9	3.8	0.1	86	3.2	2.5	0.2	
		36S/011E -16 NW														
23 KLAMATH ICE CO.		42-13.40 121-01.40	36/04		51.7	9.0	70.						383.	53.		
		38S/009E -33 NW														
24 J. K. O'NEIL		42-08.30 121-38.10	72/03	222		7.6	45.2	22.	5.4	6.4	5.2	101	9.5	2.5	0.2	
		39S/010E -34 NW														
24 J. K. O'NEIL		42-08.30 121-38.10	74/05	190	23.0	7.4	50.	26.	5.1	6.1	5.5	112	13.			
		39S/010E -34 NW														

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Map Code	Name	Minor and Trace Elements											
		Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
KLAMATH COUNTY													
02 O.I.T. NO. 5									<0.01	0.03	0.03	<0.02	
02 O.I.T. NO. 6		1.0											
02 O.I.T. NO. 6			0.12										
02 OREGON WATER CORP.(1)										<0.05			
02 OREGON WATER CORP.(2)										0.09	<0.01		
02 OREGON WATER CORP.(3)										0.05	<0.01		
03 HOWARD HOLLIDAY		0.04	0.02							0.09	ND		
04 MAZAMA SCHOOL										0.09			
06 ABE BOEHM		1.4	0.16							0.1	2.4		
06 ABE BOEHM													
06 DAN O'CONNER													
06 JACK LISKEY		0.65	0.08										
06 JACK LISKEY										0.09			
06 JACK LISKEY													
06 O. H. OSBORN		0.77									0.26	ND	
07 OLENE GAP HOT SPRINGS									0.91	0.03	0.03	0.06	
07 OLENE GAP HOT SPRINGS		1.0	0.15	0.02	<0.1	0.58	0.08	0.01			<0.02	<0.02	
07 OLENE GAP HOT SPRINGS													
08 ROENICKE HOT SPRING		1.9											
16 MELVIN FEIGI		ND							2.9		0.02		
22 RAY SMITH WELL									0.3		0.03		
23 KLAMATH ICE CO.												ND	
24 J. K. O'NEIL									0.03	<0.01	0.02	0.02	
24 J. K. O'NEIL													

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements																	
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potas- sium (K)	Cal- cium (Ca)	Mag- nesium (Mg)	Alka- linity (HCO3)	Sulfate (SO4)	Chlor- ide (Cl)	Fluor- ide (F)		
LAKE COUNTY																	
05	ANA RIVER SPRING	42-59.8 120-45.3 30S/017E -06	48/12		18.9	8.4	37.	39.	3.2	5.2	3.1	108	6.7	13.	0.2		
14	SUMMER LAKE HOT SPRING (WOODWARD)	42-43.53 120-38.75 33S/017E -12 NE	48/10	1760	46.7	8.5	96.	399.	6.8	1.4	0.4	374	111.	285.	2.2		
14	SUMMER LAKE HOT SPRING (WOODWARD)	42-43.53 120-38.75 33S/017E -12 NE	72/00	1790	43.0	8.43	94.	390.	4.6	2.1	0.1	426	120.	280.	2.2		
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	56/10	1110	98.0	8.3	146.	209.	9.5	12.		74	265.	116.			
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	57/10	1140	86.0	8.4	140.	208.	10.	8.0	2.4	74	258.	120.	4.5		
23	HUNTERS HOT SPRINGS (LAKEVIEW)	42-13.32 120-22.09 39S/020E -04 NW	72/00	1120	96.0	7.77	140.	210.	8.5	13.	<0.1	81	260.	120.	4.4		
24	LEITHEAD HOT SPRINGS (JOYLAND PLU)	42-09.71 120-20.60 39S/020E -27 NE	48/06	813	69.4	7.7	66.	152.	2.2	15.	0.4	84	152.	99.	3.1		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	42-09.35 120-20.67 39S/020E -27 SE	48/05	1320	85.0	7.3	140.	268.	8.8	8.5	1.4	208	223.	146.	6.9		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	42-09.35 120-20.67 39S/020E -27 SE	72/00	1370	88.0	7.76	130.	280.	9.0	8.8	0.1	236	240.	170.	5.4		
28	ANTELOPE HOT SPRINGS	42-29.97 119-41.48 35S/026E -32 NW	48/08	876	40.0	8.3	169.	191.	13.	10.	2.5	376	57.	64.	3.60		
32	FISHER HOT SPRINGS	42-17.84 119-46.55 38S/025E -10 NW	72/00	513	68.0	7.93	77.	92.	7.9	8.4	1.0	107	59.	56.	3.5		
33	CRUMP SPRING	42-13.60 119-52.78 38S/024E -34 SW	48/09	935	40.0	8.7	125.	175.	8.7	18.	2.	130	116.	150.	1.9		
33	CRUMP SPRING	42-13.60 119-52.78 38S/024E -34 SW	72/00	1490	78.0	7.26	180.	280.	11.	16.	0.2	155	200.	240.	4.9		
33	CRUMP WELL (1)	42-13.59 119-52.87 38S/024E -34 SW	59/07	1580	99.0	8.7	167.	298.	12.	10.	0.5	143	209.	263.	5.2		
33	CRUMP WELL (2)	42-13.59 119-52.87 38S/024E -34 SW	60/09	1460	88.0	8.1		281.	10.					248.			
LANE COUNTY																	
01	BELKNAP HOT SPRINGS	44-11.65 122-02.90 16S/006E -11 NE	03/00		86.7		80.9	364.	69.	455.	13.		168.	1343.			
01	BELKNAP HOT SPRINGS	44-11.65 122-02.90 16S/006E -11 NE	72/00	4300	71.0	7.62	96.	690.	15.	210.	0.2	19	170.	1300.	1.2		
02	FOLEY SPRINGS	44-09.20 122-05.85 16S/006E -28 NW	76/03	4800	80.6	8.	60.4	475.	11.2	494.	0.8	16	550.	1304.	0.81		
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44-04.95 122-14.00 17S/005E -20	73/00	2890	44.0	7.76	50.	392.	6.3	225.	0.1	21	260.	788.	0.8		
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44-04.95 122-14.00 17S/005E -20 NW	76/03	2660	42.0	8.2	47.	320.	6.8	196.	0.2	18	185.	693.	0.87		
04	WALL CREEK WARM SPRINGS	43-48.45 122-18.55 20S/004E -26 NW	76/03	2340	41.0	7.2	62.7	315.	10.8	130.	1.		108.	602.	4.1		
05	MCCREDIE SPRINGS	43-42.35 122-17.20 21S/004E -36 NW	74/00	6730	73.	7.29	79.	1000.	22.	460.	0.9	21	240.	2200.	2.7		
05	MCCREDIE SPRINGS	43-42.35 122-17.20 21S/004E -36 NW	76/03	6770	71.0	7.4	65.4	910.	28.	500.	0.9	20		2232.	2.68		

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Minor and Trace Elements

Map Code	Name	Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
LAKE COUNTY													
05	ANA RIVER SPRING	0.5							0.1		0.15		
14	SUMMER LAKE HOT SPRING (WOODWARD)	1.0							0.1		0.03		
14	SUMMER LAKE HOT SPRING (WOODWARD)	6.9	0.15	<0.02	<0.1	0.07	1.				<0.02	<0.02	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	7.2	0.2			0.5			7.2				
23	HUNTERS HOT SPRINGS (LAKEVIEW)	7.1							0.3	ND	0.01	ND	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	6.9	0.15	0.04	<0.1	0.32	0.4	0.08		0.034m	<0.02	<0.02	0.0004
24	LEITHEAD HOT SPRINGS (JOYLAND PLU)	7.0							0.2		0.05		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	9.9							0.3		0.02		
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	11.2	0.15	0.04	<0.1	0.17	1.	0.1		0.014m	<0.02	<0.02	0.0017
28	ANTELOPE HOT SPRINGS	1.5							0.2		0.02		
32	FISHER HOT SPRINGS	2.2	0.04	0.02	<0.1	0.05	0.4	0.03		0.011m	<0.02	<0.02	<0.0001
33	CRUMP SPRING	7.3							1.5		0.04		
33	CRUMP SPRING	13.6	0.4	0.07	0.1	0.12	0.4	0.1		0.017m	<0.02	0.03	0.0004
33	CRUMP WELL (1)	18.	0.39			0.31	0.9	0.1	1.0	0.65	0.15	N	
33	CRUMP WELL (2)	13.	0.33										
LANE COUNTY													
01	BELKNAP HOT SPRINGS											T	
01	BELKNAP HOT SPRINGS	6.4	0.95	0.05	<0.1	1.4	33.	0.2			0.02	0.02	<0.0001
02	FOLEY SPRINGS	10.2	0.96							<0.01	<0.05		
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	5.1	0.52	0.03	<0.1	2.0					<0.02	<0.02	0.0005
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	6.2	0.64							<0.05	0.1	<0.05	
04	WALL CREEK WARM SPRINGS	6.6	0.57							<0.05		<0.05	
05	MCCREDIE SPRINGS	18.	1.4	0.11	0.1					0.010m	0.02	0.10	
05	MCCREDIE SPRINGS	17.8	1.98								0.1	0.05	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements															
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potas- sium (K)	Cal- cium (Ca)	Mag- nesium (Mg)	Alka- linity (HCO3)	Sulfate (SO4)	Chlor- ide (Cl)	Fluor- ide (F)
LANE COUNTY															
06	KITSON SPRINGS	43-41.35 122-22.50 22S/004E -06	58/03	10500	44.4	7.4	47.	1450.	28.	726.	5.7	27	197.	3420.	2.8
06	KITSON SPRINGS	43-41.35 122-22.50 22S/004E -06 NE	78/05	10100	43.	7.31	45.	1500.	26.	710.	1.6	24	210.	3450.	2.4
08	BIGELOW HOT SPRINGS	44-14.35 122-03.50 15S/006E -26 NW	76/03	3800	61.0	7.8	68.9	540.	16.6	188.	1.		102.	1148.	1.37
MALHEUR COUNTY															
03	NEAL HOT SPRINGS	44-01.45 117-27.60 18S/043E -09 NW	72/00	1010	87.0	7.32	180.	190.	16.	8.8	0.2	200	120.	120.	9.4
04	BEULAH HOT SPRINGS	43-56.65 118-08.15 19S/037E -02 SE	72/00	1090	60.0	7.56	170.	200.	6.0	24.	0.2	163	290.	55.	4.7
05	VALE HOT SPRINGS	43-58.96 117-13.98 18S/045E -20 SE	74/00	1530	73.0	7.47	130.	310.	16.	19.	0.8	143	103.	360.	6.1
05	VALE HOT SPRINGS	43-58.96 117-14.98 18S/045E -20 SE	74/08		90.								112.	350.	
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	43-53.48 117-30.00 19S/043E -30 NW	73/00	740	70.0	8.71	115.	160.	3.2	3.2	<0.05	129	110.	74.	6.8
08	MITCHELL BUTTE HOT SPRINGS	43-45.78 117-09.34 21S/045E -12 NE	72/00	559	62.0	8.69	94.	110.	1.6	4.6	<0.1	78	130.	28.	10.4
18	UNNAMED HOT SPRING AT THREE FORKS	42-32.0 117-10.9 35S/045E -03	35/07		35.0		44.	62.		12.	1.6	119	31.	19.	4.9
18	UNNAMED HOT SPRING AT THREE FORKS	42-32.0 117-10.9 35S/045E -03	73/00	338	34.0	8.11	40.	61.	1.2	10.5	0.7	110	34.	18.	4.2
19	UNNAMED HOT SPRING NEAR MCDERMITT	42-04.7 117-45.6 40S/042E -25	57/05	604	53.5	9.2	90.	135.	1.8	1.2		263	46.	15.	7.0
19	UNNAMED HOT SPRING NEAR MCDERMITT	42-04.7 117-45.6 40S/042E -25	72/00	598	52.0	8.79	72.	130.	1.0	0.6	<0.1	263	52.	14.	6.6
23	LUCE HOT SPRINGS	43-28.15 118-12.08 24S/037E -20	72/00	1330	63.0	7.43	110.	240.	9.7	34.	0.5	162	290.	140.	4.8
24	JONESBORO WARM SPRING	43-47.5 117-57.5 20S/039E -29 SE			44.5	9.6	70.	72.	0.7	1.0	<0.1	148	38.	11.	0.8
25	JUNTURA WARM SPRING #1	43-45.5 118-04.0 21S/038E -09 SW			25.0	9.4	55.	24.	8.2	48.	21.	204	15.	120.	1.0
26	JUNTURA WARM SPRING #2	43-45.5 118-05.5 21S/038E -17 NW			35.0	9.7	79.	78.	0.8	1.0	<0.1	133	43.	140.	1.3
27	ARTESIAN WELL	43-41.8 117-05.7 21S/046E -33 SE	77/03	670	46.0	9.5	43.7	124.	0.8	1.8	0.1	94	164.	12.2	2.7
28	ALKALI FLAT GRADIENT WELL	44-06.60 117-13.60 17S/045E -08 NE	75/05	2400	24.0	8.3	32.0	482.	6.7	16.4	0.5	140	135.2	598.	2.2
29	NORTH HARPER BLM WELL	43-55.76 117-12.72 19S/045E -09 SE	76/06	714	36.0	8.0	39.7	134.	2.2	3.0	0.5	192	121.	4.3	1.51
30	UNNAMED WARM SPRING NEAR BULLY CREEK	44-01.95 117-26.95 18S/043E -04 SE	77/06	115	37.0	7.8	99.	1.	0.4	36.6	14.7	45	1.0	0.5	0.7
MARION COUNTY															
01	BREITENBUSH HOT SPRINGS	44-46.86 121-58.54 09S/007E -20 NE	72/00	4030	92.0	7.31	83.	720.	31.	100.	1.3	144	143.	1300.	3.4

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/L; (ND) not detected; (m) monomeric aluminum]

Map Code	Name	Minor and Trace Elements											
		Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
LANE COUNTY													
06 KITSON SPRINGS		25.	1.8				6.6	0.9	2.7	0.27	0.01	ND	
06 KITSON SPRINGS		22.	2.0	0.10	0.1					0.002m	<0.04	0.15	<0.0001
08 BIGELOW HOT SPRINGS		6.5	1.1							<0.05	0.1	<0.005	
MALHEUR COUNTY													
03 NEAL HOT SPRINGS		4.1	0.3	0.09	0.1	0.16	0.5	0.06		0.008m	<0.02	0.06	0.0001
04 BEULAH HOT SPRINGS		4.7	0.24	<0.02	<0.1	0.17	0.1	0.03		0.006m	<0.02	0.03	0.0001
05 VALE HOT SPRINGS		9.4	0.28	0.09	<0.1					0.017m	<0.02	0.04	
05 VALE HOT SPRINGS													
06 UNNAMED HOT SPRINGS NEAR LITTLE VALLEY		4.7	0.11	0.02	<0.1	<0.05					<0.02	<0.02	0.0007
08 MITCHELL BUTTE HOT SPRINGS		0.49	0.03	<0.02	<0.1	<0.05	0.2	0.01	2.9	0.015m	<0.02	<0.02	0.0001
18 UNNAMED HOT SPRING AT THREE FORKS		0.11	0.04	<0.02	<0.1	0.06					0.02		
18 UNNAMED HOT SPRING AT THREE FORKS		0.70	ND						ND		<0.02	<0.02	
19 UNNAMED HOT SPRING NEAR MCDERMITT		1.1	0.06	<0.02	<0.1	<0.05	0.4	0.008		0.013m	<0.02	<0.02	0.0001
19 UNNAMED HOT SPRING NEAR MCDERMITT		6.6	0.27	0.04	<0.1	0.42	0.5	0.03			<0.02	0.04	0.0001
23 LUCE HOT SPRINGS													
24 JONESBORO WARM SPRING		<0.1	<0.1										
25 JUNTURA WARM SPRING #1		<1.0	<0.1										
26 JUNTURA WARM SPRING #2		<1.0	<0.1										
27 ARTESIAN WELL		0.31	0.04						0.02	0.1	<0.1	<0.05	
28 ALKALI FLAT		14.	0.4						0.03	0.01	0.1	0.05	
29 NORTH HARPER BLM WELL		0.26	0.21						0.14	<0.05	<0.05	<0.05	
30 UNNAMED WARM SPRING NEAR BULLY CREEK		0.15	0.04						0.06	0.28	0.4	0.05	
MARION COUNTY													
01 BREITENBUSH HOT SPRINGS		4.1	1.8	0.18	0.1	0.73	5.	0.1			0.02	0.22	0.0002

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio 1978;
Concentrations in mg/l; (ND) not detected]

Major Elements																
Map Code	Name	Location	Date Yr/Mo	Sp Cond (umho)	Temp (C)	pH	Silica (SiO2)	Sodium (Na)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Alkalinity (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	
MARION COUNTY																
01 BREITENBUSH HOT SPRINGS - WELL		44-46.86 121-58.54 09S/007E -20 NE	78/02		110.0	8.5	182.	690.	34.	90.	1.3	88	96.	1170.	4.0	
MULTNOMAH COUNTY																
01 CORBETT WARM SPRING		45-32.5 122-17.5 01N/004E -27 SE		570	18.0	8.2	44.2	85.	8.9	21.7	0.8	127	5.9	77.4	2.4	
02 YMCA CAMP COLLINS		45-30.2 122-18.3 01S/034E -10 NW	56/09	517	23.3	8.6	60.	10.	9.6	5.2	0.2	124	1.2	92.	3.2	
UMATILLA COUNTY																
01 BINGHAM SPRINGS		45-44.47 118-13.96 03N/037E -18 NE	54/04	765	34.4	8.6	68.	133.	7.6	14.	3.5	82	3.2	192.	4.0	
03 LEHMAN SPRINGS		45-09.06 118-39.55 05S/033E -12 NE	72/00	252	61.0	9.18	44.	53.	0.7	0.9	0.1	127	23.	5.4	2.1	
UNION COUNTY																
01 COVE WARM SPRING		45-17.67 117-48.38 03S/040E -22 NW	57/06	150	29.4	9.8	29.	30.	0.5	1.6		70	9.8	5.0	0.3	
01 WELL		45-19.89 118-05.43 03S/038E -05 SW	55/01		27.	7.9	84.	27.	5.	5.	0.3		3.3	3.2	0.5	
01 WELL		45-19.89 118-05.43 03S/038E -05 SW	55/01		25.	7.9	72.	30.	5.	4.8	1.3	63	4.8	2.1	0.5	
01 WELL		45-20.07 118-05.83 03S/038E -06 NE	57/05	146	27.		71.	19.	5.	10.	0.2	84	4.5	1.	0.5	
02 HOT LAKE		45-14.63 117-57.51 04S/039E -05 SE	72/00	688	80.0	9.21	48.	130.	2.7	4.9	<0.1	99	56.	140.	1.7	
05 WAGNER WELL		45-27.43 117-59.84 01S/038E -24 SE	50/08	148	29.	8.0		28.	4.0	3.6	0.8	72	8.3	3.1	2.3	
07 MEDICAL HOT SPRINGS		45-01.08 117-37.48 06S/041E -25 NE			60.0		97.	191.	3.4	62.	1.2	22	432.	77.		
07 MEDICAL HOT SPRINGS		45-01.08 117-37.48 06S/041E -25 NE	73/00	1173	60.0	8.23	80.	190.	7.0	72.	0.2	28	400.	77.	1.2	
WALLOWA COUNTY																
01 COOK CREEK WARM SPRING		45-53.49 116-52.41 05N/048E -30 NW	74/11	610	36.0	7.95	46.1	61.	2.5	36.	1.1	44	163.8	20.	0.39	
WASCO COUNTY																
01 KAHNEETAH HOT SPRINGS		44-51.72 121-12.05 08S/013E -20 NE	73/00	1370	52.0	8.32	104.	325.	3.4	3.2	<0.05	511	34.	155.	21.	
02 MILTON MARTIN WELL		45-31.70 121-12.95 01N/013E -32 NE	58/07	279	22.2	8.5	84.	41.	7.2	15.	2.9	167	2.4	6.0	0.9	
03 J. SANDOZ WELL		45-33.8 121-16.6 01N/012E -38	58/07	378	27.8	7.9	95.	62.	11.	16.	4.6		1.5	7.5	1.6	

Table 1: CHEMICAL COMPOSITION OF THERMAL SPRING AND WELL WATERS
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Concentrations in mg/l; (ND) not detected; (m) monomeric aluminum]

Map Code	Name	Minor and Trace Elements											
		Boron (B)	Lithium (Li)	Rubidium (Rb)	Cesium (Cs)	Strontium (Sr)	Bromide (Br)	Iodide (I)	Nitrate (NO3)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Mercury (Hg)
MARION COUNTY													
01	BREITENBUSH HOT SPRINGS - WELL	5.43	1.9										
MULTNOMAH COUNTY													
01	CORBETT WARM SPRING	1.2	0.03						0.01	0.16	0.23	0.10	
02	YMCA CAMP COLLINS	0.38							0.5		0.06		
UMATILLA COUNTY													
01	BINGHAM SPRINGS	10.							0.2		0.23		
03	LEHMAN SPRINGS	0.12	0.03	<0.02	<0.1	<0.05	0.006	0.001			<0.02	<0.02	0.0003
UNION COUNTY													
01	COVE WARM SPRING	0.08							ND				
01	WELL												
01	WELL												
01	WELL												
02	HOT LAKE	2.9	0.03	<0.02	<0.1	<0.05	0.4	0.08			<0.02	<0.02	0.0032
05	WAGNER WELL	0.1							0.2				
07	MEDICAL HOT SPRINGS												
07	MEDICAL HOT SPRINGS	2.2	0.05	0.02	<0.1	0.80	0.2				<0.02	<0.02	0.0004
WALLOWA COUNTY: I													
01	COOK CREEK WARM SPRING		<0.01						0.13	0.16	0.15	<0.05	
WASCO COUNTY													
01	KAHNEETAH HOT SPRINGS	2.6	0.52	0.02	<0.1	<0.05					<0.02	<0.02	0.0003
02	MILTON MARTIN WELL								ND	1.0	0.03	ND	
03	J. SANDOZ WELL									ND	0.04	ND	

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
BAKER COUNTY				
01 RADIUM HOT SPRINGS		55/05	HAINES 1:24000	SCOTT AND BARKER, 1962
01 RADIUM HOT SPRINGS		72/00	HAINES 1:24000, BAKER 1:250000	MARINER AND OTHERS, 1974
02 SAM-O SPRING		77/02	BAKER 1:24000, BAKER 1:250000	MARINER AND OTHERS, 1975
05 KROPP HOT SPRING			NORTH POWDER 1:24000, GRANGEVILLE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
06 FISHER HOT SPRING		72/06	ROCK CREEK 1:24000, CANYON CITY 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
CLACKAMAS COUNTY				
01 ACID-SULFATE SPRING ON MT. HOOD		76/06	MT. HOOD SOUTH 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01 MT. HOOD FUMARoles		35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01 MT. HOOD FUMARoles		35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01 MT. HOOD FUMARoles		35/00	MT. HOOD SOUTH 1:24000	PHILLIPS, 1936
01 MT. HOOD FUMARoles		51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01 MT. HOOD FUMARoles		51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01 MT. HOOD FUMARoles		51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01 MT. HOOD FUMARoles		51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
01 MT. HOOD FUMARoles		51/00	MT. HOOD SOUTH 1:24000	AYERS AND CRESWELL, 1951
02 SWIM WARM SPRINGS		76/12	MT. HOOD SOUTH 1:24000, THE DALLES 1:250000	AYERS AND CRESWELL, 1951
03 AUSTIN HOT SPRINGS (CAREY)		72/00	FISH CREEK MTN. 1:62500, VANCOUVER 1:250000	OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY, UNPUBLISHED DATA
04 BAGBY HOT SPRINGS		70/03	BATTLE AX 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974
04 BAGBY HOT SPRINGS		77/09	BATTLE AX 1:62500	MARINER AND OTHERS, 1975
05 GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT		76/08	HIGH ROCK 1:62500, THE DALLES 1:250000	NEHRING AND OTHERS, 1979
DESCHUTES COUNTY				
01 EAST LAKE HOT SPRINGS		73/00	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
01 EAST LAKE HOT SPRINGS		75/08	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01 EAST LAKE HOT SPRINGS		77/07	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02 PAULINA HOT SPRINGS			NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02 PAULINA HOT SPRINGS		77/07	NEWBERRY CRATER 1:125000, CRESCENT 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
02 WARM WELL AT LITTLE CRATER CAMPGROUND		75/08	NEWBERRY CRATER 1:125000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
DOUGLAS COUNTY				
01 UMPQUA HOT SPRINGS		77/09	TOKETE FALLS 1:62500	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01 UMPQUA HOT SPRINGS		78/06	TOKETE FALLS 1:62500	MARINER AND OTHERS, 1978
				OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
GRANT COUNTY				
01	BITTER HOT SPRINGS	73/00	BITTER 1:62500, CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
04	BLUE MOUNTAIN HOT SPRINGS	72/00	PRAIRIE CITY 1:62500, CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
05	JOAQUIN MILLER RESORT	78/07	CANYON MTN. 1:24000, JOHN DAY 1:62500	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
07	WEBER HOT SPRING	72/00	CANYON CITY 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
HARNEY COUNTY				
01	UNNAMED SPRING	31/09	BUCHANAN 1:24000	PIPER AND OTHERS, 1939
02	O. J. THOMAS	68/09	HARNEY 1:62500	LEONARD, 1970
04	MILLPOND SPRING	31/08	BURNS 1:24000	PIPER AND OTHERS, 1939
05	HARNEY VALLEY DEV CO. OIL TEST WELL	68/09	HARNEY 1:62500	LEONARD, 1970
08	ISLAND RANCH WELL	69/08	LAWEN 1:62500	LEONARD, 1970
09	CRANE HOT SPRINGS	31/08	CRANE 1:62500, BURNS 1:250000	PIPER AND OTHERS, 1939
09	CRANE HOT SPRINGS	68/09	CRANE 1:62500	LEONARD, 1970
09	CRANE HOT SPRINGS	72/00	CRANE 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
10	WARM SPRING NEAR VENATOR	77/06	BURNS 1:250000	GONTHIER AND OTHERS, 1977
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	31/08	BURNS 1:250000	PIPER AND OTHERS, 1939
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	72/00	CRANE 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
22	MICKEY SPRINGS	70/07	ADEL 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
22	MICKEY SPRINGS	72/00	ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
22	MICKEY SPRINGS	76/09	ADEL 1:250000	NEHRING AND OTHERS, 1979
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
22	MICKEY SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	55/11	ADEL 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	72/03	ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
23	ALVORD HOT SPRINGS	76/09	ADEL 1:250000	NEHRING AND OTHERS, 1979
23	ALVORD HOT SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23	ALVORD HOT SPRINGS	76/09	ADEL 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
24	HOT BORAX LAKE	53/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
24	HOT BORAX LAKE	61/06	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
HARNEY COUNTY				
24	HOT BORAX LAKE	72/00	BORAX LAKE 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979 OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979 LEONARD, 1970
27	UNNAMED HOT SPRING NEAR TROUT CREEK	70/08	ADEL 1:250000	
27	UNNAMED HOT SPRING NEAR TROUT CREEK	72/00	ADEL 1:250000	
39	GOODMAN SPRING (HOTCHKISS)	68/09	BURNS 1:24000	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	53/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	53/09	BORAX LAKE 1:24000	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	57/05	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73/06	BORAX LAKE 1:24000, ADEL 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979 U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	76/09	BORAX LAKE 1:24000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
44	HOTCHKISS WELL	31/08	BURNS 1:24000	PIPER AND OTHERS, 1939
44	HOTCHKISS WELL	68/09	BURNS 1:24000	LEONARD, 1970
45	HINES LUMBER CO. WELL	68/07	BURNS 1:24000, BURNS 1:62500	LEONARD, 1970
46	CITY OF MINES WELL	68/07	BURNS 1:24000, BURNS 1:62500	LEONARD, 1970
JACKSON COUNTY				
01	JACKSON HOT SPRING	52/04	ASHLAND 1:62500	ROBISON, 1972
KLAMATH COUNTY				
	ALFRED JACOBSEN	74/05	MERRILL 1:62500	SAMMEL, 1976
	ANNIE SPRING		CRATER LAKE NATIONAL PARK AND VICINITY 1:62500	SAMMEL, 1976
	BILL WILL	74/06	MERRILL 1:62500	SAMMEL, 1976
	CLAUDE SHUCK	74/05	MERRILL 1:62500	SAMMEL, 1976
	CLYDE DEHILINGER	74/06	MERRILL 1:62500	SAMMEL, 1976
	FALCON HEIGHTS SCHOOL	74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
	GEORGE CARTER	74/06	MERRILL 1:62500	SAMMEL, 1976
	GEORGE STACY CO.	74/06	MERRILL 1:62500	SAMMEL, 1976
	JACK O'CONNER	74/05	MERRILL 1:62500	SAMMEL, 1976
	LEN DOBRY	74/05	MERRILL 1:62500	SAMMEL, 1976

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
KLAMATH COUNTY				
LESTER BROOKSHIRE		74/05	MERRILL 1:62500	SAMMEL, 1976
MELVIN MCCOLLUM		74/05	MERRILL 1:62500	SAMMEL, 1976
MONTE DEHILLINGER		74/06	MERRILL 1:62500	SAMMEL, 1976
O'CONNER LIVESTOCK CO.		74/06	MERRILL 1:62500	SAMMEL, 1976
OREGON WATER CORP.(4)		70/08	MERRILL 1:62500	SAMMEL, 1976
POPE'S MEAT CO.		74/06	MERRILL 1:62500	SAMMEL, 1976
RAY BIKLER		74/05	MERRILL 1:62500	SAMMEL, 1976
ROBERT LANGLEY		74/05	MERRILL 1:62500	SAMMEL, 1976
S. AND C. KILGORE			GERBER RESERVOIR 1:62500	SAMMEL, 1976
TOWN OF MERRILL		55/02	MERRILL 1:62500	NEWCOMB AND HART, 1958
U.S. AIR FORCE(1)		72/10	KLAMATH FALLS 1:62500	SAMMEL, 1976
U.S. AIR FORCE(2)		72/10	KLAMATH FALLS 1:62500	SAMMEL, 1976
WEYERHAUSER WELL NO. 4		72/08	KLAMATH FALLS 1:62500	SAMMEL, 1976
01 EAGLE POINT SPRING		72/08	MODOC POINT 1:62500	SAMMEL, 1976
02 J. E. FRIESEN		55/02	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02 LOIS MERRUYS		54/12	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02 MEDO-BELL DAIRY		55/01	KLAMATH FALLS 1:62500	NEWCOMB AND HART, 1958
02 MEDO-BELL DAIRY		75/07	KLAMATH FALLS 1:62500	SAMMEL, 1976
02 MILLS SCHOOL			KLAMATH FALLS 1:62500	NEHRING AND OTHERS, 1979
02 MOYINA WATER CO.		66/08	KLAMATH FALLS 1:62500	SAMMEL, 1976
02 O.I.T. NO. 5		67/00	KLAMATH FALLS 1:62500	NEHRING AND OTHERS, 1979
02 O.I.T. NO. 6		72/08	KLAMATH FALLS 1:62500	PETERSON AND GROH, 1967
02 O.I.T. NO. 6		75/03	KLAMATH FALLS 1:62500	SAMMEL, 1976
02 OREGON WATER CORP.(1)		30/03	KLAMATH FALLS 1:62500	NEHRING AND OTHERS, 1979
02 OREGON WATER CORP.(2)		71/09	KLAMATH FALLS 1:62500	SAMMEL, 1976
02 OREGON WATER CORP.(3)		71/09	KLAMATH FALLS 1:62500	SAMMEL, 1976
03 HOWARD HOLLIDAY		74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
04 MAZAMA SCHOOL			MERRILL 1:62500	SAMMEL, 1976
06 ABE BOEHM		74/05	KLAMATH FALLS 1:62500	SAMMEL, 1976
06 ABE BOEHM		75/08	KLAMATH FALLS 1:62500	NEHRING AND OTHERS, 1979
06 DAN O'CONNER		74/05	MERRILL 1:62500	SAMMEL, 1976
06 JACK LISKEY		74/05	MERRILL 1:62500	SAMMEL, 1976
06 JACK LISKEY		74/05	MERRILL 1:62500	NEHRING AND OTHERS, 1979
06 JACK LISKEY		75/08	MERRILL 1:62500	SAMMEL, 1976
06 O. H. OSBORN		74/05	MERRILL 1:62500	NEHRING AND OTHERS, 1979
07 OLENE GAP HOT SPRINGS		67/00	MERRILL 1:62500	PETERSON AND GROH, 1967
U7 OLENE GAP HOT SPRINGS		72/00	MERRILL 1:62500, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974
07 OLENE GAP HOT SPRINGS		75/07	MERRILL 1:62500	MARINER AND OTHERS, 1975
08 ROENICKE HOT SPRING				SAMMEL, 1976
16 MELVIN FEIGI		72/10	MERRILL 1:62500	NEHRING AND OTHERS, 1979
22 RAY SWITH WELL		70/10	MERRILL 1:62500	SAMMEL, 1976
23 KLAMATH ICE CO.		36/04	KLAMATH FALLS 1:62500	PETERSON AND GROH, 1967
24 J. K. O'NEIL		72/03	MERRILL 1:62500	MARINER AND OTHERS, 1974

OREGON DEPARTMENT OF GEOLOGY AND
MINERAL INDUSTRIES, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES

[Map code refers to Bowen, Peterson, and Riccio, 1978;

Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
KLAMATH COUNTY				
24 J. K. O'NEIL		74/05	MERRILL 1:62500	SAMMEL, 1976
LAKE COUNTY				
05 ANA RIVER SPRING		48/12	KLAMATH FALLS 1:250000	TRAUGER, 1950
14 SUMMER LAKE HOT SPRING (WOODWARD)		48/10	SLIDE MTN. 1:24000	TRAUGER, 1950
14 SUMMER LAKE HOT SPRING (WOODWARD)		72/00	SLIDE MTN. 1:24000, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979 U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23 HUNTERS HOT SPRINGS (LAKEVIEW)		56/10	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
23 HUNTERS HOT SPRINGS (LAKEVIEW)		57/10	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
23 HUNTERS HOT SPRINGS (LAKEVIEW)		72/00	LAKEVIEW NE 1:24000, KLAMATH FALLS 1:250000	TRAUGER, 1950
24 LEITHEAD HOT SPRINGS (JOYLAND PLUNGE, LEO)		48/06	LAKEVIEW NE 1:24000	TRAUGER, 1950
25 BARRY RANCH HOT SPRINGS (GUS ALLEN)		48/05	LAKEVIEW NE 1:24000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
25 BARRY RANCH HOT SPRINGS (GJS ALLEN)		72/00	LAKEVIEW NE 1:24000	TRAUGER, 1950
28 ANTELOPE HOT SPRINGS		48/08	WARNER PEAK 1:24000	MARINER AND OTHERS, 1974
32 FISHER HOT SPRINGS		72/00	CRUMP LAKE 1:24000, ADEL 1:250000	MARINER AND OTHERS, 1975 TRAUGER, 1950
33 CRUMP SPRING		48/09	ADEL 1:24000	MARINER AND OTHERS, 1974
33 CRUMP SPRING		72/00	ADEL 1:24000	MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979
33 CRUMP WELL (1)		59/07	ADEL 1:24000	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
33 CRUMP WELL (2)		60/09	ADEL 1:24000	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
LANE COUNTY				
01 BELKNAP HOT SPRINGS		03/00	MCKENZIE BRIDGE 1:62500	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
01 BELKNAP HOT SPRINGS		72/00	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 NEHRING AND OTHERS, 1979 OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
02 FOLEY SPRINGS		76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
03 COUGAR RESERVOIR HOT SPRINGS (RIDER)		73/00	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
03 COUGAR RESERVOIR HOT SPRINGS (RIDER)		76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
04 WALL CREEK WARM SPRINGS		76/03	SARDINE BUTTE 1:62500, ROSEBERG 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
05 MCCREDIE SPRINGS		74/00	OAKRIDGE 1:62500, ROSEBERG 1:250000	MARINER AND OTHERS, 1975
05 MCCREDIE SPRINGS		76/03	OAKRIDGE 1:62500, ROSEBERG 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
LANE COUNTY				
06 KITSON SPRINGS		58/03	OAKRIDGE 1:62500	MADISON, 1966
06 KITSON SPRINGS		78/05	OAKRIDGE 1:62500	J.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
08 BIGELOW HOT SPRINGS		76/03	MCKENZIE BRIDGE 1:62500, SALEM 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
MALHEUR COUNTY				
03 NEAL HOT SPRINGS		72/00	JAMIESON 1:62500, BAKER 1:250000	MARINER AND OTHERS, 1974
04 BEULAH HOT SPRINGS		72/00	BEULAH 1:62500, BURNS 1:250000	MARINER AND OTHERS, 1975
05 VALE HOT SPRINGS		74/00	VALE EAST 1:24000, BOISE 1:250000	NEHRING AND OTHERS, 1979
05 VALE HOT SPRINGS		74/08	VALE EAST 1:24000	MARINER AND OTHERS, 1974
06 UNNAMED HOT SPRINGS NEAR LITTLE VALLEY		73/00	HARPER 1:62500, BOISE 1:250000	MARINER AND OTHERS, 1975
08 MITCHELL BUTTE HOT SPRINGS		72/00	MITCHELL BUTTE 1:24000, BOISE 1:250000	NEHRING AND OTHERS, 1979
18 UNNAMED HOT SPRING AT THREE FORKS		35/07	JORDAN VALLEY 1:250000	MARINER AND OTHERS, 1974
18 UNNAMED HOT SPRING AT THREE FORKS		73/00	JORDAN VALLEY 1:250000	MARINER AND OTHERS, 1975
19 UNNAMED HOT SPRING NEAR MCDERMITT		57/05	JORDAN VALLEY 1:250000	U.S. GEOLOGICAL SURVEY, UNPUBLISHED DATA
19 UNNAMED HOT SPRING NEAR MCDERMITT		72/00	JORDAN VALLEY 1:250000	MARINER AND OTHERS, 1974
23 LUCE HOT SPRINGS		72/00	MCEWEN BUTTE 1:24000	MARINER AND OTHERS, 1975
24 JONESBORO WARM SPRING			WESTFALL BUTTE 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
25 JUNTURA WARM SPRING #1			BEULAH 1:62500, BURNS 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
26 JUNTURA WARM SPRING #2			BEULAH 1:62500, BURNS 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
27 ARTESIAN WELL		77/03	ADRIAN 1:24000, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
28 ALKALI FLAT GRADIENT WELL		75/05	MOORES HOLLOW 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
29 NORTH HARPER BLW WELL		76/06	JAMIESON 1:62500, BAKER 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
30 UNNAMED WARM SPRING NEAR BULLY CREEK		77/06	JAMIESON 1:62500, BOISE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
MARION COUNTY				
01 BREITENBUSH HOT SPRINGS		72/00	BREITENBUSH HOT SPRINGS 1:62500	MARINER AND OTHERS, 1974
01 BREITENBUSH HOT SPRINGS - WELL		78/02	BREITENBUSH HOT SPRINGS 1:62500	MARINER AND OTHERS, 1975
				NEHRING AND OTHERS, 1979
				OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

Table 2: REFERENCES FOR ANALYSES
[Map code refers to Bowen, Peterson, and Riccio, 1978;
Map reference refers to U. S. Geological Survey topographic maps]

Map Code	Name	Sample Date	Map Reference	Analysis Reference
MULTNOMAH COUNTY				
01 CORBETT WARM SPRING			WASHOUGAL 1:24000, VANCOUVER 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
02 YMCA CAMP COLLINS		56/09	WASHOUGAL 1:24000, VANCOUVER 1:250000	NEUMOMB, 1972
UMATILLA COUNTY				
01 BINGHAM SPRINGS		54/04	BINGHAM SPRINGS 1:24000, PENDLETON 1:250000	HOGENSON, 1964
03 LEHMAN SPRINGS		72/00	LEHMAN SPRINGS 1:24000, PENDLETON 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
UNION COUNTY				
01 COVE WARM SPRING		57/06	COVE 1:24000, GRANGEVILLE 1:250000	HAMPTON AND BROWN, 1964
01 WELL		55/01	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
01 WELL		55/01	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
01 WELL		57/05	LA GRANDE SE 1:24000	HAMPTON AND BROWN, 1964
02 HOT LAKE		72/00	CRAIG MTN. 1:24000, GRANGEVILLE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975 VEHRING AND OTHERS, 1979
05 WAGNER WELL		50/08	IMBLER 1:24000	HAMPTON AND BROWN, 1964
07 MEDICAL HOT SPRINGS			FLAGSTAFF BUTTE 1:24000, GRANGEVILLE 1:250000	LINDGREN, 1931
07 MEDICAL HOT SPRINGS		73/00	FLAGSTAFF BUTTE 1:24000, GRANGEVILLE 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
WALLOWA COUNTY				
01 COOK CREEK WARM SPRING		74/11	WAPSHILLA CREEK 1:24000, GRANGEVILLE 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA
WASCO COUNTY				
01 KAHNEETAH HOT SPRINGS		73/00	EAGLE BUTTE 1:24000, BEND 1:250000	MARINER AND OTHERS, 1974 MARINER AND OTHERS, 1975
02 MILTON MARTIN WELL		58/07	THE DALLES 1:62500, THE DALLES 1:250000	NEUMOMB, 1972
03 J. SANDOZ WELL		58/07	WHITE SALMON 1:62500, THE DALLES 1:250000	OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES, UNPUBLISHED DATA

geothermometry. The only other waters which "stand out" as chemically different are from the base of Mt. Hood and Newberry Caldera. These waters have unusually large concentrations of magnesium for thermal fluids, probably due to water-rock reaction at low temperatures. The rest of the samples are from southeastern and southcentral Oregon where volcanic flows are interbedded with tuffaceous sediments. The waters from these springs contain more nearly equal proportions of sulfate, chloride, and bicarbonate.

Table 3 contains gas and isotopic data for the relatively small number of springs for which data exist. The data from Mt. Hood and East Lake are misleading. The Mt. Hood analyses are from fumaroles which discharged principally water vapor. Air contamination appears to be a problem in all of these samples. However, it is probable that carbon dioxide is the principal gas rising from depth. The water vapor is probably from the vaporization of liquid water in fractures and pore spaces. The East Lake-Paulina Lake gas samples are also contaminated by air and altered by gas-water reaction. The thermal "springs" at East and Paulina lakes issue in or at the shoreline of the respective lakes. The proportions of the various gases in these samples appear to be controlled by the discharge rates. Vents with the largest gas discharges have the highest proportions of carbon dioxide. The slower the discharge rate, the cooler the water in contact with the gas, and the more CO_2 will dissolve. The methane and carbon dioxide do not appear to have a common origin since the carbon dioxide appears to be of deep origin ($\delta^{13}\text{C} = -6$ permil) while the methane appears to be of biologic origin ($\delta^{13}\text{C}$ about -50 permil). It is probable that the methane originates from the anaerobic decay of plant material trapped in the lava and ash flows. Finally, some air contamination may be unavoidable in these samples since nitrogen and oxygen may be exsolving from the cold lake water as the hot CO_2 -charged gas from depth contacts it.

In terms of the deuterium and oxygen(18) isotopic compositions (table 3) of the thermal waters, four samples appear to have undergone considerable evaporation: East Lake, Hot Borax Lake, and samples from the Abe Boehm and Jack Liskey wells near Klamath Falls. These samples are all greatly enriched (>10 permil) relative to nearby fresh and thermal waters, and have appreciable oxygen shifts relative to meteoric water.

The O^{18} compositions of dissolved sulfate range from $+15$ to -10 permil. Marine sulfates are typically about $+15$ permil, while high-temperature hydrothermal systems are usually about -10 permil.

Table 3: GAS AND ISOTOPIC COMPOSITION OF THERMAL SPRING AND WELL DISCHARGES

[Map code refers to Bowen, Peterson, and Riccio, 1978;

Isotopic compositions in the standard notation and are relative to SMOW;

Gas concentrations in volume percent; (*) Ar + O₂]

Map Code	Name	Date	Temp (C)	Argon (Σ Ar)	Methane (Σ CH ₄)	Carbon Dioxide (Σ CO ₂)	Nitrogen (Σ N ₂)	Oxygen (Σ O ₂)	Del D of H ₂ O (o/oo)	Del O(18) of H ₂ O (o/oo)	Del O(18) of SO ₄ (o/oo)
BAKER COUNTY											
01	RADIUM HOT SPRINGS	72/00	58.						-138.3	-17.85	
CLACKAMAS COUNTY											
01	MT. HOOD FUMARoles	35/00	89.4		0.0011	1.13	0.116	0.011			
01	MT. HOOD FUMARoles	35/00	71.1			0.68	78.5	19.5			
01	MT. HOOD FUMARoles	35/00	89.4			1.27	0.057	0.001			
01	MT. HOOD FUMARoles	51/00			0.0005	1.49	0.035	0.004			
01	MT. HOOD FUMARoles	51/00	89.4		0.0010	2.23	0.041	0.004			
01	MT. HOOD FUMARoles	51/00			0.0014	2.12	0.044	0.003			
01	MT. HOOD FUMARoles	51/00	91.1		0.0011	1.81		0.006			
01	MT. HOOD FUMARoles	51/00	86.1			17.4	9.8	2.48			
01	MT. HOOD FUMARoles	51/00	89.4		0.0006	1.43	0.032	0.003			
02	SWIM WARM SPRINGS	76/12	26.0								
03	AUSTIN HOT SPRINGS (CAREY)	72/00	86.0						-94.5	-14.01	1.52
										-12.22	-2.41
DESCHUTES COUNTY											
01	EAST LAKE HOT SPRINGS	73/00	62.0		9.	56.	30.	6*		-9.42	
01	EAST LAKE HOT SPRINGS	75/08	49.		2.9	91.	5.1	0.9			
01	EAST LAKE HOT SPRINGS	77/07			1.95	95.55		2.72*			
02	PAULINA HOT SPRINGS				5.41	71.37					
02	PAULINA HOT SPRINGS	77/07		0.09	0.55	93.45	4.74	0.03			
DOUGLAS COUNTY											
01	UMPQUA HOT SPRINGS	77/09	46.5	<0.02	<0.005	99.38	0.49	0.04			
GRANT COUNTY											
01	RITTER HOT SPRINGS	73/00	41.0						-119.	-14.83	
04	BLUE MOUNTAIN HOT SPRINGS	72/00	58.0						-126.6	-16.13	
07	WEBERG HOT SPRING	72/00	46.0		2.	95.	1.	1*	-122.1	-15.14	
HARNEY COUNTY											
09	CRANE HOT SPRINGS	72/00	78.0						-133.5	-16.17	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	72/00	68.0		1.	9.	91.	1*	-128.5		
22	MICKEY SPRINGS	72/00	73.0		1.	23.	60.	18*	-124.3	-13.42	-7.91
23	ALVORD HOT SPRINGS	72/00	76.0						-123.6	-13.23	-6.05
24	HOT BORAX LAKE	72/00	36.0						-115.8	-11.57	-7.95
27	UNNAMED HOT SPRING NEAR TROUT CREEK	72/00	52.0						-127.4	-16.17	-9.22
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73/06	96.0						-125.4	-14.36	-8.58
KLAMATH COUNTY											
	ANNIE SPRING		25.0								
	FALCON HEIGHTS SCHOOL	74/05	37.0						-120.5	-14.40	
	MELVIN MCCOLLUM	74/05	25.0						-113.2	-15.69	
	S. AND C. KILGORE		20.0						-16.00	-14.71	
	WEYERHAUSER WELL NO. 4	72/08	22.						-109.1	-16.00	
01	EAGLE POINT SPRING	72/08	35.						-109.7	-15.22	
02	MEDO-BELL DAIRY	75/07	81.						-119.4	-14.95	-5.45
02	MILLS SCHOOL		89.0						-121.8	-14.83	-4.94
02	O.I.T. NO. 6	75/03	79.						-118.7	-14.99	-5.45

Table 3: GAS AND ISOTOPIIC COMPOSITION OF THERMAL SPRING AND WELL DISCHARGES
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Isotopic compositions in the standard notation and are relative to SMOW;
 Gas concentrations in volume percent; (*) Ar + O₂]

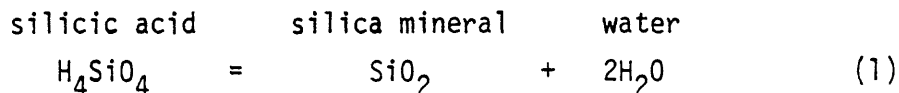
Map Code	Name	Date	Temp (C)	Argon (% Ar)	Methane (% CH ₄)	Carbon Dioxide (% CO ₂)	Nitrogen (% N ₂)	Oxygen (% O ₂)	Del 0 of H ₂ O (o/oo)	Del 0(18) of S04 (o/oo)
KLAMATH COUNTY										
06 ABE BOEHM		74/05	25.0						-73.2	-7.38
06 ABE BOEHM		75/08	25.						-6.78	15.42
06 JACK LISKEY		74/05	93.0						-116.6	-2.13
06 JACK LISKEY		74/05	22.0						-87.2	-8.83
06 JACK LISKEY		75/08	25.						-8.57	8.69
06 O. H. OSBORN		74/05	90.0						-117.0	-1.85
07 OLENE GAP HOT SPRINGS		72/00	74.0						-113.3	-4.82
07 OLENE GAP HOT SPRINGS		75/07	87.						-115.3	-13.73
16 MELVIN FEIGI		70/10	31.0						-16.80	-13.32
LAKE COUNTY										
14 SUMMER LAKE HOT SPRING (WOODWARD)		72/00	43.0						-115.0	-4.00
23 HUNTERS HOT SPRINGS (LAKEVIEW)		72/00	96.0						-119.0	-3.69
25 BARRY RANCH HOT SPRINGS (GUS ALLEN)		72/00	88.0		42.	2.	54.	2*	-119.4	-13.72
32 FISHER HOT SPRINGS		72/00	68.0						-117.0	-4.71
33 CRUMP SPRING		72/00	78.0		6.	14.	75.	5*	-115.5	-13.28
LANE COUNTY										
01 BELKNAP HOT SPRINGS		72/00	71.0						-95.8	0.35
03 COUGAR RESERVOIR HOT SPRINGS (RIDER)		73/00	44.0						-92.5	-11.97
05 MCCREDIE SPRINGS		74/00	73.		<1.	<1.	98.	1*	-94.0	
MALHEUR COUNTY										
03 NEAL HOT SPRINGS		72/00	87.0		6.		62.	12*	-138.7	-8.37
04 BEULAH HOT SPRINGS		72/00	60.0						-131.7	-6.56
05 VALE HOT SPRINGS		74/00	73.0						-135.0	-3.91
05 VALE HOT SPRINGS		74/08	90.						-15.00	-8.63
06 UNNAMED HOT SPRINGS NEAR LITTLE VALLEY		73/00	70.0						-139.7	
08 MITCHELL BUTTE HOT SPRINGS		72/00	62.0						-137.3	
18 UNNAMED HOT SPRING AT THREE FORKS		73/00	34.0						-127.4	
19 UNNAMED HOT SPRING NEAR MCDERMITT		72/00	52.0						-134.6	
23 LUCE HOT SPRINGS		72/00	63.0						-134.0	
MARION COUNTY										
01 BREITENBUSH HOT SPRINGS		72/00	92.0						-97.5	-2.67
01 BREITENBUSH HOT SPRINGS - WELL		78/02	110.0						-12.59	-3.28
UMATILLA COUNTY										
03 LEHMAN SPRINGS		72/00	61.0		<0.1	<0.1	94.	4*	-121.3	
UNION COUNTY										
02 HOT LAKE		72/00	80.0		9.	<1.	90.	2*	-127.7	4.63
07 MEDICAL HOT SPRINGS		73/00	60.0						-130.2	
WASCO COUNTY										
01 KAHNEETAH HOT SPRINGS		73/00	52.0						-118.9	

GEOOTHERMOMETRY

The chemical composition of the thermal waters can be used, under certain conditions, to provide estimates of the last temperature of equilibrium of the water and the country rock. The variables which are most often used include silica concentration, and relative proportions among sodium, potassium, calcium, and magnesium. Sufficient isotopic data on sulfate and water are available on some of the samples to calculate temperatures of equilibrium from the sulfate-water isotope geothermometer. The silica, Na-K-Ca, and sulfate-water geothermometers, which are used to estimate most of the temperatures, are valid only for hot-water systems and only when certain assumptions are met. These assumptions, discussed in detail by Fournier and others (1974), are listed below:

1. Temperature-dependent reactions at depth control the concentration of the constituents used in the geothermometer.
2. The reservoir contains an adequate supply of the reactants.
3. Water-rock equilibrium is established in the reservoir.
4. The constituents used in the geothermometer do not re-equilibrate with the confining rock as the water flows to the surface.
5. Mixing of thermal and nonthermal groundwater does not occur.

The concentration of silica in a thermal water depends principally on the temperature-dependent solubility of quartz, chalcedony, alpha-cristobalite, or amorphous silica (Fournier, 1973; Fournier and Rowe, 1966). The dissolved silica is generally present as H_4SiO_4 , which is the silica species in equilibrium with the respective silica mineral:



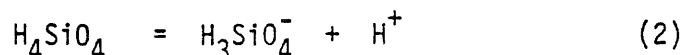
This is the reaction on which all of the silica geothermometers are based. We may make the following practical generalizations:

1. The solubility of quartz limits silica concentrations in all high-temperature reservoirs ($>180^\circ\text{C}$) and quartz may be the

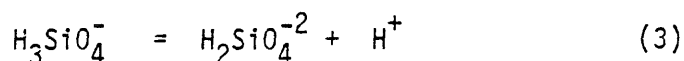
limiting mineral in granitic aquifers down to temperatures at least as low as 90°C (R. O. Fournier, oral communication).

2. Chalcedony limits silica concentrations in lower-temperature reservoirs and may be the limiting mineral in basaltic rock up to 180°C (Arnorsson, 1975).

The silica geothermometers give apparently good results in thermal systems which are associated with springs of neutral to slightly acid pH. However, several thermal systems listed in the tables discharge dilute alkaline waters with anomalously large silica concentrations. These dilute thermal waters contain little or no dissolved carbon dioxide and typically occur in granitic terrains. Since the silica geothermometers are based on equilibrium with H_4SiO_4 , the concentration of this dissolved species must be calculated to obtain an accurate estimate of the temperature in the thermal reservoir. At any temperature and pH, the total dissolved silica concentration is distributed among H_4SiO_4 , H_3SiO_4^- , and $\text{H}_2\text{SiO}_4^{2-}$:



and



Equation (3) is important only at very alkaline pH's (>10) and is not important for the thermal waters encountered in Oregon. Equation (2), however, is important in waters with pH's above 8. For example, at a temperature of 80°C and pH of 9, approximately 44 percent of the dissolved silica is in the dissociated form (H_3SiO_4^-); while, at a pH of 7, less than 1 percent of the dissolved silica is in the dissociated form. For example, if total dissolved silica is 100 mg/L, and chalcedony is the limiting silica mineral then temperature estimates should be reduced from 111°C (pH 7) to 78°C (pH 9). To correct for the dissociation of silica, we have used a correction which requires that the pH of the thermal spring is approximately the same as that in the thermal reservoir. This assumption requires that the equilibrium constants for the weak acids remain approximately constant despite temperature changes. The concentration of silicic acid (H_4SiO_4) is calculated at the spring temperature and pH. This concentration, recast as SiO_2 , is used in the appropriate geothermometer. This correction works best in systems which have aquifer-temperatures near the measured spring temperature. Corrected values for the waters

with high pH's are shown in parentheses in table 4. Changes in the dissociation constants of the weak acids as functions of temperature will result in temperature estimates which are slightly too low for systems in which the true aquifer temperature is appreciably above the spring temperature.

Mixing of thermal (high silica) and nonthermal (low silica) waters can sharply reduce the temperatures estimated from the silica geothermometers. However, it is possible to calculate the temperature of the thermal aquifer if sufficient chemical and isotopic data are available for both the thermal and cold waters, if chemical equilibrium has not taken place at or below the mixing temperature, and if there has been no conductive heat loss (Fournier and Truesdell, 1974). The problem with any unexplored system is in proving that the water issuing at the surface is mixed. The simplest proof would be a linear trend between measured spring temperatures and chloride concentration. Normal groundwater usually has low chloride concentrations, while thermal waters from high-temperature systems contain at least several hundred milligrams per liter chloride. A linear trend between the isotopic compositions of the water (deuterium and oxygen(18)) and dissolved chloride is also definitive proof of mixing. Thermal and shallow groundwaters do not usually originate from the same precipitation area and so they have different deuterium concentrations. Since deuterium concentrations do not usually change as a result of water-rock reactions, source waters are isotopically "tagged" and change composition only by mixing or evaporation (boiling). The oxygen isotopic compositions of thermal and fresh waters usually differ by several parts per mil. As water-rock reaction proceeds, the water becomes progressively enriched in the heavier oxygen atoms. Very few areas have a sufficient number of springs of differing chemical and isotopic composition to prove mixing by the rigorous criteria discussed above. Mixing models were not used in preparing table 4, since mixing has not been demonstrated at most sites.

The Na-K-Ca geothermometer (Fournier and Truesdell, 1973) is based on an empirical relationship between the proportions of sodium to potassium, square root of calcium to sodium, and measured reservoir temperatures. Temperatures estimated from the Na-K-Ca geothermometer can be sharply increased by loss of calcium after the thermal fluid leaves the reservoir. Sensitivity of the geothermometer to loss of calcium can be tested in a specific water by doubling the measured calcium concentration and recalculating the estimated reservoir temperature. A change of only a few degrees indicates that the loss of calcium does not appreciably alter the estimated reservoir temperature. High magnesium concentrations or large magnesium

Table 4: GEOTHERMOMETER CALCULATIONS(C)

[Map code refers to Bowen, Peterson, and Riccio, 1978;

Numbers in parentheses are calculated from silicic acid (H₄SiO₄) concentration calculated at the spring temperature;
Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO ₂ conductive	SiO ₂ adiabatic	SiO ₂ chalcedony	SiO ₂ opal	Sulfate- water
BAKER COUNTY											
01	RADIUM HOT SPRINGS	57.2	106	130	97		125(65)	122	97(33)	6	
01	RADIUM HOT SPRINGS	58.0	81	108	77		124(69)	121	96(37)	5	
02	SAH-O SPRING	27.0	152	165	120	52	115	115	88	-1	
05	KROPP HOT SPRING	43.0	74	110	100		109	109	79	-8	
06	FISHER HOT SPRING	37.0					90(44)	93	60(11)	-24	
CLACKAMAS COUNTY											
01	ACID-SULFATE SPRING ON MT. HOOD		114	90	-16		62	67	29	-48	
02	SWIM WARM SPRINGS	26.0	165	159	83	cold	120	118	91	2	109
03	AUSTIN HOT SPRINGS (CAREY)	86.0	91	118	87	90	126	123	98	7	181
04	BAGBY HOT SPRINGS	57.2	70	93	49		126(65)	123	98(33)	7	
04	BAGBY HOT SPRINGS	58.0	68	91	49		121(78)	119	93(47)	3	
05	GEOTHERMAL GRADIENT TEST NEAR AUSTIN HOT	35.6	140	137	61		87	90	56	-27	
DESCHUTES COUNTY											
01	EAST LAKE HOT SPRINGS	62.0	188	155	44		87	90	56	-27	
01	EAST LAKE HOT SPRINGS	49.0					180	168	158	56	
02	PAULINA HOT SPRINGS		190	178	98	cold	182	170	161	58	
02	WARM WELL AT LITTLE CRATER CAMPGROUND	35.5	189	169	75	cold	166	156	142	43	
DOUGLAS COUNTY											
01	UMPOUA HOT SPRINGS	46.5	96	135	141		131	128	104	12	
01	UMPOUA HOT SPRINGS	46.0	101	136	132		135	131	108	15	
GRANT COUNTY											
01	RITTER HOT SPRINGS	41.0	60	92	71		118(68)	117	90(31)	-16	
04	BLUE MOUNTAIN HOT SPRINGS	58.0	91	126	118		99	100	69		
05	JOAQUIN MILLER RESORT	40.0	89	121	104	61					
07	WEBERG HOT SPRING	46.0	140	169	162	92	126	124	99	7	
HARNEY COUNTY											
02	O. J. THOMAS	72.0	60	104	116	102	131(71)	127	103(39)	11	
05	HARNEY VALLEY DEV CO. OIL TEST WELL	46.0	61	105	115	96	120	118	91	1	
08	ISLAND RANCH WELL	41.0	60	120	196	115	105(76)	106	76(45)	-11	
09	CRANE HOT SPRINGS	80.0	86	120	109		125	122	97	6	
09	CRANE HOT SPRINGS	78.0	90	124	113		127	124	99	8	
10	WARM SPRING NEAR VENATOR	41.0	55	88	67		226(192)	205	213(173)	101	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	59.0	82	126	144	82	133	129	105	13	
15	UNNAMED HOT SPRING NEAR HARNEY LAKE	68.0	85	130	150	105	133	129	105	13	
??	MICKY SPRINGS	85.0	120	179	272	111	169	158	145	45	
					220	204	180	168	159	56	273

Table 4: GEOTHERMOMETER CALCULATIONS(C)

[Map code refers to Bowen, Peterson, and Riccio, 1978;

Numbers in parentheses are calculated from silicic acid (H4SiO4) concentration calculated at the spring temperature;
Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO2 conductive	SiO2 adiabatic	SiO2 chalcedony	SiO2 opal	Sulfate- water
HARNEY COUNTY											
22	MICKEY SPRINGS	86.0	138	198	312		185	172	164	61	
22	MICKEY SPRINGS	86.0	136	196	309	195	185	172	164	61	
22	MICKEY SPRINGS		138	205	349		180	168	159	56	
23	ALVORD HOT SPRINGS	82.2	145	193	252	182	155	147	130	33	
23	ALVORD HOT SPRINGS	76.0	153	198	254	164	148	141	122	26	231
23	ALVORD HOT SPRINGS	78.5	146	194	253	160	152	145	127	30	
23	ALVORD HOT SPRINGS	78.5	144	192	252	157	151	145	126	30	
24	HOT BORAX LAKE	29.4	127	161	163		174	164	152	51	
24	HOT BORAX LAKE	31.1	133	168	174	157	178	166	156	54	
24	HOT BORAX LAKE	36.0	143	176	181		176	165	155	53	336
27	UNNAMED HOT SPRING NEAR TROUT CREEK		181	191	152	174	124	122	96	6	
27	UNNAMED HOT SPRING NEAR TROUT CREEK	52.0	118	143	118	141	160	135	114	19	235
39	GOODMAN SPRING (HOTCHKISS)	22.0	169	156	69		98	99	68	-17	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	73.9	144	175	173		147	141	122	26	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	79.4	147	179	182		170	160	148	47	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	87.0	149	183	193		165	156	142	42	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	96.0	144	176	178		165	156	142	42	231
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	91.0	145	176	178		176	165	154	53	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	97.0	136	169	172		169	159	146	46	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	90.5	141	172	171		163	154	139	40	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	86.0	139	172	174		164	155	141	41	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	97.0	138	171	174		166	157	143	44	
43	UNNAMED HOT SPRING NEAR HOT BORAX LAKE	84.0	138	172	177		167	157	144	44	
44	HOTCHKISS WELL	27.0	160	146	56		103	103	73	-13	
44	HOTCHKISS WELL	27.0	171	155	64		98	99	68	-17	
45	HINES LUMBER CO. WELL	25.0	190	167	70		106	106	77	-10	
46	CITY OF HINES WELL	17.0	230	192	81	46	111	110	81	-7	
JACKSON COUNTY											
01	JACKSON HOT SPRING	35.0	64	95	72	42	114(89)	113	86(58)	-3	
KLAMATH COUNTY											
	ALFRED JACOBSEN	30.0	250	221	131	78	114	113	86	-3	
	HILL HILL	20.0	284	217	83	cold	74	78	42	-38	
	CLAUDE SHUCK	24.0	252	203	84	46	108	108	79	-9	
	CLYDE DEHILINGER	24.0	213	189	95	53	120	118	91	1	
	FALCON HEIGHTS SCHOOL	37.0	192	181	104	33	125	122	97	6	

Table 4: GEOTHERMOMETER CALCULATIONS(C)
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Numbers in parentheses are calculated from silicic acid (H₄SiO₄) concentration calculated at the spring temperature;
 Waters with magnesium-corrected ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO ₂ conductive	SiO ₂ adiabatic	SiO ₂ chalcedony	SiO ₂ opal	Sulfate-water
KLAMATH COUNTY											
	GEORGE CARTER	22.0	160	156	83	126	93	95	62	-22	
	GEORGE STACY CO.	25.0	231	183	61		85	88	54	-29	
	JACK O'CONNER	38.0	90	116	83		114	113	86	-3	
	LEN DOBRY	21.0	201	180	88	95	114	113	86	-3	
	LESTER BROOKSHIRE	25.0	213	173	57		86	89	55	-28	
	MELVIN MCCOLLUM	25.0	231	178	50		104	104	74	-12	
	MONTE DEHLINGER	26.0	273	207	73	22	105	106	76	-11	
	O'CONNER LIVESTOCK CO.	30.0	108	123	72	102	125	122	97	6	
	OREGON WATER CORP.(4)	26.0					113	112	84	-4	
	POPE'S MEAT CO.	22.0	180	161	67		72(69)	77	40(38)	-39	
	RAY BIXLER	22.0	234	182	55		101	102	71	-15	
	ROBERT LANGLEY	23.0	252	200	78	25	102	103	72	-14	
	TOWN OF MERRILL	21.0	165	155	71	41	89	92	59	-25	
	U.S. AIR FORCE(1)	31.0	227	209	129	100	105	105	75	-12	
	U.S. AIR FORCE(2)	30.0	220	201	117	65	103	103	73	-13	
	WEYERHAUSER WELL NO. 4	22.0	178	159	65		55	62	23	-53	
	EAGLE POINT SPRING	35.0	169	190	170		89	92	59	-25	
01	J. E. FRIESEN	73.0	83	109	75		130(111)	126	102(82)	10	
02	LOIS MERRUYS	71.0	80	106	73		127(115)	124	99(86)	8	
02	MEDO-BELL DAIRY	81.0	83	109	75		125(102)	123	98(72)	7	185
02	MEDO-BELL DAIRY	81.0									
02	MILLS SCHOOL	89.0	47	83	67		124	121	96	5	
02	MOYINA WATER CO.	50.0	196	177	86	64	114	113	85	-4	
02	O.I.T. NO. 5	89.0	57	91	72		120(104)	118	92(74)	2	
02	O.I.T. NO. 6	88.0	83	108	71		81	84	49	-32	
02	O.I.T. NO. 6	79.0					131	128	104	12	185
02	OREGON WATER CORP.(1)	21.0					98	99	68	-17	
02	OREGON WATER CORP.(2)	21.0					70	75	39	-40	
02	OREGON WATER CORP.(3)	20.0					72	77	40	-39	
03	HOWARD HOLLIDAY	25.0	181	157	56		75	79	44	-36	
04	MAZAMA SCHOOL	61.0	93	129	126	96	133	129	105	13	
06	ABE BOEHM	25.0	114	132	87	57	137	133	110	17	
06	ABE BOEHM	25.0									58
06	DAN O'CONNER	24.0	254	207	91	34	94	96	63	-21	
06	JACK LISKEY	93.0	83	111	82		131(106)	128	104(76)	12	138
06	JACK LISKEY	22.0	85	121	115	38	137	133	110	17	
06	JACK LISKEY	25.0									93
06	O. H. OSBORN	90.0	87	113	83		131(65)	128	104(33)	12	135
07	OLENE GAP HOT SPRINGS	73.9	72	101	72		124	122	96	6	
07	OLENE GAP HOT SPRINGS	74.0	115	130	80	122	136	132	109	16	196
07	OLENE GAP HOT SPRINGS	87.0									
08	ROENICKE HOT SPRING	65.0	90	112	72	85	100	101	70	-16	
16	MELVIN FEIGI	31.0	71	103	80		143(132)	137	116(105)	22	
22	RAY SMITH WELL	25.0	145	143	68		102	103	72	-14	
23	KLAMATH ICE CO.	51.7					118(99)	117	90(69)		
24	J. K. O'NEIL		249	203	87	20	97	99	67	-18	
24	J. K. O'NEIL	23.0	230	194	88	cold	102	103	72	-14	

Table 4: GEOTHERMOMETER CALCULATIONS(C)
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Numbers in parentheses are calculated from silicic acid (H₄SiO₄) concentration calculated at the spring temperature;
 Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	SiO ₂ conductive	SiO ₂ adiabatic	SiO ₂ chalcedony	SiO ₂ opal	Sulfate- water
LAKE COUNTY											
05	ANA RIVER SPRING	18.9	162	157	80	27	83	91	57	-26	
14	SUMMER LAKE HOT SPRING (WOODWARD)	46.7	76	130	182	113	135(123)	131	108(95)	15	
14	SUMMER LAKE HOT SPRING (WOODWARD)	43.0	61	112	149		134(127)	130	107(99)	14	189
23	HUNTERS HOT SPRINGS (LAKEVIEW)	98.0	125	148	120		159	151	135	37	
23	HUNTERS HOT SPRINGS (LAKEVIEW)	86.0	128	154	134	74	157	149	133	35	158
23	HUNTERS HOT SPRINGS (LAKEVIEW)	96.0	119	143	114		157	149	133	35	
24	LEITHEAD HOT SPRINGS (JOYLAND PLUNGE, LEO)	69.4	69	96	61		115	114	86	-2	
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	85.0	107	140	130	102	157	149	133	35	
25	BARRY RANCH HOT SPRINGS (GUS ALLEN)	88.0	106	139	131		152	145	127	31	
28	ANTELOPE HOT SPRINGS	40.0	149	168	138	87	168	159	146	45	
32	FISHER HOT SPRINGS	68.0	165	169	112	123	123	121	95	4	
33	CRUMP SPRING	40.0	130	147	104	112	150	143	125	29	
33	CRUMP SPRING	78.0	117	144	122		173	162	151	50	202
33	CRUMP WELL (1)	99.0	118	150	141	144	169	159	146	46	
33	CRUMP WELL (2)	88.0	112								
LANE COUNTY											
01	BELKNAP HOT SPRINGS	86.7	226	202	110	183	126	123	98	7	
01	BELKNAP HOT SPRINGS	71.0	87	113	82	34	135	131	108	15	148
02	FOLEY SPRINGS	80.6	91	106	52		111	110	82	-6	
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	44.0	74	95	48		102	103	72	-14	
03	COUGAR RESERVOIR HOT SPRINGS (RIDER)	42.0	86	103	51		99	100	69	-16	
04	WALL CREEK WARM SPRINGS	41.0	110	125	73		113	112	84	-5	
05	MCCREDIE SPRINGS	73.0	88	114	81	74	124	122	96	6	
05	MCCREDIE SPRINGS	71.0	104	125	86	84	115	114	86	-3	
06	KITSON SPRINGS	44.4	82	110	83		99	100	69	-16	
06	KITSON SPRINGS	43.0	77	107	81	71	97	98	67	-18	
08	BIGELOW HOT SPRINGS	61.0	104	125	85	120	117	116	89	-1	
MALHEUR COUNTY											
03	NEAL HOT SPRINGS	87.0	163	181	151		173	162	151	50	210
04	BEULAH HOT SPRINGS	60.0	103	124	85		169	159	146	46	
05	VALE HOT SPRINGS	73.0	132	157	135	150	152	145	127	31	201
05	VALE HOT SPRINGS	90.0									161
06	UNNAMED HOT SPRINGS NEAR LITTLE VALLEY	70.0	83	118	109		145(126)	139	119(98)	24	215
08	MITCHELL BUTTE HOT SPRINGS	62.0	70	99	72		134(118)	130	107(90)	14	
18	UNNAMED HOT SPRING AT THREE FORKS	35.0					96	97	66	-19	

Table 4: GEOTHERMOMETER CALCULATIONS(C)
 [Map code refers to Bowen, Peterson, and Riccio, 1978;
 Numbers in parentheses are calculated from silicic acid (H4SiO4) concentration calculated at the spring temperature;
 Waters with magnesium-correction ratios > 50 are indicated by the term "cold"]

Map Code	Name	Measured	Na-K	Na-K-Ca 1/3	Na-K-Ca 4/3	Na-K-Ca Mg-corrected	Si02 conductive	Si02 adiabatic	Si02 chalcedony	Si02 opal	Sulfate-water
MALHEUR COUNTY											
18	UNNAMED HOT SPRING AT THREE FORKS	34.0	83	98	42		92	94	61	-23	
19	UNNAMED HOT SPRING NEAR MCDERMITT	53.5	66	107	109		131(101)	128	104(71)	12	
19	UNNAMED HOT SPRING NEAR MCDERMITT	52.0	45	90	104		120(106)	118	91(76)	1	
23	LUCE HOT SPRINGS	63.0	119	137	96		143	137	116	22	
24	JONESBORO WARM SPRING	44.5	53	89	73		118(70)	117	90(39)		
25	JUNTURA WARM SPRING #1	25.0	285	205	59		106(84)	106	77(53)	-10	
26	JUNTURA WARM SPRING #2	35.0	56	92	78		124(76)	122	96(44)	6	
27	ARTESIAN WELL	46.0	39	78	71		96(57)	97	65(24)	-19	
28	ALKALI FLAT GRADIENT WELL	24.0	68	108	109		82	85	51	-31	
29	NORTH HARPER BLM WELL	36.0	75	109	94	95	91	93	61	-23	
30	UNNAMED WARM SPRING NEAR BULLY CREEK	37.0	266	148	-24		137	132	110	16	
MARION COUNTY											
01	BREITENBUSH HOT SPRINGS	92.0	122	149	128		127	124	99	8	179
01	BREITENBUSH HOT SPRINGS -WELL	110.0	130	155	134		174(157)	163	152(133)	50	176
MULTNOMAH COUNTY											
01	CORBETT WARM SPRING	18.0	178	170	92	158	95	98	66	-19	
02	YMCA CAMP COLLINS	23.3	430	283	103	260	111(104)	110	81(75)	-7	
UMATILLA COUNTY											
01	BINGHAM SPRINGS	34.4	138	151	102	70	117(110)	115	88(81)	-1	
03	LEHMAN SPRINGS	61.0	66	97	72		96	97	66	-19	
UNION COUNTY											
01	COVE WARM SPRING	29.4	75	95	46		78(40)	82	47(7)	-34	
01	WELL	27.0	224	194	92	168	128	125	100	8	
01	WELL	25.0	215	190	94	81	120	118	91	1	
01	WELL	27.0	258	200	73	195	119	117	90	1	
02	HOT LAKE I	80.0	85	114	89		100(62)	101	70(30)	-16	63
05	WAGNER WELL	29.0	203	183	93	94					
07	MEDICAL HOT SPRINGS	60.0	78	97	48		135	131	109	15	
07	MEDICAL HOT SPRINGS	60.0	114	125	66		125	122	97	6	
WALLOWA COUNTY											
01	COOK CREEK WARM SPRING	36.0	119	118	40		98	99	68	-17	
WASCO COUNTY											
01	KAHNEETAH HOT SPRINGS	52.0	56	102	120		139	135	113	19	
02	MILTON MARTIN WELL	22.2	220	188	84	89	128(124)	125	100(96)	8	
03	J. SANDOZ WELL	27.8	221	196	103	69	134	130	107	14	

to calcium ratios have long been considered a qualitative indicator of low reservoir temperature (Ellis, 1970; White, 1970). The recently developed Na-K-Ca-Mg geothermometer (Fournier and Potter, 1979) quantifies this observation and results in generally better agreement between the silica and cation geothermometers, particularly in the lower (<150°C) temperature range. The magnesium-corrected Na-K-Ca geothermometer was not calculated for samples with Na-K-Ca temperatures of less than 70°C.

To apply the magnesium correction, the ratio (R), defined by Fournier and Potter (1978) to be:

$$R = \frac{\text{millequivalents Mg} \times 100}{\text{millequivalents Mg} + \text{milliequivalents Ca} + \text{milliequivalents K}} \quad (4)$$

was determined for all samples with magnesium, calcium, and potassium concentrations larger than the detection limits. If R was greater than 50, the sample was designated "cold" and no quantitative temperature was calculated. A magnesium-corrected temperature was calculated for all remaining samples, but was printed only if the corrected temperature was less than the uncorrected Na-K-1/3Ca temperature. The Na-K temperatures are based on the revised equation of Fournier (1979).

The sulfate-water isotope geothermometer (McKenzie and Truesdell, 1977) is based on the temperature-dependent fractionation of the isotopes of oxygen (O^{16}/O^{18}) between water and dissolved sulfate. McKenzie and Truesdell (1977) describe three end-member models for calculating reservoir temperatures with the sulfate-water isotope geothermometer: (1) conductive heat loss, (2) one-step steam loss, and (3) continuous steam loss. Samples from isolated springs with low flows and/or no steam loss, and condensed total-flow samples from wells, are assumed to have cooled conductively without any change in isotopic composition. One-step steam loss occurs in geysers and steam wells having two-phase flow from which only the water is collected. Continuous steam loss may occur in springs issuing in areas having fumaroles and steaming ground. If dilution occurs but is not detected, temperatures less than the actual reservoir temperature will be estimated. Generally, the continuous-steam-loss model is best for boiling springs and the conductive-heat-loss model for all other samples. Erroneous temperature estimates will be produced if nonthermal equilibrated sulfate is added by processes such as solution of gypsum, oxidation of sulfide to sulfate, or mixing with sulfate bearing brines.

Besides these quantitative indicators of subsurface temperature, the presence of travertine or siliceous sinter is generally a good qualitative indicator of temperature. Travertine indicates low temperatures, while siliceous sinter indicates temperatures of 180°C or more (White, 1970). Only Hot Lake and Mickey Springs in southern Harney County, and Neal Hot Springs in northern Malheur County, have large sinter deposits.

The following procedure is recommended to determine which estimated subsurface temperature (table 4) is best:

1. Examine the Mg-corrected Na-K-Ca and the Na-K-4/3Ca temperatures and select the lower temperature as the better estimate. If neither is less than 100°C, then select the Na-K-1/3Ca temperature as the best cation-based estimate of the last temperature of water-rock equilibrium.
2. If the spring is boiling, select the quartz adiabatic temperature as the best silica-based temperature indicator. Otherwise, selection of the best silica-based temperature depends on having some knowledge of the principal rock type in the area of the individual hot spring. In alkaline waters discharging from granite, quartz solubility seems to limit silica concentrations at temperatures as low as 75°C. In waters of neutral pH, quartz solubility limits silica concentrations at temperatures of more than 180°C in basalts, and 90°C in granite.
3. Consider the temperatures estimated from the sulfate-water geothermometer to be speculative. Although tantalizing, these temperatures must be substantiated by additional information.

After careful application of the geothermometers, some samples may remain which give inconsistent or otherwise doubtful results. For example, dissolution of glass from vitric or lapilli tuffs releases large quantities of silica which renders the silica geothermometer useless. The high silica concentration at Beulah Hot Springs in Malheur County and at the warm springs near Venator in Harney County may be meaningless since both springs issue from vitric tuffs. The low temperatures estimated from the Na-K-Ca geothermometers indicate that the springs are not an important geothermal resource.

The chemical composition of the thermal waters issuing along the shores of East Lake and Paulina Lake are also difficult to interpret. These springs have negligible flow rates, high silica concentrations (up to 200 mg/L), and issue from lapilli tuffs. Solution of glass from the lapilli tuffs could account for the large silica and relatively large magnesium concentrations. Since the temperatures of the springs increases as gas discharge increases, the "springs" are probably drowned gas vents. The concentrations of silica, sodium, potassium, and calcium in these thermal waters may be functions of the length of time that the heated lake water has been in contact with the tuff and may have no relationship to the temperature at depth. The relatively large magnesium concentration also favors a low-temperature system.

The sulfate-water isotope geothermometer produces considerably higher estimated temperatures of water-rock equilibrium than the chemical geothermometers in most systems. The high temperatures estimated from the sulfate-water isotope geothermometer may indicate that the systems have a deep reservoir in which isotopic equilibrium is being established, and a shallower, cooler reservoir in which chemical equilibrium is being established. This is possible because the rate of sulfate-water isotopic equilibrium is relatively slow. Times to achieve equilibrium depend on both temperature and pH (Lloyd, 1968). To achieve 99-percent equilibration at neutral pH's, 330 years would be required at 100°C, 52 years at 150°C, and 12 years at 200°C. However, it is possible that the sulfate is added to the system slowly as the fluids circulate, thus requiring longer times to achieve 99-percent equilibration. An alternate explanation for the high temperatures estimated in the Cascades is that the sulfate represents fossil sulfate associated with the mineralization which is common in the Western Cascades. However, until additional data are available, it will not be possible to determine if the high apparent temperatures of sulfate-water isotopic equilibrium are real or the result of solution of "fossil" sulfate, mixing of thermal and nonthermal waters, reduction of sulfate, membrane filtration, different rates of isotopic exchange between sulfate, water, and rock, or other nonthermal effects.

SUMMARY

Most of the thermal springs in the central and northern parts of the Cascades in Oregon contain appreciable connate marine water similar to cold connate marine waters discharged from mineral springs and deep wells in the Willamette Valley and the Coast Range. Thermal springs in the southern part of the Cascades discharge similar waters to which a significant amount of CO_2 has been added. Numerous cold CO_2 -charged springs also issue in this area. Dilute, alkaline thermal waters issue from springs associated with granitic rocks, principally in northeastern Oregon. These waters are sufficiently alkaline to require that the silica geothermometer be corrected for the dissociation of silicic acid. Near-surface water-rock reactions have rendered the chemical composition of thermal water at Newberry Caldera useless for geothermal calculations. Based on the geothermometers, the following areas have the greatest geothermal potential: Alvord Area (including Mickey Springs, Alvord Hot Springs, and Hot Borax Lake), Vale Hot Springs, Neal Hot Springs, Crump Spring, Lakeview, and Breitenbush Hot Springs. Areas for which the geothermometers do not agree include Klamath Falls and part of the Cascades.

ACKNOWLEDGEMENT

Joseph F. Riccio of the Oregon Department of Geology and Mineral Industries provided many of the raw data.

REFERENCES

- Arnorsson, Stefan, 1975, Application of the silica geothermometer in low temperature hydrothermal areas in Iceland: *American Journal of Science*, v. 275, p. 763-784.
- Ayers, F. D., and Creswell, A. E., 1951, The Mount Hood fumaroles: *Mazama*, v. 3, no. 13, p. 33-40.
- Bowen, R. G., Peterson, N. V., and Riccio, J. F., compilers, 1978, Low to intermediate-temperature thermal springs and wells in Oregon: Oregon Department of Geology and Mineral Industries, Geological Map Series, GMS-10.
- Brook, C. A., Mariner, R. H., Mabey, D. R., Swanson, J. R., Guffanti, Marianne; and Muffler, L. J. P., 1979, Hydrothermal convection systems with reservoir temperatures $\geq 90^\circ\text{C}$, in Muffler, L. J. P., ed., *Assessment of geothermal resources of the United States - 1978*: U.S. Geological Survey Circular 790, p. 18-85.

- Brown, Eugene, Skougstad, M. W., and Fishman, M. J., 1970, Methods for collection and analysis of water samples for dissolved minerals and gases: U.S. Geological Survey Techniques of Water Resources Investigations, Book 5, Chapter A1, 160 p.
- Corcoran, R. E., and Walker, G. W., 1969, Geology of the Owyhee Upland Province, in Mineral and Water Resources of Oregon: Washington, U.S. Government Printing Office, p. 80-83.
- Ellis, A. J., 1970, Quantitative interpretation of chemical characteristics of hydrothermal systems, in United Nations symposium on development and utilization of geothermal resources, Pisa 1970, v. 2, pt. 1: Geothermics, Special Issue 2, p. 516-528.
- Fenneman, N. M., 1946, Physical divisions of the United States: U.S. Geological Survey, scale 1:7,000,000.
- Fournier, R. O., 1973, Silica in thermal waters: Laboratory and field investigations, in Proceedings of international symposium on hydrogeochemistry and biogeochemistry, Japan, 1970, Volume 1, Hydrochemistry: Washington, D.C., J. W. Clark, ed., p. 122-139.
- Fournier, R. O., and Rowe, J. J., 1966, Estimation of underground temperatures from the silica content of water from hot springs and wet-stream wells: American Journal of Science, v. 264, p. 685-697.
- Fournier, R. O., 1979, A revised equation for the Na/K geothermometer, in Expanding the Geothermal Frontier, Transactions of the Geothermal Resources Council Annual Meeting, 24-27 September, 1979, Reno, Nevada, Volume 3, p. 221-224.
- Fournier, R. O., and Potter, R. W., 1978, A magnesium correction for the Na-K-Ca geothermometer: U.S. Geological Survey Open-File Report 78-486, 24 p.
- Fournier, R. O., and Truesdell, A. H., 1973, An empirical Na-K-Ca geothermometer for natural waters: Geochimica et Cosmochimica Acta, v. 37, p. 1255-1275.
- Fournier, R. O., and Truesdell, A. H., 1974, Geochemical indicators of subsurface temperature - Part 2, Estimation of temperature and fraction of hot water mixed with cold water: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 263-270.

- Fournier, R. O., White, D. E., and Truesdell, A. H., 1974, Geochemical indicators of subsurface temperature - Part 1, Basic assumptions: U.S. Geological Survey Journal of Research, v. 2, no. 3, p. 259-262.
- Gonthier, J. B., Collins, C. A., and Anderson, D. B., 1977, Ground-water data for the Drewsey Resource Area, Harney and Malheur Counties, Oregon: U.S. Geological Survey Open-File Report 77-741, 28 p.
- Griggs, A. B., 1969, Geology of the Cascade Range, in Mineral and Water Resources of Oregon: Washington, U.S. Government Printing Office, p. 53-59.
- Groh, E. A., 1966, Geothermal energy potential in Oregon: The Ore Bin, v. 28, no. 7, p. 125-135.
- Hampton, E. R., and Brown, S. G., 1964, Geology and ground water resources of the upper Grand Ronde River Basin, Union County, Oregon: U.S. Geological Survey Water-Supply Paper 1597, 99 p.
- Hogenson, G. M., 1964, Geology and ground water of the Umatilla River Basin, Oregon: U.S. Geological Survey Water-Supply Paper 1620, 162 p.
- Leonard, A. R., 1970, Ground water resources in Harney Valley, Oregon: Oregon State Ground-water Report no. 16, 85 p.
- Leonard, A. R., and Harris, A. B., 1974, Ground water in selected areas, Klamath Basin, Oregon: Oregon Water Resources Department Ground-water Report 21, 104 p.
- Lindgren, Waldemar, 1901, The gold belt of the Blue Mountains of Oregon: U.S. Geological Survey 22nd Ann. Report, pt. 2, p. 551-776.
- Lloyd, R. M., 1968, Oxygen isotope behavior in the sulfate-water system: Journal of Geophysical Research, v. 73, p. 6099-6110.
- McKenzie, W. F., and Truesdell, A. H., 1977, Geothermal reservoir temperatures estimated from the oxygen isotope compositions of dissolved sulfate and waters from hot springs and shallow drill-holes: Geothermics, v. 5, p. 51-61.
- Madison, R. J., 1966, Water-quality data in the Willamette Basin, Oregon, 1910-1964: U.S. Geological Survey Basic-Data Release, 40 p.

- Mariner, R. H., Brook, C. A., Swanson, J. R., and Mabey, D. R., 1978, Selected data for hydrothermal convection systems in the United States with estimated temperatures $\geq 90^{\circ}\text{C}$: Backup data for U.S. Geological Survey Circular 790, U.S. Geological Survey Open-File Report 78-858, 493 p.
- Mariner, R. H., Presser, T. S., Rapp, J. B., and Willey, L. M., 1975, The minor and trace elements, gas, and isotope compositions of the principal thermal springs of Nevada and Oregon: U.S. Geological Survey Open-File Report, 27 p.
- Mariner, R. H., Rapp, J. B., Willey, L. M., and Presser, T. S., 1974, The chemical composition and estimated minimum thermal reservoir temperatures of selected hot springs in Oregon: U.S. Geological Survey Open-File Report, 32 p.
- Nehring, N. L., Mariner, R. H., White, L. D., Huebner, M. A., Roberts, E. D., Harmon, Karen, Bowen, P. A., and Tanner, Lane, 1979, Sulfate geothermometry of thermal waters in the western United States: U.S. Geological Survey Open-File Report, 79-1135, 11 p.
- Newcomb, R. C., 1972, Quality of the ground water in basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Supply Paper 1999-N, p. N1-N71.
- Newcomb, R. C., and Hart, D. H., 1958, Preliminary report on the ground water resources of the Klamath River Basin, Oregon: U.S. Geological Survey Open-File Report 466, 248 p.
- Peterson, N.V., and Groh, E. A., 1967, Geothermal potential of Klamath Falls area, Oregon, a preliminary study: The Ore Bin v. 29, no. 11, p. 209-231.
- Phillips, K. N., 1936, A chemical study of the fumaroles of Mount Hood: Mazama, v. 18, no. 12, p. 44-46.
- Piper, A. M., 1942, Ground water resources of the Willamette Valley, Oregon: U.S. Geological Survey Water-Supply Paper 890, 194 p.
- Piper, A. M., Robinson, T. W., and Park, C. F., Jr., 1939, Geology and ground water resources of the Harney Basin, Oregon: U.S. Geological Survey Water-Supply Paper 841, 190 p.

- Presser, T. S., and Barnes, Ivan, 1974, Special techniques for determining chemical properties of geothermal water: U.S. Geological Survey Water-Resources Investigations 22-74, 11 p.
- Robinson, J. H., 1972, Availability and quality of ground water in the Ashland Quadrangle, Jackson County, Oregon: U.S. Geological Survey Hydrologic Investigations Atlas HA-421.
- Sammel, E. A., 1976, Hydrologic reconnaissance of the geothermal area near Klamath Falls, Oregon, with a section on preliminary interpretation of geophysical data by D. L. Peterson: U.S. Geological Survey Water-Resources Investigation Open-File Report 76-127, 129 p.
- Scott, R. C., and Baker, F. B., 1962, Data on uranium and radium in the ground water of the United States, 1954 to 1957: U.S. Geological Survey Professional Paper 426, 115 p.
- Teshin, V. N., Swanson, J. R., and Orris, G. J., 1979, GEOTHERM - Geothermal resources file, in Expanding the Geothermal Frontier, Transaction of the Geothermal Resources Council Annual Meeting, 24-27 September 1979, Reno, Nevada, v. 3, p. 721-724.
- Thayer, T. P., and Wagner, N. S., 1969, Geology of the Blue Mountain Region, in Mineral and Water Resources of Oregon: Washington, U.S. Government Printing Office, p. 68-74.
- Trauger, F. D., 1950, Factual ground-water data in Lake County, Oregon: Portland, Oregon, U.S. Geological Survey Open-File Report, 287 p.
- Wagner, N. S., 1959, Natural sources of carbon dioxide in Oregon: The Ore Bin, v. 21, no. 11, p. 103-113.
- Walker, G. W., 1969, Geology of the High Lava Plains Province, in Mineral and Water Resources of Oregon: Washington, U.S. Government Printing Office, p. 77-79.
- Walker, G. W., and Peterson, N. V., 1969, Geology of the Basin and Range Province, in Mineral and Water Resources of Oregon: Washington, U.S. Government Printing Office, P. 83-88.
- Waring, G. A., 1965, Thermal springs of the United States and other countries of the world--a summary: U.S. Geological Survey Professional Paper 492, 833 p.

White, D. E., 1960, Summary of chemical characteristics of some waters of deep origin, in Synopsis of Geologic Results: U.S. Geological Survey Professional Paper 400-A, p. B452-B454.

White, D. E., 1970, Geochemistry applied to the discovery, evaluation, and exploitation of geothermal energy resources, in United Nations symposium on development and utilization of geothermal resources, Pisa, 1970, v. 1, pt. 2, Geothermics, Special Issue 2, p. 58-80.