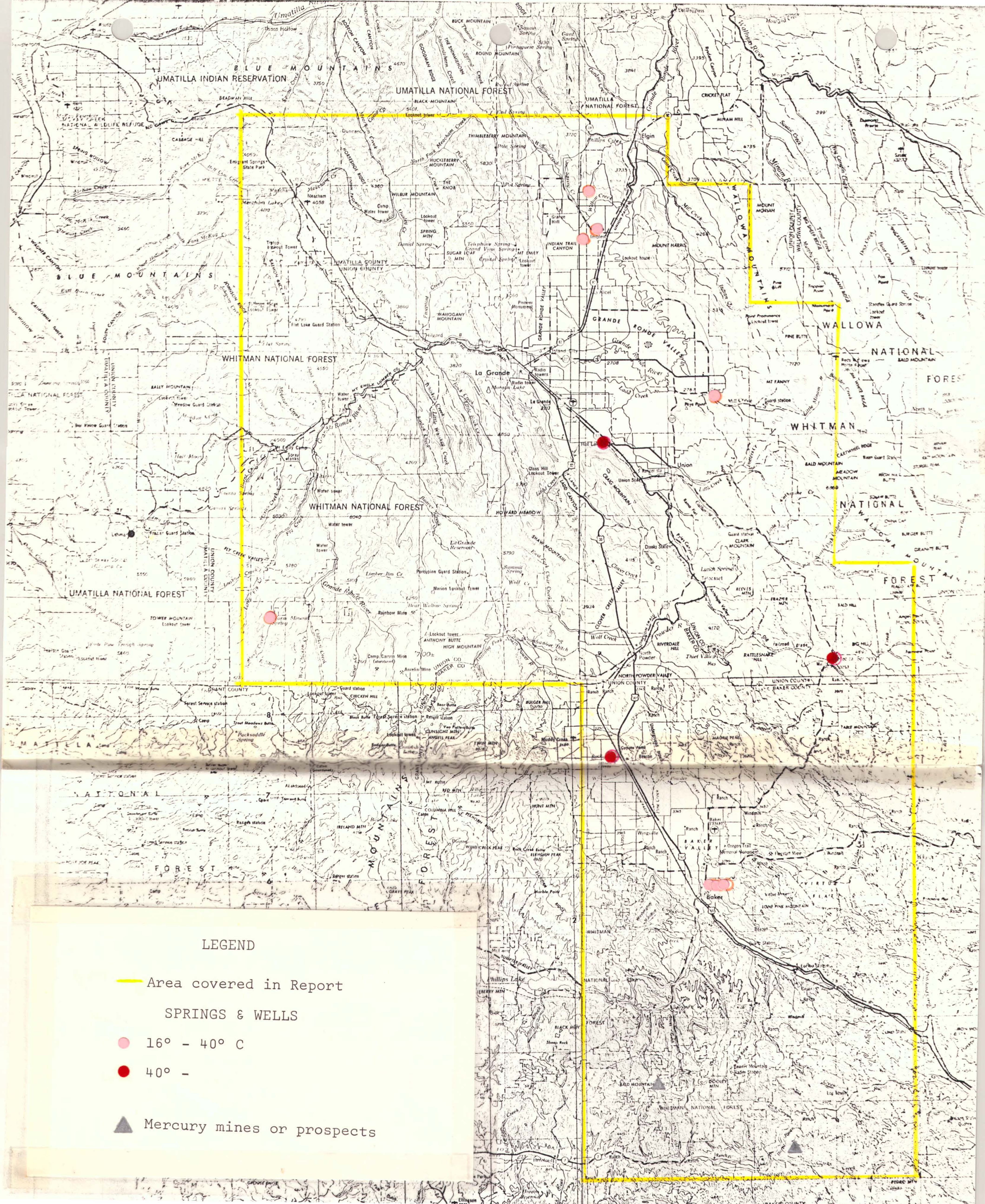
LaGRANDE-BAKER VALLEY AREA

April 8, 1974
AMAX EXPLORATION, INC.
M. H. Alldredge

T A B L E O F C O N T E N T S

A



LEGEND
Area covered in Report
SPRINGS & WELLS
16° - 40° C
40° -
Mercury mines or prospects
BLUE MOUNTAINS
UMATILLA INDIAN RESERVATION
UMATILLA NATIONAL FOREST
WHITMAN NATIONAL FOREST
WALLOWA NATIONAL FOREST
WALLOWA MOUNTAINS
GRANDE RONDE VALLEY
La Grande
Elgin
Union
North Powder
Baker
UNION COUNTY
BAKER COUNTY
UMATILLA COUNTY

B

Spring No.	BAKER COUNTY SPRING NAME	Sec.	Twp.	Range	Quadrangle	(°C) Temp	Discharge (gal/min)	Associated Rocks	Remarks
	Baker County (Nelson) Sam-O Mineral Spr.	2	12S	43E	Durkee 15'	26.6		Faulted Jurassic or Triassic Strata	2 springs, local use
	Baker County Radium Hot Springs	NE1/4 28	7S	39E	Haines 7-1/2	57.2	small	Jointed diorite	also 2 wells, 10 mi. NW Baker
	Baker County Sam-O Spring	SE1/4 16	9S	40E	Baker 7-1/2	26.6	400	Alluvium over-lying Tertiary volcanics	irrigation use, near Baker
	Baker County Huntington City Well	18	14S	45E	Huntington 15	24			water bearing zone 500 ft.
	Baker County William Wendt Well	16	9S	40E	Baker 7-1/2	24.4			
	Baker County Baker Packing Co. Well	16	9S	40E	do	26.1			
	Baker County Sunny Slope Co. Well	15	9S	40E	do	warm		Tertiary Volcanics near fault zone	
	Baker County do	15	9S	40E	do	do		do	
		Within	study	area					

Spring No.	GRANT COUNTY SPRING NAME	Sec.	Twp.	Range	Quadrangle	(°C) Temp	Discharge (gal/min)	Associated Rocks	Remarks
	Grant County Ritter Hot Spgs.	NW1/4 8	8S	30E	Ritter 15'	43.3	35	Tertiary Faulted Columbia R. Basalt	Resort
	Grant County Hot Sulfur Spgs.	35	10S	32S	Susanville 15'	48.8		do.	Resort, on camp creek 6 mi. S of Susanville.
	Grant County (Miller Resort) Bear Gulch Spring	SE1/4 11	15S	31E	John Day 15'	39	2	Upper tertiary lava	near Canyon Creek
	Grant County Blue Mtn. Hot Spg.	13	14S	34E	Prairie City 15'	60		Carboniferous Strata	Several springs near mouth of Reynolds Creek
	Grant County Lime Kiln Spgs.	North Central 10	14S	33E	do.	21			
	Grant County Brisbois Ranch Spring	13,24, 25	17S	27E	Izee 15'	22			Springs on 3 mi. long zone
	Grant County Weberg Springs	18	18S	26E		50			

Spring No.	UNION COUNTY SPRING NAME	Sec.	Twp.	Range	Quadrangle	(^{o}C) Temp	Discharge (gal/min)	Associated Rocks	Remarks
	Union County Unnamed	6	1S	39E	Elgin 7-1/2	warm		Tertiary Columbia River Basalt	Several springs, local use
	Union County Hot Lake Spgs	SE1/4 5	4S	39E	Craig Mt. 7-1/2	82.3	175	Tertiary Columbia River Basalt	Bathing, 10 mi. SE of LaGrande
	Union County Medical Springs	NE1/4 25	6S	41E	Medical Spgs 7-1/2	60	50	Carboniferous Greenstone	2 springs, local use
	Union County Cove Springs	22	3S	40E	Cove 7-1/2	29	226		Water supply for swimming pool
	Union County Warm Mineral Springs	West Central 12	6S	35E	Fly Valley 7-1/2	28	25-50		Sulfurous odor
	Union County Wagner Well	24	1S	38E	Imbler 7-1/2	29			Well depth 1150'
	Union County Clayton Fox Well	20	1S	39E	do.	27			Well depth 1468'

Spring No.	UMATILLA COUNTY SPRING NAME	Sec.	Twp.	Range	Quadrangle	(°C) Temp	Discharge (gal/min)	Associated Rocks	Remarks
	Umatilla County Lehman Spring	NE1/4 12	5S	33E	Lehman Spring 7-1/2	69	75	Tertiary Columbia R. Basalt	10 springs, resort
	Umatilla County Hideaway Springs	SE1/4 17	5S	33E	do	38	150	do	several springs, 7 mi. SW of Lehman Spring
	Umatilla County Bingham Springs	NE1/4 18	3N	37E	Bingham Springs 7-1/2	34	80	Fracture zone in Lava	
	Umatilla County Hermiston City Well	10	4N	28E	Hermiston 7-1/2	24			Water heaving zone about 500'

OREGON

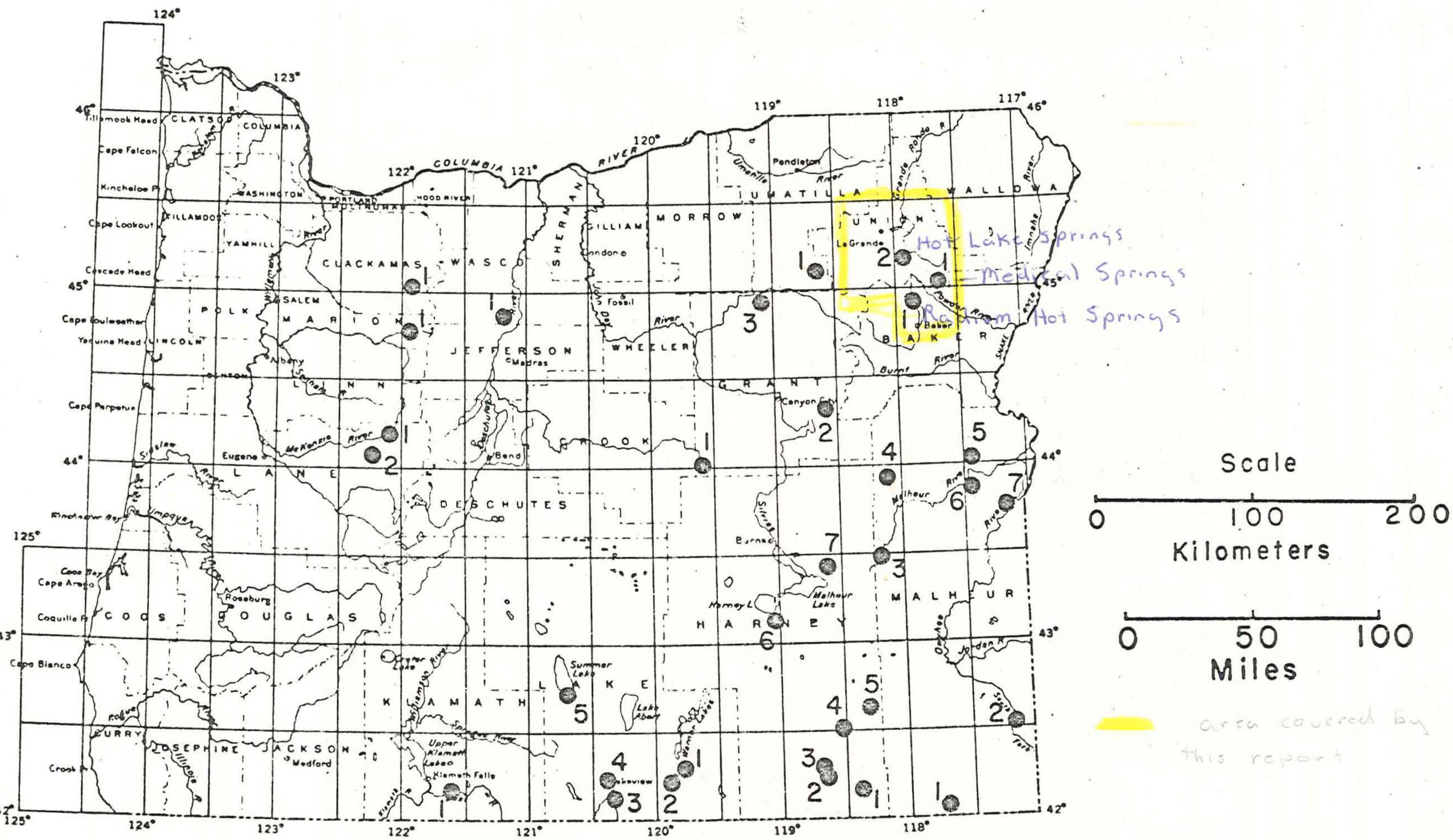


Figure 1. Map of the State of Oregon showing the location of sampled thermal springs and wells. The numbered dots correspond to sampled springs listed by county in tables 1, 2, 3, and 4 of the text.

The following pages are from: The Chemical Composition and Estimated Minimum Thermal Reservoir Temp of Selected Hot Springs in Oregon

Table 1.--Location and topographic map coverage of selected hot springs

Spring	Location	Topographic map coverage
	Baker County	
1 Radium Hot Springs (well)	NE 1/4 sec. 28, T. 7S., R. 39E.	Haines, Ore. (7-1/2'); Baker, Oregon-Idaho (2°)
	Clackamas County	
1 Austin Hot Springs	NW 1/4 sec. 30, T. 6S., R. 7E.	Fish Creek Mtn. Ore., (15'); Vancouver, Ore.-Wash. (2°)
	Grant County	
1 Weberg Hot Spring	sec. 18, T. 18S., R. 26E.	; Burns, Oregon (2°)
2 Blue Mountain Hot Springs	S 1/2 sec. 13, T. 14S., R. 34 E.	Prairie City, Ore. (15'); Canyon City, Oregon (2°)
3 Ritter Hot Springs	NW 1/4 sec. 8, T. 8S., R. 30E.	Ritter, Ore. (15'); Canyon City, Oregon (2°)
	Harney County	
1 Unnamed hot spring (Trout Creek)	sec. 16, T. 39S., R. 37E.	; Adel, Oregon (2°)
2 Hot Lake	sec. 15, T. 37S., R. 33E.	; Adel, Oregon (2°)
3 Unnamed hot spring (near Hot Lake)	sec. 15, T. 37S., R. 33E.	; Adel, Oregon (2°)
4 Alvord Spring (Indian Spring)	sec. 33, T. 34S., R. 34E.	; Adel, Oregon (2°)
5 Mickey Springs	sec. 13, T. 33S., R. 35E.	; Adel, Oregon (2°)
6 Unnamed hot spring (near Harney Lake)	sec. 36, T. 27S., R. 29-1/2E.	; Burns, Oregon (2°)
7 Crane Hot Springs	S 1/2 sec. 34, T. 24S., R. 33E.	Crane, Ore. (15'); Burns, Oregon (2°)
	Klamath County	
1 Olene Gap Hot Springs	SW 1/4 sec. 14, T. 39S., R. 10E.	Merrill, Ore.-Calif. (15'); Klamath Falls, Ore.-Calif. (2°)
	Lake County	
1 Fisher Hot Springs	NW 1/4 sec. 10, T. 38S., R. 25E.	Crump Lake, Ore. (7-1/2'); Adel, Oregon (2°)
2 Crump (Charles Crump's Spring)	sec. 27, T. 38S., R. 24E.	; Adel, Oregon (2°)
3 Barry Ranch Hot Springs	SE 1/4 sec. 27, T. 39S., R. 20E.	Lakeview NE, Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)
4 Hunters Hot Springs	NW 1/4 sec. 4, T. 39S., R. 20E.	Lakeview NE, Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)
5 Summer Lake Hot Spring	NE 1/4 sec. 12, T. 33S., R. 17E.	Slide Mtn. Ore. (7-1/2'); Klamath Falls, Ore.-Calif. (2°)

Table 1.--Location and topographic map coverage of selected hot springs--Continued

Spring	Location	Topographic map coverage
	Lane County	
1 Belknap Hot Springs	NE 1/4 sec. 11, T. 16S., R. 6E.	McKenzie Bridge, Ore. (15'); Salem, Oregon (2°)
2 Cougar Reservoir Hot Spring	sec. 7, T. 17S., R. 5E.	McKenzie Bridge, Ore. (15'); Salem, Oregon (2°)
	Malheur County	
1 Unnamed hot springs (near McDermitt)	sec. 25, T. 40S., R. 42E.	; Jordan Valley, Ore.-Idaho (2°)
2 Unnamed hot springs (at Three Forks)	sec. 3, T. 35S., R. 45E.	; Jordan Valley, Ore.-Idaho (2°)
3 Unnamed hot spring (near Riverside)	sec. 20, T. 24S., R. 37E.	; Burns, Oregon (2°)
4 Beulah Hot Springs	SE 1/4 sec. 2, T. 19S., R, 37E.	Beulah, Oregon (15'); Burns, Oregon (2°)
5 Neal Hot Springs	NW 1/4 sec. 9, T. 18S., R. 43E.	Jamieson, Oregon (15'); Baker, Idaho-Oregon (2°)
6 Unnamed hot springs (near Little Valley)	NW 1/4 sec. 30, T. 19S., R. 43E.	Harper, Oregon (15'); Boise, Idaho-Oregon (2°)
7 Mitchell Butte Hot Spring	NE 1/4 sec. 12, T. 21S., R. 45E.	Mitchell Butte, Ore. (7-1/2'); Boise, Idaho-Oregon (2°)
	Marion County	
1 Breitenbush Hot Springs	NE 1/4 sec. 20, T. 9S., R. 7E.	Breitenbush Hot Spring, Ore. (15'); Canyon City, Ore. (2°)
	Umatilla County	
1 Lehman Springs	NE 1/4 sec. 12, T. 5S., R. 33E.	Lehman Springs, Ore. (7-1/2'); Pendleton, Ore.-Wash. (2°)
	Union County	
1 Medical Hot Springs	NE 1/4 sec. 25, T. 6S., R. 41E.	Flagstaff Butte, Ore. (7-1/2'); Grangeville, Idaho-Ore.-Wash. (2°)
2 Hot Lake	SE 1/4 sec. 5, T. 4S., R. 39E.	Craig Mtn., Ore. (7-1/2'); Grangeville, Idaho-Ore.-Wash. (2°)
	Wasco County	
1 Kahneeta Hot Springs (Kah-Ne-Tah)	E 1/2 sec. 20, T. 8S., R. 13E.	Eagle Butte, Ore. (7-1/2'); Bend, Oregon (2°)

Table 2.--Chemical analyses of selected hot springs

in mg/l

Spring	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Baker County															
1 Radium Hot Springs (well)	58	9.56	290	78	1.5	0.1	58	1.1	0.01	86	27	34	17	1.3	0.42
Clackamas County															
1 Austin Hot Springs	86	7.63	1,720	81	35	.1	300	7.1	.4	56	<1	140	430	1.4	2.5
Grant County															
1 Weberg Hot Spring	46	6.53	2,570	82	38	7.8	610	36	.7	1,710	1	13	50	3.9	15
2 Blue Mountain Hot Springs	58	7.96	610	47	2.2	.2	140	3.3	.07	323	3	11	15	10.6	1.6
3 Ritter Hot Springs	41	9.68	319	70	1.4	<.05	72	.82	.01	86	28	9	29	4.0	2.6
Harney County															
1 Unnamed hot spring (Trout Creek)	52	6.77	1,168	105	18	.8	270	10.8	.68	439	1	204	24	12.8	.89
2 Hot Lake	36	7.28	2,410	190	16	.3	500	31	.65	420	<1	350	300	9.0	16.6
3 Unnamed hot spring (near Hot Lake)	96	7.30	2,020	160	14	.3	450	28	.51	374	4	434	250	7.2	15
4 Alvord Spring (Indian Spring)	76	6.73	4,590	120	13	2.2	960	69	2.1	1,196	1	220	780	10.2	30
5 Mickey Springs	73	8.05	2,490	200	.9	.1	550	35	1.1	774	11	230	240	16	10.5
6 Unnamed hot spring (near Harney Lake)	68	7.26	2,970	92	12	1.8	630	13	.45	566	1	140	590	3.3	11.3
7 Crane Hot Springs	78	8.10	810	83	3.7	.1	170	3.9	.09	202	3	86	79	9.0	7.9
Klamath County															
1 Olene Gap Hot Springs	74	7.68	1,140	98	40	.2	190	7.2	.15	53	<1	400	59	1.2	1.0
Lake County															
1 Fisher Hot Springs	68	7.93	513	77	8.4	1.0	92	7.9	.04	105	1	59	56	3.5	2.2
2 Crump (Charles Crump's Spring)	78	7.26	1,490	180	16	.2	280	11	.4	153	<1	200	240	4.9	13.6
3 Barry Ranch Hot Springs	88	7.76	1,370	130	8.8	.1	280	9.0	.15	232	2	240	170	5.4	11.2
4 Hunters Hot Springs	96	7.77	1,120	140	13	<.1	210	8.5	.15	79	<1	260	120	4.4	6.9
5 Summer Lake Hot Spring	43	8.43	1,790	94	2.1	.1	390	4.6	.15	406	10	120	280	2.2	6.9

Table 2.--Chemical analyses of selected hot springs--Continued

Spring	Temperature (°C)	pH	Specific conductance	Silica (SiO_2)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Boron (B)
Lane County															
1 Belknap Hot Springs	71	7.62	4,300	96	210	.2	690	15	.95	17	<1	170	1,300	1.2	6.4
2 Cougar Reservoir Hot Spring	44	7.76	2,890	50	225	.1	392	6.3	.52	19	<1	260	788	.8	5.1
Malheur County															
1 Unnamed hot springs (near McDermitt)	52	8.79	598	72	.6	<.1	130	1.0	.06	237	13	52	14	6.6	1.1
2 Unnamed hot springs (at Three Forks)	34	8.11	338	40	10.5	.7	61	1.2	.04	108	1	34	18	4.2	.11
3 Unnamed hot spring (near Riverside)	63	7.43	1,330	110	34	.5	240	9.7	.27	160	<1	290	140	4.8	6.6
4 Beulah Hot Springs	60	7.56	1,090	170	24	.2	200	6.0	.24	161	1	290	55	4.7	4.7
5 Neal Hot Springs	87	7.32	1,010	180	8.8	.2	190	16	.3	198	<1	120	120	9.4	4.1
6 Unnamed hot springs (near Little Valley)	70	8.71	740	115	3.2	<.05	160	3.2	.11	127	1	110	74	6.8	4.7
7 Mitchell Butte Hot Spring	62	8.69	559	94	4.6	<.1	110	1.6	.03	72	3	130	28	10.4	.49
Marion County															
1 Breitenbush Hot Springs	92	7.31	4,030	83	100	1.3	720	31	1.8	142	<1	140	1,300	3.4	4.1
Umatilla County															
1 Lehman Springs	61	9.18	252	44	.9	.1	53	.7	.03	101	13	23	5.4	2.1	.12
Union County															
1 Medical Hot Springs	60	8.23	1,173	80	72	.2	190	7.0	.05	26	<1	400	77	1.2	2.2
2 Hot Lake	80	9.21	688	48	4.9	<.1	130	2.7	.03	75	12	56	140	1.7e	2.9
Wasco County															
1 Kahneeta Hot Springs (Kah-Ne-Tah)	52	8.32	1,370	104	3.2	<.05	325	3.4	.52	493	9	34	155	21	2.6

Table 3.--Geologic setting and estimated thermal aquifer temperatures of selected hot springs

Spring	Spring temperature (°C)	Flow (lpm)	Gas	Spring deposits: $CaCO_3$	Spring deposits: Silica	Rock type of the spring	Estimated thermal aquifer temperature: Silica conductive	Silica adiabatic	Na-K	Na-K-1/3Ca	Na-K-4/3Ca
Baker County											
1 Radium Hot Springs (well)**	58	1,100	X	--	--	Alluvium, quartzdiorite, and basalt	123	122	48	109	77
Clackamas County											
1 Austin Hot Springs***	86	950	T	T	--	Olivine basalt, basaltic andesite and pyroxene andesite	124	123	61	118	88
Grant County											
1 Weberg Hot Spring	46	40	X	T	--	Arkosic sandstone	125	124	130	170	162
2 *Blue Mountain Hot Springs	58	250	--	T	--	Andesite	99	101	61	126	118
3 Ritter Hot Springs**	41	130	--	--	--	Basalt	118	117	20	92	71
Harney County											
1 *Unnamed hot spring (Trout Creek)	52	200	T	--	--	Andesite, basalt, and rhyolite	140	135	97	144	118
2 Hot Lake	36	3,500	T	--	X	Alluvium, andesite, and basalt	176	165	134	176	181
3 Unnamed hot spring (near Hot Lake)	96	15	X	T	X	Alluvium, andesite, and basalt	165	156	134	176	178
4 *Alvord (Indian) Hot Spring	76	500	T	T	X	Rhyodacite, andesite, and basalt	148	142	148	199	254
5 *Mickey Springs	73	100	X	T	X	Andesitic tuff-breccia	179	168	136	207	330
6 *Unnamed hot spring (near Harney Lake)	68	550	T	T	--	Basaltic tuff, and olivine basalt	132	129	52	130	151
7 Crane Hot Springs	78	550	T	--	--	Augite andesite	127	125	59	124	114
Klamath County											
1 Olene Gap Hot Springs**	74	200	T	--	--	Andesite, basalt, and andesitic tuff-breccia	136	132	93	130	80
Lake County											
1 Fisher Hot Springs	68	70	T	T	--	Alluvium and olivine basalt	123	121	167	170	112
2 Crump (Charles Crump's Spring)	78	0-50	T	T	X	Alluvium and olivine basalt	173	162	96	144	123
3 *Barry Ranch Hot Springs	88	200	X	T	T	Andesite, andesitic tuff-breccia, and rhyolite	153	146	81	140	131
4 Hunters Hot Springs	96	2,300	T	T	T	Alluvium, andesite, and andesitic tuff-breccia	157	149	98	143	114
5 *Summer Lake Hot Spring***	43	75	T	T	--	Alluvium, andesite, andesitic tuff-breccia	134	130	22	112	149

Table 3.--Geologic setting and estimated thermal aquifer temperatures of selected hot springs--Continued

Spring	Spring temperature (°C)	Flow (lpm)	Gas	Spring deposits		Rock type at the spring	Estimated thermal aquifer temperature				
				$CaCO_3$	Silica		Silica conductive	Silica adiabatic	Na-K	Na-K-1/3ca	Na-K-4/3ca
Lane County											
1 Belknap Hot Springs**	71	300	--	--	--	Olivine basalt	135	131	56	114	82
2 Cougar Reservoir Hot Spring**	44	200	--	--	--	Andesite, basalt, and basic tuff-breccia	89	92	38	95	49
Malheur County											
1 *Unnamed hot springs (near McDermitt)	52	750	T	--	--	Basalt	118	118	3	91	105
2 Unnamed hot springs (at Three Forks)**	34	4,000	--	--	--	Basalt	95	97	52	100	44
3 *Unnamed hot springs (near Riverside)	63	200	T	T	--	Andesite	142	137	98	138	97
4 Beulah Hot Springs	60	50	T	T	X	Vitric tuff	169	159	76	125	86
5 Neal Hot Springs	87	90	T	T	X	Basalt	173	162	164	181	151
6 *Unnamed hot springs (near Little Valley)***	70	550	T	T	T	Basalt and andesite	145	139	51	119	109
7 Mitchell Butte Hot Spring**	62	60	--	T	--	Volcanic arkose	133	130	33	100	72
Marion County											
1 Breitenbush Hot Springs	92	3,400	--	X	--	Andesite	127	124	103	149	128
Umatilla County											
1 Lehman Springs***	61	275	X	T	--	Andesite	98	98	28	97	73
Union County											
1 Medical Hot Springs**	60	200	X	T	--	Basalt	125	123	91	125	67
2 Hot Lake	80	1,500	T	T	--	Basalt and mylonite	102	103	53	115	90
Wasco County											
1 *Kahneeta Hot Springs (Kah-Ne-Tah)	52	200	T	T	--	Rhyolite, andesite, basalt, and tuffs	139	135	17	103	121

* Mixed waters

** Temperature estimates based on the solubility of cristobalite improve the agreement between the silica and cation geothermometers at Radium Hot Springs (72°C), Ritter Hot Springs (70°C), Olene Gap Hot Springs (84°C), Belknap Hot Springs (84°C), Cougar Reservoir Hot Springs (51°C), the unnamed hot springs near Three Forks (39°C), Mitchell Butte Hot Springs (83°C), and Medical Hot Springs (74°C). Solubility data from Fournier and Rowe (1962).

***Temperature estimates based on the solubility of chalcedony improve the agreement between the silica and cation geothermometers at Austin Hot Springs (95°C), the unnamed hot springs near Little Valley (112°C), Summer Lake Hot Springs (107°C), and perhaps, Lehman Hot Springs (68°C). Solubility data from Fournier (1973).

Table 4.--Age of bedrock and geologic coverage of each spring

Spring	Age of bedrock	Geologic reference
	Baker County	
1 Radium Hot Springs (well)	Quaternary alluvium, Late Cretaceous diorite, and Permian greenstone	Gilluly (1937)
	Clackamas County	
1 Austin Hot Springs	Pliocene to Holocene mafic flows and perhaps pyroclastic rocks	Peck, Griggs, Schlicker, Wells, and Dole (1964)
	Grant County	
1 Weberg Hot Spring	Lower and Middle Jurassic sandstone and volcanic rocks	Brown and Thayer (1966)
2 Blue Mountain Hot Springs	Miocene and Pliocene andesite flows	Brown and Thayer (1966)
3 Ritter Hot Springs	Miocene and Pliocene basalt flows	Brown and Thayer (1966)
	Harney County	
1 Unnamed hot spring (Trout Creek)	Quaternary alluvium, Miocene to Pliocene basalt, andesite, and rhyolite flows	Walker and Repenning (1965)
2 Hot Lake	Quaternary alluvium and playa deposits	Walker and Repenning (1965)
3 Unnamed hot spring (near Hot Lake)	Quaternary alluvium and playa deposits	Walker and Repenning (1965)
4 Alvord (Indian) Spring	Miocene rhyodacite, basalt, and andesite	Walker and Repenning (1965)
5 Mickey Springs	Miocene andesitic tuff-breccia, basalts, and andesites	Walker and Repenning (1965)
6 Unnamed hot spring (near Harney Lake)	Pliocene basalts, tuffs, and welded tuffs	Walker and Swanson (1967); Greene, Walker and Corcoran (1972)
7 Crane Hot Springs	Quaternary alluvium, Pliocene and Pleistocene pyroclastic rocks, and Pliocene basalt and andesite	Leonard (1970); Greene, Walker, and Corcoran (1972)
	Klamath County	
1 Olene Gap Hot Springs	Pliocene and Pleistocene basalts and associated pyroclastic rocks	Peterson and Groh (1967)
	Lake County	
1 Fisher Hot Springs	Quaternary alluvium and Miocene to Pliocene olivine basalt	Walker and Repenning (1965)
2 Crump (Charles Crump's Spring)	Quaternary alluvium and Miocene to Pliocene olivine basalt	Walker and Repenning (1965); Peterson (1959)
3 Barry Ranch Hot Springs	Oligocene(?) and Miocene basalt or andesite flows, tuff-breccia, tuff, and tuffaceous rocks	Walker (1963)

Table 4.--Age of bedrock and geologic coverage of each spring--Cont'd

Spring	Age of bedrock	Geologic reference
4 Hunter Hot Springs	Quaternary alluvium, Quaternary to late Tertiary basalts and andesites, middle Tertiary tuffs	Walker (1963)
5 Summer Lake Hot Spring	Tertiary and Quaternary sedimentary rocks overlying Tertiary andesite flows	Walker (1963)
	Lane County	
1 Belknap Hot Springs	Pliocene to Holocene basic volcanic flows and pyroclastic rocks	Peck, Griggs, Schlicker, Wells, and Dole (1964)
2 Cougar Reservoir Hot Spring	Miocene mafic to intermediate flows, tuffs, and tuff-breccias	Peck, Griggs, Schlicker, Wells, and Dole (1964)
	Malheur County	
1 Unnamed hot springs (near McDermitt)	Quaternary alluvium, Tertiary and Quaternary pediment gravels, and Miocene volcanic rocks	Walker and Repenning (1966)
2 Unnamed hot springs (at Three Forks)	Miocene and Pliocene volcanic flows and tuffs	Walker and Repenning (1966)
3 Unnamed hot springs (near Riversdie)	Miocene basalt	Walker and Repenning (1965)
4 Beulah Hot Springs	Miocene and Pliocene vitric tuff	Greene, Walker, and Corcoran (1972); Bowen (1956)
5 Neal Hot Springs	Miocene(?) volcanic flows	Walker (1973)
6 Unnamed hot springs (near Little Valley)	Pliocene basalt and sedimentary volcanic rocks	Corcoran, Doak, Porter, Pritchett, and Privrasky (1962)
7 Mitchell Butte Hot Spring	Pliocene conglomerate, sandstone, and siltstones	Corcoran, Doak, Porter, Pritchett, and Privrasky (1962)
	Marion County	
1 Breitenbush Hot Springs	Miocene basalt flows, tuff-breccias, and tuffs, near an area of propylitically altered rock	Peck, Griggs, Schlicker, Wells, and Dole (1964)

Table 4.--Age of bedrock and geologic coverage of each spring--Cont'd

Spring	Age of bedrock	Geologic reference
	Umatilla County	
1 Lehman Springs	Miocene basalt	Wagner (1954)
	Union County	
1 Medical Hot Springs	Miocene basalts and andesites, Permian and Triassic metavolcanic and metasedimentary rocks	Walker (1973)
2 Hot Lake	Miocene basalt	Hampton and Brown (1964)
	Wasco County	
1 Kahneeta Hot Springs (Kah-Ne-Tah)	Oligocene and Miocene rhyolites and tuffs	Waters (1968); Hodge (1941)

Chemical Character of the Ground Water

General Character

The ground water in the Baker Valley area in general does not contain excessive amounts of dissolved material. On the average it is slightly to moderately hard, some of it being very hard, and most of it low in chloride and free of odor and color.

The chemical studies and observations were based on 108 relatively complete chemical analyses furnished by the Bureau of Reclamation (see table 4). In addition, samples of ground water from approximately 307 wells and springs were analyzed by field methods for hardness and chloride content (see tables 1 and 2).

Temperature

The average ground-water temperature in the upper 100 feet of the earth in Baker Valley is approximately 50° F. Water encountered at greater depth commonly is a little warmer, temperature increases about 1.8° F. per 100 feet of depth. Ground-water temperatures too high to be accounted for by normal earth-temperature gradients are found in wells 9/40-16G1 and -16H1, which have temperatures of 76° and 79° F., respectively. These wells are located at the eastern outskirts of Baker, and the temperatures are comparable to that of the water in nearby wells 9/40-15G1 and -15G2, which are reportedly drilled in the volcanic rocks of Tertiary age. The high temperature of the ground water may be due to the location of the wells near a fault zone. At the northern end of Baker Valley, just north of Haines, a number of hot springs, developed as a resort area, occur near a fault zone in the granodiorite of the Coyote Hills.

Although analyses were not made for consecutive summer and fall months for any of the wells, it seems reasonable to surmise that near the surface the sodium concentration continues to increase through the late summer and fall until the advent of the seasonal recharge when the annual cycle is completed.

Boron is one of the important chemical constituents commonly found in low concentrations in natural waters. It is an essential element for normal plant growth but in excess of the desirable concentrations is likely to be injurious to plant life. Crops sensitive to boron cannot tolerate concentrations much greater than one part per million.

The boron content is low in most ground and surface water in the valley area and the waters that do have high concentrations are those which also have high sodium percentages. The maximum boron concentration of any analyzed samples of ground water in Baker Valley is 1.88 parts per million. That concentration was shown by an artesian well that obtains its water from volcanic rocks of Tertiary age at the southeast edge of the valley. Baldock Slough, at the bridge crossing in the southeast corner of sec. 15, T. 9 S., R. 40 E., showed a concentration between 2.14 and 3.28 parts per million through April, May, and June (see table 4) but this is stagnant water and represents exceptional conditions. Water from Sam-O Spring has a concentration of 1.84 parts per million. It is probable that the flow of Sam-O Spring and possibly other unknown ground-water increments enriched by evaporation is largely responsible for the concentration of boron in the slough at that place. Those high boron waters would be of doubtful quality for the irrigation of such crops as potatoes, wheat, barley, and lima beans, since these crops are only semitolerant to boron and will not stand concentrations of much more than two parts per million. These waters would probably be suitable for sugar beets, common garden vegetables, and alfalfa, as those plants are more tolerant of boron.

Table 2.- Records of representative springs in Baker Valley, Baker County, Oreg.

Location	Owner or occupant of property	Name	Topography 1/ and altitude (feet above sea level)	Water-bearing material	Occurrence	Yield		Use 2/	Temperature (F.)	Total hardness of water as $CaCO_3$ 3/ 4/	Chloride content of water as Cl 4/	Remarks
						Gallons per minute	Date					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
7/39-28C1	Chris Lee	Radium Hot Springs	Ap-3311	Diorite	May be on trace of regional block fault		Oct. 1, 1928 July 2, 1949	Bath	135	5	12	Has slight odor of hydrogen sulfide gas; used to supply public swimming pool.
8/38-12F1	Gus D. Sachos	None	T-3558	Terrace deposits	Along contact between pervious sand and impervious clay stratum.	2	May 11, 1949	D, S	47	105	4	Little fluctuation reported.
9/39-6K1	E. L. Bowman	None	S-3800	Alluvial fan deposits	Steep alluvial fan	1	Apr. 22, 1949	D, S	46	90	2	Water table spring; very little fluctuation.
9/39-11E1	C. W. Gardner	None	T-3464	Terrace deposits	Contact between valley alluvium and terrace sediments	7	Apr. 20, 1949	D, S	45	140	1	Located close to fault trace.
9/39-11J1	Frank Toney	None	S-3466	Volcanic rock	At foot of fault scarp	-	Apr. 18, 1949	D, S	54	85	5	Reported to have very constant flow.
9/40-1E2	Wm. Peyron	None	Ap-3400	Valley deposits	Apparently situated on trace of major fault	½	May 12, 1949	S	66	30	10	One of five spring seeps in immediate vicinity.
9/40-16J1	City of Baker	Sam O Springs	Ap-3463	do.	May be on trace of major fault	300	Apr. 13, 1949	N	80	55	11	Water flows into meadow pasture; formerly supplied water to natatorium.
9/40-20E1	R. D. Putnam	None	S-3555	Terrace deposits	May be on trace of fault	5	Apr. 19, 1949	S, Irr	50	195	17	Flow greatest from June to December; developed by augering horizontally into spring seep in edge of terrace.
9/40-32E1	Unknown	None	S-3496	do.	Contact of gravel on basalt at edge of terrace; possibly near fault trace.	10	May 10, 1949	D, S	62	50	3	

1/ Ap, alluvial plain; S, hillside or slope to major valley; T, terrace. 2/ D, domestic; Irr, irrigation, N, none; S, stock. 3/ Determined in field by soap method. 4/Parts per million.

Unpublished records subject to revision

Table 1.- Records of representative wells- Continued

Well # (1)	Owner (2)	Topography and aprox altitude (3)	Type (4)	Depth (ft) (5)	Diameter (in) (6)	Depth of casing (ft) (7)	Depth to top (ft) (8)	Thickness (9)	Character of material (10)	Ground water occurrence (11)	ft below land surface datum (12)	Date (13)	type of Pump, yield g/m (14)	Use (15)	CaCO3 ppm (16)	Cl- ppm (17)	Remarks (18)
T.9 3, R. 40 E.- Continued.																	
10H2	Clarence Hatfield	Ts-3423	Dn	23.8	5					Unconfined	12.76	Apr. 14, 1949	P	D, S	90	32	
10H3	do.	Ts-3425	Dg	11.9	16-24		8	2	Coarse gravel	do.	9.69	do.		S	35	9	
10J1	Sunny Slope Co.	Ts-3425	Dr	43.0	6				Fine sand	do.	17.57	do	P	N	135	106	Pumps some fine sand.
11B1	do.	Ts-3432	Dr	54.6	6					do.	31.26	May 12, 1949	P	N			
11D1	Gus Gekus	Ts-3401	Dr	350	6					do.	11-12	Mar. 25, 1949	C	D, S	405	48	
15G1	Sunny Slope Co.	Ts-3473	Dr	740	14		700	40	Basalt	Confined	18	Mar. 24, 1949	T, 2200	Irr			Drilled 16-inch, and gravel-packed around 14-inch casing; drawdown of 16 feet reported. See table 4 for chemical analysis.
15G2	do.	Ts-3466	Dr	740	18	60	700	40	do.	do.	10.79	do.	T, 1500	S,	57	6	Drawdown of 16 feet reported; water has slight odor of hydrogen sulfide; temperature reported to be 73° F.
16A1	John Everson	Ap-3422	Dg	11.5	72		4	7.5	Coarse gravel and sand	Unconfined	7.46	Apr. 14, 1949	C	Irr	115	31	Owner reports well will pump dry in 15-20 minutes with 2-3/4-horse power centrifugal pump.
16B1	W. A. Bobisud	Ap-3423	Dg	14.2	48				Gravel	do.	10.77	do.		N	235	29	
16G1	William Wendt	Ap-3428	Dr	530	20-4				Sand	Confined	6.54	do.	T	Irr	50	11	Water has slight taste of hydrogen sulfide; temperature of 76° F. Reportedly flowed at 80 gallons per minute when drilled.
16G2	Stewart Sullivan	Ap-3428	Dr	462.0	6					do.	6.00	May 12, 1949	T	Irr	75	12	
[illegible]H1	Baker Packing Co.	Ap-3421	Dr	600	8					do.	Flowing	Apr. 13, 1949		S	40	11	Flow estimated at 2 gallons per minute; water has slight odor of hydrogen sulfide gas; temperature of 79° F. See table 4 for chemical analysis.

Unpublished records
subject to revision

Table 4.- Analyses of water from wells, springs, and streams- Continued

Number	Sample number BR	Source	Date	Specific conductance	Dissolved solids	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Carbonate (CO_3)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Boron (B)	pH	Percent sodium
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
9/40-7G2	WX-6	Drilled well about 2 miles northwest of Baker, owned by Clyde Ward, for irrigation.	July 1947	220		30.20 1.51	9.27 0.76	13.11 0.57	4.69 0.12	0.00	143.35 2.35	16.32 0.34	3.55 0.10	Tr.	7.0	19
9/40-8D1	V-5	Dug well about 2½ miles north of Baker, owned by John Kirkland, for domestic and stock use.	June 1947	380		38.40 1.92	11.71 0.96	40.71 1.77	1.17 0.03	0.00	170.80 2.80	44.16 0.92	17.75 0.50	0.04 .004	7.2	38
9/40-8G1	L (1)	Dug well about 2 miles north of Baker owned by Elmer Satterberg, for irrigation.	[illegible] 1946	331	220	35.40 1.77	11.59 0.95	23.92 1.04	0.00	0.00	164.09 2.69	15.36 0.32	12.78 0.36		6.8	28
	(2)	do.	February 1947	340	229	34.20 1.71	12.81 1.05	1.12		0.00	143.35 2.35	26.40 0.55	15.98 0.45		7.2	29
	(3)[2/]	do.	April 1947	290	232	30.60 1.53	8.42 0.69	65.32 2.84	5.08 0.13	0.00	142.13 2.33	21.12 0.44	12.43 0.35	0.12 .011	7.2	55
	(4)	do.	May 1947	210		23.20 1.16	8.66 0.71	15.41 0.67	2.35 0.06					0.00	8.1	2[illegible]
	(5)[2/]	do.	June 1947	250		30.80 1.54	10.61 0.87	19.32 0.84	0.39 0.01	0.00	158.60 2.60	13.44 0.28	0.00	Tr.	7.2	2[illegible]
9/40-8P1	T-5	Dug well in Baker at intersection of H Street and U. S. Highway 30, owned by Omar Bowers, for irrigation purposes.	do.	470		45.60 2.28	15.25 1.25	52.67 2.29	1.96 0.05	0.00	195.20 3.2	62.88 1.31	31.95 0.9	0.12 .011	7.4	39
9/40-15G1	R-5	Drilled well about 2 miles northeast of Baker, owned by Sunny Slope Co., for irrigation.	do.	600		12.00 0.60	7.56 0.62	174.57 7.59	9.78 0.25	0.00	475.80 7.8	12.00 0.25	14.20 0.40	1.88 .177	8.1	84
9/40-16H1	S-5	Drilled well about 1 mile east of Baker, owned by the Baker Packing Co., for stock use.	do.	650		14.20 0.71	7.32 0.60	172.27 7.49	9.78 0.25	0.00	542.90 8.90	0.96 0.02	17.75 0.50	1.64 .153	7.9	8[illegible]
9/40-16J1	Q-5	Sam-O Spring about 1 mile east of Baker, owned by the city of Baker but not in use.	do.	650		13.00 0.65	14.83 1.22	184.92 8.04	10.17 0.26	0.00	573.40 9.4	1.44 0.03	17.75 0.50	1.84 .170	8.0	79

2/ [illegible]

Unpublished records subject to revision

ppm top line
milligram equivalents

Cove Springs
Hot Lake Springs.

March 18, 1932. The average discharge for the 49-year period of record is 384 cfs. The period of large discharge is short and in most years is limited to the months February through May. The months July through October of most years are months of low streamflow. During that low-flow period, most of the creeks draining the older metamorphic and intrusive igneous rocks of the Elkhorn Range are dry. The creeks draining areas where the Tertiary volcanic rocks overlie the older metamorphic and igneous rocks maintain a rather constant, though small, flow even in the driest part of the summer. Other spring outflow that enters the river does so in the lower reaches of the creeks and in the part of the main stem that is underlain by the basaltic lava rocks.

The creeks in the Grande Ronde River drainage area above La Grande have two distinct drainage patterns. The creeks that drain the older metamorphic and igneous rocks have a dendritic (tree-like) drainage pattern, whereas the creeks and streams draining the layered Tertiary volcanic rocks have a trellis (roughly rectangular) drainage pattern.

The upland areas west and east of La Grande are underlain by lava rocks that discharge ground water from interflow zones. This outflowing ground water appears as numerous seeps and small springs on slopes and in declivities. Thus, moderate supplies of water are available for livestock and wildlife in these upland areas. Similar seeps and springs feed water to the lower reaches of the creeks and form the dry-season "base flow" which discharges from the uplands.

Many springs issue from the foot of the escarpments around the edge of the valley floor. Only the hot spring at Hot Lake, the Cove Spring, and a few others discharge significant amounts of water from single orifices. The lower parts of the alluvial fans contain many spring and seep areas, where the ground-water recharge farther up the fan emerges and drains to creeks and drainage ditches.

In general, the chief characteristics of the runoff of the upper Grande Ronde basin are the wide seasonal variation in discharge and the moderately high total water yield in comparison to most other streams in eastern Oregon.

GEOLOGY OF THE AREA

GENERAL DESCRIPTION AND RELATIONSHIP OF THE ROCK UNITS

The oldest rocks exposed in the upper Grande Ronde basin are pre-Teritary in age and consist of metamorphosed sedimentary and volcanic rocks that were intruded by igneous masses. These igneous intrusive rocks are a part of the Bald Mountain batholith described by Lindgren (1901, p. 574–594) and Taubeneck (1957), and

Geol and Ground Water Resources, Upper Grande Ronde River Basin, Oregon USGS WSP 1597

d around the Grande Ronde
heastward as the northwest
r basin. This broad moun-
Grande Ronde River basin is
es long, north to south; from
s northward for another 20
15 miles. It ranges in alti-
e upland surface is dissected
and only small parts of the
e ridges. The greater part
early maturity of the erosion
rd slope of the mountainous
Blue Mountains, broad cross
itude and structural pattern
s of the Blue Mountain up-
e Elkhorn Range of the Blue
nwest of the area; the east-
llowed by the Grande
Ronde Valley, and the diverse
f Mount Emily and vicinity

ll the drainage from the Blue
Ronde River in the prominent
nde Ronde syncline and enters
n stem of the Grande Ronde
north slope of the Elkhorn
ives the discharge of Chicken,
. and lesser creeks from the
Railroad Canyon, Fivepoint,
Farther north, Willow Creek
Grande Ronde River in the
hillips Creek drains the Blue
River in Indian Valley.
ntermittent, flowing strongly
and during the spring thaw
nonths. During late summer
rate pools and local stretches
nd more deeply incised creeks
charge, even during the sum-
ge is largely reduced to out-
"dry" creeks are underlain by
surface underflow passes.
e [illegible] at La Grande ranges
per second), which occurred
8,880 cfs, which occurred on

CHEMICAL QUALITY OF GROUND WATER

Except in a few places the quality of ground water in the Grande Ronde River basin is excellent. All waters sampl potable and within the desirable ranges of hardness and salin public supply and most industrial uses. Samples of water fi wells and 3 springs within the area were analyzed by the Geo Survey. Chemical analyses of water samples from two well obtained from other sources. These 24 analyses are shown o 4, along with 2 analyses of water from the Grande Ronde Riv

HARDNESS

Certain constituents, especially calcium and magnesium, in cause hardness, which affects the use of detergents and dy causes the deposition of scale when the water is heated, an sumes soap in laundry operations. Water has been classified by the Geological Survey (1953) according to the following scale of hardness:

Hardness as $CaCO_3$ (parts per million)	*Class*
0–60	Soft
61–120	Moderately hard
121–200	Hard
More than 200	Very hard

The hardness of the water sampled in the upper Grande Ronde River basin ranged from a high of 156 ppm in well 3/39–7N1 to a low of 4 ppm in spring 3/40–22D1. The average hardness of the waters from 5 wells in the basalt is 18, whereas that of the water from 16 wells in the alluvium is about 93. Of the 3 springs sampled, the water from the 2 hot springs has an average hardness of 7 ppm, whereas the water from the cold spring has a hardness of 36 ppm.

CHLORIDE, SULFATE, AND NITRATE

The chloride content of the water sampled ranged from 0.2 to 129 ppm. That of water from the basalt averaged 2.0 ppm, and that of water from 16 wells in the alluvial fill, 4.2 ppm. The water of well 3/39–7N1, which was drilled into lacustrine deposits of the valley fill, contains 28 ppm of chloride. Hot Lake Spring (4/39–5K1) has the highest chloride concentration, 129 ppm, of all waters sampled in the Grande Ronde basin.

The sulfate and nitrate concentrations in the water analyzed are generally low. The highest sulfate concentration (56 ppm) occurs in the waters of Hot Lake Spring, and the lowest (0.3 ppm) occurs in well 1N/38–21C1. The average sulfate content of 17 ground waters sampled (excluding that of spring 4/39–5K1) is 5.4 ppm.

The highest nitrate concentrations in the 24 water samples so analyzed are 50 ppm for a sample from well 1/39–4N1 and 49 ppm in well 1/39–17L1. Both wells are north of Imbler and are drilled in

TABLE 4.—*Chemical analyses of water from wells and springs of the upper Grande Ronde River basin*—Continued

Well, spring, or river Date of collection	2/39-30H1 4/17/58	3/38-5M1 1/21/55 [a]	3/38-5M2 1/21/55 [a]	3/38-6H2 5/10/57	3/38-8K1 7/31/57	3/39-7N1 7/31/57	3/39-30B1 7/31/57	3/40-22D1 6/2/57 Cove	4/39-5K1 5/10/57 Hot Lake	4/39-11H1 8/22/57	4/40-7H1 7/31/57	Grande Ronde River 1 mi. below Five Point 4/19/58	Grande Ronde River at Rhinehart 4/19/58
(Well, spring, or river)	Well	Well	Well	Well	Well	Well	Well	Spring	Spring	Well	Well	River	River
Temperature (°F)	50	77	80	81		54	52	85	180	58		40	45
Silica (SiO_2)	53	72	84	71	43	42	44	29	81	34	36	31	31
Iron (Fe):													
Total	.02	Tr.	Tr.	.03				.03	.00	.00		.38	.49
In solution				.02				.00	.00	.00			
Manganese (Mn)	.02	0	0	.01						.03		.02	.02
Calcium (Ca)	30	4.8	5	10	30	36	14	1.6	3.6	11	25	5.0	5.5
Magnesium (Mg)	13	1.3	.3	.2	13	16	6.6	.0	.3	4.3	12	1.6	1.8
Sodium (Na)	13	30	27	19	15	87	15	30	128	25	16	3.1	3.4
Potassium (K)	1.9	5	5	5.0	4.0	5.8	4.6	.5	2.7	4.2	5.5	1.5	1.7
Bicarbonate (HCO_3)	185	63	(?)	84	135	134	118	5	0	104	181	31	34
Carbonate (CO_3)	0		0	0	0	0	0	32	31	0	0	0	0
Hydroxide									4				
Sulfate (SO_4)	1.2	4.8	3.3	4.5				8.8	56	7.4		.9	1.2
Chloride (Cl)	1.5	2.1	3.2	1.0	10	28	.8	5.0	129	8.8	.8	.2	.5
Fluoride (F)	.1	.5	.5	.5				.3	1.6	.3		.0	.0
Nitrate (NO_3)	2.0			.0	19	.4	.4	.0	.0	.4	.3	.3	.6
Boron (B)	.03							.08				.01	.02
Dissolved solids:													
Calculated	207	166	163					109		146		59	63
Residue at 180°C	201			146	238	421	146	112	461	152	186	76	79
Hardness as $CaCO_3$	130	15	18	26	128	156	62	4	10	45	112	19	21
Noncarbonate hardness	0			0	17	46	0	0	0	0	0	0	0
Sodium-adsorption ratio (SAR)	.50	3.1	3.1	1.6	.57	3.0	.82	5.3	12.4	1.6	.66	1.7	1.8
Specific conductance (micromhos at 25°C)	286			146	327	658	188	150	676	207	280	54	61
pH	8.2	7.9	7.9		7.1	8	7.4	9.8	9.5	8.0	7.5	7.2	7.2
Color	0	3	4									35	40

[a] By Oregon State Board of Health.

ppm

Bingham Spring is 9 miles North of the northern boundary of the study Area.

for ground water in addition to that obtained from springs and shallow wells tapping the water perched in the soil on top of the basalt.

Locally, irregularities in the dip of the basalt flows and in other structural features cause the ground-water conditions to be favorable for the drilling of wells. The upland community of Meacham is located on a slightly eastward-dipping downwarp and has several drilled wells that are reliable sources of water. One 279-foot drilled well in the basalt (1/35–10C1) flowed 25 gpm (gallons per minute) when first drilled and was test pumped at 314 gpm with a 24-foot drawdown of the water level. Several other drilled wells in the vicinity yield reliable domestic supplies. Only about 5 miles to the south, however, the community of Kamela lies near the crest of the Blue Mountain anticline. Here a 996-foot drilled well in the basalt (1/35–36N1) was abandoned because of low yield and deep water level.

Numerous springs discharge in scattered localities in the upland districts. Most of them are at or just below the rims of the upland plateaus and yield less than 2 gpm. Many of them discharge water from the soil overlying the basalt. A few emerge from fractures or scoria in the second or third lava flow below the rim. Water from one of these minor springs, 2/28–23E1, was analyzed by the Geological Survey (table 3). That spring, owned by W. W. Weaver, discharges from broken basalt in the canyon of an unnamed tributary of the South Fork of Butter Creek (pl. 1).

Only one "hot" spring is known to exist in the area. This is Bingham Spring (3N/37–18H1), whose water has a temperature of 94° F and issues from a fractured zone in the lava in the south wall of the canyon of the Umatilla River. This spring discharges about 80 gpm from 3 openings, 2 that are close to each other and about 50 feet above river level, and another, the smallest, that is about 50 feet farther downstream and about 10 feet above river level. The spring lies just west of the axis of the Blue Mountain anticline.

BLUE MOUNTAIN SLOPE

As the basalt layers in the Blue Mountain upland lie generally horizontal and water has little opportunity to percolate into them, the annual precipitation is removed largely by evapotranspiration and surface runoff. As the streams flow northward and westward from the highland area and cross the beveled edges of the northwestward-dipping basalt of the Blue Mountain slope, water has an opportunity to enter the scoriaceous interflow zones. From there it percolates generally northwestward under the Pendleton plains and the Umatilla lowland.

Ground water occurs in wells in the Blue Mountain slope under a variety of conditions. In some places water is present in large quan-

Geology and Ground Water of the Umatilla River Basin, Oregon
Hogenson, GM
USGS WSP 1620

r temperature with increasing depth

and other derived information for
ed below:

an th[1] uifer et)	Temperature of the water (°F)	Mean annual[2] temperature (°F)	Temperature difference (°F)	Temperature increase (°F per 100 ft of depth)
221	56	48	8	3.6
126	55	48	7	5.6
465	66	52	14	3.0
348	64	52	12	3.4
301	65	52	13	4.3
160	55	52	3	1.9
750	68	52	16	2.1
355	64	48	16	4.5
	65	48	17	
427	61	48	13	3.0
59	62	48	14	24
421	51	49	2	.1
580	56	49	7	1.2
194	58	49	9	4.6
450	66	51	15	3.3
450	65	48	17	3.8
540	58	50	8	1.5
157	62	50	12	7.6
438	76	50	26	5.9
699	71	50	21	3.0
311	61	50	11	3.5
770	71	50	21	2.7
272	63	50	13	4.8
240	61	50	11	4.6
	58	50	8	12
	58	50	8	3.2

oth of a point halfway between the top and bottom of the
n the water-bearing rock was not reported, it is taken as the
water level and the bottom of the well.
m the elevation of the well site and the proximity of the site
rmiston, McNary, Meacham, Pendleton, Pilot Rock, Ukiah,
ratures for these stations were computed from weather records

ded for the water in wells, the highest
in the Umatilla lowland, the lowest was
the Pendleton plains, and the average
was 62.2° F.

e average rate of increase in temperature
to 2° F per hundred feet. The tempera-
of depth is expected to average about
al temperature for that locality. This
tly is not entirely valid for the Columbia
a River basin, as water from wells 2N/
how temperatures greater than the mean
ean depth is less than 100 feet. For this
ts in the foregoing table were computed
rface.

Of the 26 wells for which data are complete, only 4 had temperature gradients of less than 2° F per hundred feet. Of these, 2 are in the Pendleton plains area, 1 is in the Umatilla lowlands, and the other one is at the foot of the Blue Mountain slope.

Of the wells that show unusually high thermal gradients, more than 5° F per 100 feet of depth, nearly all are located in areas that contain lines of significant tectonic deformation. Well 1/27–18M1 is on the Blue Mountain slope; 4N/28–10F1 and 10P1 are near the axis of the Service anticline; and 5N/32–31F1 is high on the Horse Heaven anticline. Well 2N/29–30H1 is in a trough between the Service and Rieth anticlines.

Possibly well 2N/29–30H1 may be bridged or obstructed in such a manner that only part of the depth to its water-bearing zone could be measured; thus, an erroneous depth measurement may account for the apparently very high temperature of the water, which may come from much greater depth.

Near Pilot Rock, where the mean annual temperature for the years 1945–54 was 51.8° F, the water temperatures listed are for wells drawing water from different depths. One well (1/32–19Q1) yields water at 55° F from an aquifer whose mean depth is 160 feet, and another (17G1) yields water at a temperature of 65° F from an aquifer whose mean depth is 301 feet. A third well (9L1) yields water at a temperature of 66° F, mainly from an aquifer whose mean depth is 465 feet, and a fourth (23J1) yields water at 68° F from an aquifer whose mean depth is 750 feet. These four wells would indicate a temperature gradient of 1° F per 50 feet of depth to 160 feet, 1° F per 14 feet of depth from 160 to 301 feet, 1° F per 164 feet of depth from 301 feet to 465 feet, 1° F per 142 feet of depth from 465 feet to 750 feet; the overall gradient would be 1° F per 47 feet of depth from the atmospheric temperature to the temperature of the water at 750 feet. If these data were plotted temperature against depth, the result would not be a smooth curve. The roughness of the curve seems to indicate that the ground water from the main producing zone of some wells may be mixed with water from higher or lower water-bearing zones, or that the rock has different temperature zones within it.

The warmest ground water known in the Umatilla River basin issues from Bingham Spring (3N/37–18H1) in the canyon of the Umatilla River near the crest of the Blue Mountain anticline. Hot springs are commonly considered to represent water that has risen along faults or other conduits from deeper strata. Using a temperature gradient of 1° F for each 50 feet of depth and starting from a mean annual temperature of 50° F, the 94° F temperature of the spring would require that its water rise without temperature loss from a depth of some 2,000 feet. However, the nearest recognizable fault is about half a mile downstream from the spring, and the position of the spring near the crest of the anticline makes it difficult to explain the source of sufficient hydraulic head to cause the water to rise in such volume from such a depth. The water possibly could have reached a depth of 2,000 feet in its percolation to the springs if it came from the south and passed under the high mountain mass south of the spring. Fractures along the crest of the anticline may be open, thus creating a greater vertical permeability than is common. If water were traveling in a straight line from the junction of the south fork of the Umatilla River and Thomas Creek (altitude about 3,500 feet) to Bingham Spring (altitude about 2,200 feet) the water would have to descend vertically 1,300 feet in the basalt and would pass under a mountain mass which reaches an altitude about 4,500 feet above sea level, or 2,300 feet above Bingham Spring.

Another possible source of the heat is residual heat in an igneous intrusive mass near the surface. However, this hypothesis is doubted, because only one hot spring is known and because the only other possible indication of the presence of such an igneous mass is the high concentration of boron in the water from this spring. The possibility exists that fault zones may contain abnormally warm rock due to mechanical disruption of the rock during fault movements and may pass such heat on to the circulating ground water.

USE OF GROUND WATER

HISTORY OF GROUND-WATER DEVELOPMENT

There have been three major periods of ground-water development in the Umatilla basin. These correspond to periods of general increase in population, agriculture, and industry.

The earliest period of settlement in the area was characterized by little or no ground-water development. Prior to the termination of the Indian wars in 1857, the population was transient and consisted mostly of trappers, traders, small settlements of white stockmen and missionaries, and Indians. Most of the settlements were temporary and several were destroyed or the people were frightened away during the Indian wars. In 1863, gold mining was started in the Powder River valley to the southeast, and several ranches were started in the Umatilla area to raise cattle, sheep, and foodstuffs for the miners. During that time the ranches and settlements were widely scattered and relied mostly on surface or spring water for domestic and stock use and upon surface water for any irrigation.

The change in emphasis from stockraising to grain farming as the dominant industry took place between 1875 and 1900. By the end of that period, most of the Pendleton plains and much of the Umatilla lowlands were under cultivation. Many of the settlements and ranch

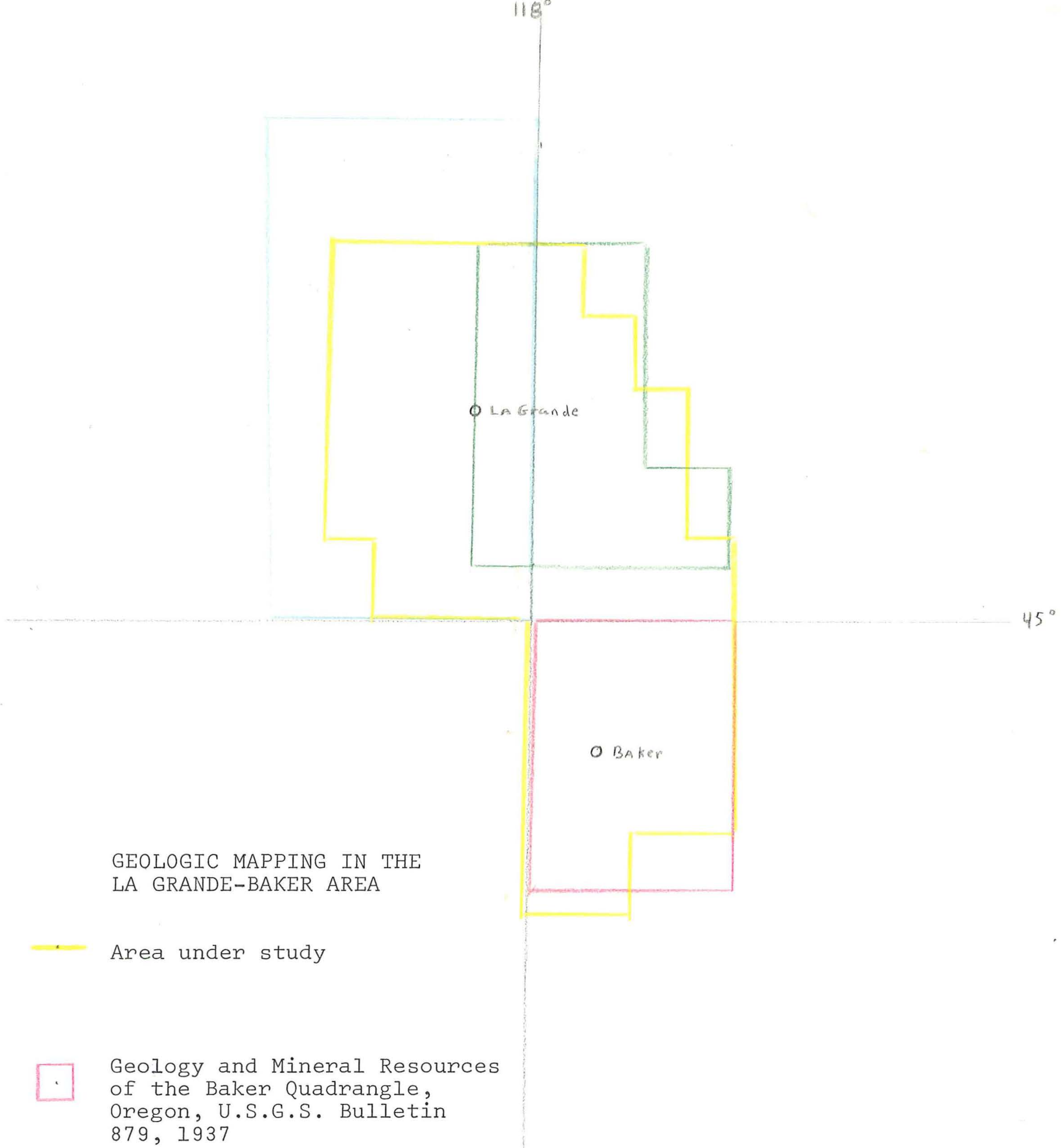
TABLE 3.—*Chemical analyses of water from wells and springs of the Umatilla River basin, Oregon*

[Chemical constituents in parts per million. Analysis by U.S. Geological Survey unless otherwise indicated]

Well or spring	Date of collection	Temperature (°F)	Silica (SiO_2)	Iron (Fe) Total	Iron (Fe) In solution	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Dissolved solids Sum	Dissolved solids Residue at 180° C	Hardness $AsCaCO_3$	Hardness Noncarbonate	Sodium-adsorption-ratio (SAR)	Specific conductance (micromhos at 25° C)	pH
1N/28-28D1	Apr. 28, 1953	64	70	0.2	-----	-----	15	5.7	40	5.2	163	0	0.6	15	0.1	0.4	0.23	233	225	61	0	2.2	285	8.1
1N/31-30B1	Apr. 27, 1953	----	66	.1	-----	-----	36	12	22	4.4	154	0	26	20	.4	9.9	.00	273	277	139	13	.8	378	7.8
1N/32-1D1	do	53	61	.0	-----	-----	18	6.8	20	3.2	130	0	5.6	4.5	.6	.9	.00	185	181	73	0	1.2	224	7.9
24R1	do	51	13	2.7	-----	-----	13	5.8	17	2.8	93	0	8.6	8.0	.3	.6	.01	115	118	56	0	.9	188	7.3
1N/33-7F1	do	56	68	.1	-----	-----	25	12	20	4.8	167	0	9.5	6	.5	1.5	.02	230	225	112	0	.8	296	7.7
2N/27-11H1	Apr. 28, 1953	61	66	.1	-----	-----	14	7.5	32	9.0	161	0	.8	9.5	.6	.2	.08	219	211	66	0	1.7	273	8.1
2N/32-2R1 [1]	Jan. 7, 1949	----	40	.01	-----	-----	27	7.6	31		130	0	21	26	.3	-----	-----	217		98				7.7
10F1 [2]	June 13, 1952	----	49	.03	0.01	-----	32	12	30	5.2	220	----	11	7.9	.2	2.9	.08	299	-----	129	0	1.2	385	7.8
35H1	Mar. 3, 1953	----	43	.06	.06	0.00	9.2	2.8	70	9.9	145	9	35	21	.7	.1	.01	272	-----	34	0	5.2	383	8.5
3N/27-36A1	Apr. 28, 1953	52	47	.0	-----	-----	47	16	58	5.4	333	0	14	9.5	.5	11	.03	372	376	184	0	1.9	571	7.4
3N/32-22C1	Mar. 3, 1953	----	49	-------	.11	.00	28	13	43	7.6	186	----	31	23	.7	3.2	.05	290	-----	123	0	1.7	433	8.0
[Bingham Sprgs.] 3N/37-18H1 [3]	Apr. 1, 1954	94	68	.20	.00	-----	14	3.5	133	7.6	64	9	.2	192	4.0	.2	10	464	-----	50	0	8	765	8.6
4N/27-22L1 [1]	Apr. 26, 1941	----	-----	.15	-----	-----	38	11	-----	-----	148	----	11	11	-----	-----	-----	-----	-----	140	----	-----	-----	7.7
4N/28-10P1 [4]	Aug. 3, 1950	76	-----	-----	-----	-----	-----	-----	-----	-----	-----	----	-----	14	.9	-----	-----	-----	329	66	----	-----	-----	8.4
11N1 [4]	Aug. 10, 1950	71	-----	-----	-----	-----	-----	-----	-----	-----	112	28	-----	23	1.7	-----	-----	-----	239	15	----	-----	-----	8.4
4N/31-9P1	Apr. 27, 1953	61	52	.1	-----	-----	18	9.1	41	8.7	173	0	18	7.8	.6	6.3	.02	247	248	82	0	2.0	346	8.0
4N/33-29K1	do	54	52	.0	-----	-----	65	30	25	2.6	236	0	32	45	.4	57	.01	425	436	286	92	.6	656	7.9
4N/34-6L1 [5]	-----	----	20	1.4	-----	-----	-----	-----	-----	-----	-----	----	-----	20	-----	-----	-----	-----	-----	132	----	-----	-----	-----
22K1	Apr. 28, 1953	----	49	.0	-----	-----	64	18	56	1.0	370	0	8.4	13	.5	20	.01	412	415	234	0	1.6	642	7.9
5N/32-31F1	Apr. 27, 1953	66	52	.0	-----	-----	2.8	2.2	106	11	224	0	42	23	.6	.3	.04	350	350	16	0	11	510	8.3
1/32-9L1	do	66	71	.0	-----	-----	28	10	22	5.5	167	0	13	8.5	.5	1.8	.01	243	240	111	0	.9	310	7.8
17G1 [6]	1946	65	*60	*.2	-----	-----	-----	-----	-----	-----	137	5	-----	-----	-----	-----	-----	-----	-----	-----	----	-----	-----	*7.7
23J1	Dec. 22, 1954	68	70	.0	-----	-----	22	6.3	24	5.6	154	----	7.9	5.0	.5	.3	.02	218	-----	81	0	1.2	263	7.9
2/28-23E1 [3]	Apr. 1, 1954	58	55	.08	.02	-----	26	5.8	22	3.9	144	----	7.0	6.0	1.0	4.4	.05	202	-----	89	0	1.0	274	8.1
3/30-29R2	Mar. 29, 1954	----	20	47	.0	-----	48	8.6	22	3.1	224	----	15	5.5	.8	.3	.06	234	-----	155	0	.8	395	7.9

[1] Analysis by Charlton Laboratories, Inc., Portland, Oreg.
[2] Lithium 0.0 ppm.
[3] Spring.
[4] Analysis by Oregon State Board of Health.
[5] Analysis by L. L. Meyers, Laboratory, Oakland, Ohio.
[6] Items marked with an asterisk were determined by Northwest Filter Co., Seattle, Wash. Other items in this analysis were determined by Perolin Co. of New York.

C



GEOLOGIC MAPPING IN THE
LA GRANDE-BAKER AREA

Area under study

Geology and Mineral Resources of the Baker Quadrangle, Oregon, U.S.G.S. Bulletin 879, 1937

Geology, Ground-Water Resources, Upper Grande Ronde River Basin, Oregon, U.S.G.S. WSP 1597, 1964

Geologic Map of the Pendleton Quadrangle, U.S.G.S. Map I-727

D

COUNTY DISTRICT PROPERTY NAME	Sec.	LOCATION Twnshp	 Range	Mineralization, Cinnabar, unless otherwise noted MODE OF OCCURRENCE	Production Flasks	OWNER
Baker County		South	East			
Clark Creek Prospect	21	12S	41E			
Connor Creek	34	11S	43E	In opalized sycnite	occurrence	Frank Butchart
Crater Chimney (Gold Crater)	25, 26	11S	39E		do	International Gold Corp.
Diadem and Brindle Horse	16, 17	10S	35E		do	Etta DiMantle
Hiller Chrome-Cinnabar Mine	9	14S	36E		do	Ed Hiller and Jim Demastus
Mulkey Cinnabar Claims (White wonder)	35, 36	9S	351/2E		do	L. Rand and C. Mulkey
Quicksilver and Easy Money claims	11	13S	45E		do	L. P. Kane and John Flynn
Sumpter Placer	20	9S	37E		do	

Within study area

From "Mercury Potential of the U. S."
Bureau of Mines Info Circular - 8252

COUNTY DISTRICT PROPERTY NAME	LOCATION Sec.	 Twnshp	 Range	MODE OF OCCURRENCE	Production Flasks	OWNER
Grant County		South	East			
Chandler and Haight Prospect	33	14S	31E		occurrence	P. F. Chandler C. P. Haight
Cinnabar Mountain Claim	18	14S	30E	On wall of 3-4 foot vein	do	H. J. Johnson J. C. Machency
Dead Horse Creek Prospect	30	14S	30E		do	
Gray Prospect	29	13S	28E		do	
IXL (Hidden Treasure)	10	10S	35E		do	Gertie O'Rourk
Paramount Quicksilver Mine	16	10S	35E	In brecciated zones in serpentinite	25	Inkerman Helmer
Red Boy Mine	10	9S	35E		occurrence	
Roba Quicksilver Mine (Deer Creek)	6	16S	29E	In fault gouge, cutting argillite	8	L. H. Roba
Susanville Placer	7	10S	33E		occurrence	
Wild Cut Basin		15S	33E		do	
York and Reynolds Prospect (Broadway)	7	16S	29E		do	

COUNTY DISTRICT PROPERTY NAME	LOCATION Sec.	 Twnshp ~~North~~	 Range ~~West~~	MODE OF OCCURRENCE	Production Flasks	OWNER
Malheur County		South	East			
Clay Cinnabar Prospect	26	15S	45E		occur-rence	
Hope Butte Prospect (Jordan and Riddle)	16,21, 22,27, 28	17S	43E	In tuffs and opalite	do	John Stringer
Lackey Cinnabar grp. Stan and Berry	22, 27	15S	45E		do	
Morton Mercury Prospect	18, 19	13S	42E	Crack filling, disseminated	do	Carl Morton