RESULTS OF THE 1992-1993 LOW-TEMPERATURE GEOTHERMAL ASSESSMENT PROGRAM IN COLORADO

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ABSTRACT

Previous assessments of Colorado's low-temperature geothermal resources were completed by the Colorado Geological Survey in 1920 and in the mid to late-1970s. The purpose of the 1992-1993 low-temperature geothermal resource assessment is to update the earlier physical, geochemical, and utilization data and compile computerized databases of the location, chemistry, and general information of the low-temperature geothermal resources in Colorado. A geothermal site is an individual well or spring within a geothermal area. The 1992-1993 assessment reports that there are 93 geothermal areas in the Colorado, up from the 56 reported in 1978; there are 157 geothermal sites up from the 125 reported in 1978; and a total of 382 geochemical analyses are compiled, up from the 236 reported in 1978. Six geothermal areas are recommended for further investigation: Trimble Hot Springs, Orvis Hot Springs, an area southeast of Pagosa Springs, the eastern San Luis Valley, Rico and Dunton area, and Cottonwood Hot Springs.

INTRODUCTION

Low-temperature geothermal resources are defined as those having a surface temperature of 20 to 100°C. Previous assessments of Colorado's low-temperature geothermal resources were completed by the Colorado Geological Survey (CGS) in 1920 and in the mid to late-1970s. The purpose of the 1992-1993 low-temperature geothermal resource assessment is to update the earlier physical, geochemical, and utilization data and compile computerized databases of the location, chemistry, and general information of the low-temperature geothermal resources in Colorado.

During 1992 and 1993 the staff of the CGS visited most of the known geothermal sources that were recorded as having temperatures greater than 30°C. Physical measurements of the conductivity, Ph, temperature, flow rate, and notes on the current geothermal source utilization were taken. Ten new geochemical analyses were completed on selected geothermal sites.

The earliest work describing the geothermal resources of Colorado was completed by R. D. George et al. (1920), Mineral Waters of Colorado, CGS Bulletin 11. In 1978, the CGS published Bulletin 39, An Appraisal of Colorado's Geothermal Resources, by Barrett and Pearl which contained descriptive information on the sites, including location, current usage, geological setting and an analysis of various geothermometers for each of the geothermal areas of the state.

New assessments of geothermal resources are necessary because utilization of geothermal resources changes over a period of years. In some cases flow rates and temperature of the geothermal sources have change because of various reasons, either natural or man-induced.

The data collected and compiled for this survey are recorded in four computer databases. Figure 1 shows the location of each of the geothermal areas determined from the 1992-1993 survey.

DATA SOURCES

Data were compiled from a variety of sources including published and unpublished materials. The most important published source material includes: George et al., 1920, Colorado Geological Survey Bulletin 11; Barrett and Pearl, 1976, Colorado Geological Survey Information Series 6; and Barrett and Pearl, 1978, Colorado Geological Survey Bulletin 39. The most important unpublished sources were the Colorado Department of Water Resources well permit files, the U. S. Geological Survey WATSTOR database, and analytical reports from private laboratories given to the principal investigator by geothermal source owners and operators. As part of the assessment program ten new geochemical analyses were completed.

All geochemical data which maintained a cation-anion charge balance of ± 15% were entered into the databases. Geothermal sources with only one analysis were entered regardless of the charge balance.

DATA FORMAT

All the data describing the location, geochemical analyses, and general characteristics were compiled into databases. For purposes of this program a geothermal area is

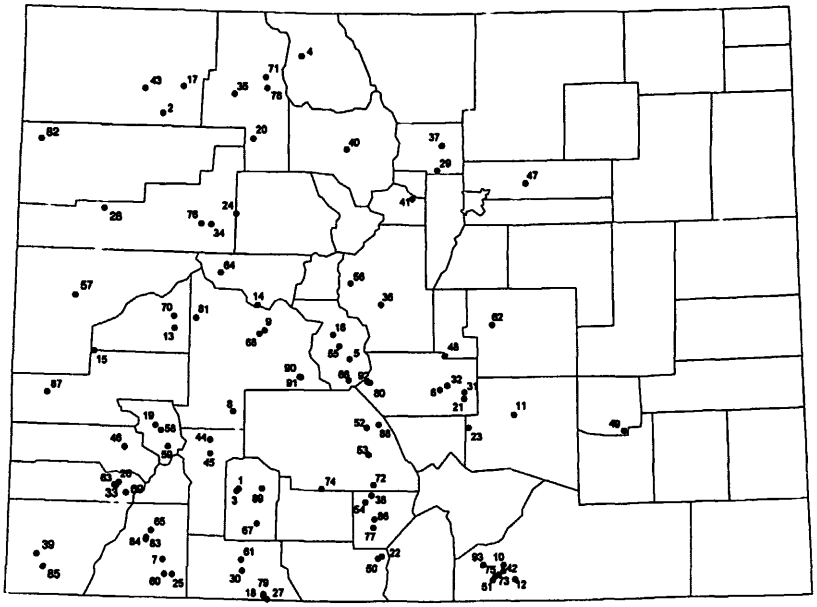

Figure 1. Colorado geothermal springs and wells.

defined as a geologically cohesive land area that may or may not contain several geothermal wells or hot springs. Generally an area is less than approximately three square miles. A site is defined as an individual geothermal well or hot spring within an area. Each geothermal area within the database has a unique ID number. Different sites within a geothermal area have unique area-site numbers. All the tables list the ID number, Site number, and Geothermal Source (Name). Excerpts from the databases are shown below in the following tables.

Table 1 is a location database (GTHLOC); it describes the county, quadrangle map, section, township, range, latitude and longitude, and Universal Transverse Mercator grid references.

Table 2 contains the long form of the geochemical database(GTHCHEM1). All the geochemical and sample data collected during this survey is stored in this Table. There can be multiple entries of geochemical data for each site.

Table 3 is the short form of the geochemical database(GTHCHEM2). It contains an abbreviated element list and has only one entry per site. Where multiple chemical analyses were available all the results were averaged to make just a single entry.

Table 4 contains the general information database (GTHGEN). It has information such as temperature, flow rate, type, references, and current usage for each geothermal site.

FLUID CHEMISTRY

Because of time constraints a lower limit of 30°C was set on any geothermal spring or well to be visited in the field. The temperature, pH, conductivity, flow rate and current usage for each site were recorded. The University of Utah Research Institute (UURI) provided 10 new geothermal water analyses as part of the low-temperature geothermal assessment program. Sites for a complete water analysis were selected on a subjective criteria of developmental significance and lack of recent or quality geochemical data. The 10 sites selected for new water analyses in Colorado are:

Craig Warm Water Well
Desert Reef (Florence)
Dotsero, South
Mt. Princeton (Hortense Well)
Ouray (Pool or Box Canyon Spring)
Routt (aka Strawberry)
Steamboat Springs (Heart Spring)
Waunita Hot Springs
Juniper Hot Springs
Pagosa Hot Springs (Big Spring)

The results of the new samples are included in Table 2. There were no new results that had serious implications for the prior known geochemistry of the geothermal areas.

Other sources of geochemical information were utilized in compiling the database. The most significant source of geochemical data was the U. S. Department of Energy sup-

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ID	Site	Geothermal Source	Type	Quadrangle	County	Sec	Qtr/Qtr	Twp	Twpd	Rge	Rged	Merid.	LatD	LatM	LatS	LonD	LonM	LonS	X-Utm	Y-Utm	Rel
1	1	Antelope Warm Spring	HS	Workman Creek	Mineral	1	SWSE	40	N	2	W	NMPM	37	44	36	107	2	14	320502	4179086	1
2	1	Axial	W	Axial	Moffat	23	NESE	4	N	93	W	6TH	40	18	1	107	47	3	263367	4464596	2
3	1	Birdsie Warm Spring	HS	Workman Creek	Mineral	14	NWNE	40	N	2	W	NMPM	37	43	42	107	3	13	319021	4177454	3
4	1	Brands Ranch	W	Pitchpine Mountain	Jackson	31	SWSE	9	N	81	W	6TH	40	42	16	106	'32	4	370371	4506869	1
5	1	Browns Canyon Warm Spring	HS	Nathrop	Chaffee	23	SESW	51	N	8	E	NMPM	38	39	13	106	3	11	408367	4278657	3
5	2	Browns Canyon (Chimney Hill)	W	Nathrop	Chaffee	28	SENE	51	N	8	E	NMPM	38	38	40	106	4	41	406180	4277665	2
5	3	Browns Grotto Warm Spring	HS	Nathrop	Chaffee	27	SWSW	51	N	8	E	NMPM	38	38	13	106	4	26	406533	4276829	3
6	1	Canon City Hot Springs	W	Royal Gorge	Fremont	31	SESW	18	S	70	W	6TH	38	25	56	105	15	41	477185	4253598	2
7	1	Carson #1 Well	W	Rules Hill	La Plata	36	NWSW	35	N	8	W	NMPM	37	15	25	107	41	57	260619	4126587	2

Abbreviations

HS= Hot Spring; W= Well; Sec= Section; Qtr= Quarter; Twp=Township, d=direction; Rge= Range, d=direction; Merid= Meridian
Lat/LonD= Latitute/Longitude Degrees, M= Minutes, S= Seconds, Dec= Decimal Degrees, Utm= Universal Tranverse Mercator Coordinates;
Rel=Reliability, 1= within 100 feet, 2=within 660 feet, 3=within 1,320 feet, 4= within 2,640 feet, 5= within 5,280 feet, 6= greater than 5,280 feet

Table 1. Location of Geothermal Sources in Colorado.

1992-1993 LOW TEMPERATURE GEOTHERMAL PROJECT

ID	Site	Geothermal Source	Type	Reference	Date Sampled	Temp °C	Cond mmohs	pH	$CaCO_3$	HCO_3	PO_4	Ca	Mg	Na	K
1	1	Antelope Warm Spring	HS	1	8/1975	32	180		90	110	ND	4.0	0.3	44.0	0.1
1	1	Antelope Warm Spring	HS	1	10/1975	32	160	8.9	95	77	0.03	1.7	0.6	43.0	0.3
1	1	Antelope Warm Spring	HS	3	6/1993	32	234	9.1							
2	1	Axial	W	4	6/1975	22	1,750	7.1	520	630	0.09	140.0	140.0	71.0	14.0
3	1	Birdsie Warm Spring	HS	1	?/1975	30	200	8.6							
3	1	Birdsie Warm Spring	HS	3	6/1993	30	218	9.2							
4	1	Brands Ranch	W	1	?/1975	30	405	6.0							
4	1	Brands Ranch	W	1	5/1993	39	524	6.4							
5	1	Browns Canyon Warm Spring	HS	1,7	?/1975	25	775	8.0				9.0		170.0	2.4
5	2	Browns Canyon (Chimney Hill)	W	7	?/1975	27						7.0		170.0	2.7
5	3	Browns Grotto Warm Spring	HS	1,7	?/1975	23	720	7.0				18.0		180.0	3.4
6	1	Canon City Hot Springs	HS	2	?/1920	35				804		169.4	53.6	160.8	33.2
6	1	Canon City Hot Springs	HS	1	9/1975	40	1,900	6.3	728	887	2.20	190.0	62.0	190.0	15.0
6	1	Canon City Hot Springs	HS	1	1/1976	40	2,010	6.2	728	888	0.03	190.0	55.0	180.0	16.0
6	1	Canon City Hot Springs	HS	1	4/1976	40	1,980	6.1	728	888	0.09	170.0	61.0	190.0	15.0
6	1	Canon City Hot Springs	HS	3	6/1993	40		6.1							
7	1	Carson #1 Well	W	4	9/1984	38	1,280	8.2	724			2.7	0.3	310.0	2.8

Abbreviations

HS= Hot Spring; W= Well; E= Estimated; ND= Not detected

REFERENCES

1 Barret, J. K. and Pearl, R. H., 1976, Hydrogeochemical data of thermal springs and wells in Colorado: Colorado Geological Survey, Inform. Ser. 6 (rev. 1993).
2 George, R. D., Curtis, H. A., Lester, O. C., Crook, J. K., and Yeo, J. B., 1920, Mineral waters of Colorado: Colorado Geological Survey Bull. 11.
3 Colorado Geological Survey 1992-1993 sampling program
4 U. S. Geological Survey WATSTOR data base
5 Colorado State Department of Water Resources well files
6 Sharp, W. N., 1970, Extensive zeolitization associated with hot springs in central Colorado: U. S. Geological Survey Prof. Paper 700-B, p. b14-b20.
7 Dick, J. D., 1976, Geothermal reservoir temperatures in Chaffee County, Colorado: Northeastern Louisiana Univ., Unpubl. MS Thesis., 171p.
8 Bush, A. L., Bromfield, C. S., and Pierson, C. T., 1959, Areal geology of the Placerville quadrangle, San Miguel County, Colorado: U. S. Geological Survey Bulletin 1072-E
9 Other Sources

Table 2. Geochemical analysis of geothermal sources in Colorado (Long List) (Milligrams/Liter).

1992-1993 LOW TEMPERATURE GEOTHERMAL PROJECT

ID	Site	Geothermal Source	Type	pH	TDS	Na	K	Ca	Mg	Fe	SiO_2	B	Li	HCO_3	SO_4	Cl	F	Cation-Anion Balance, %
1	1	Antelope Warm Spring	HS		151	44.0	0.1	4.0	0.3	0.02	41		0.01	110	2	3	2.0	5.1
2	1	Axial	W	7.1	1,250	71.0	14.0	140.0	140.0	0.11	18			630	530	17	0.6	0.4
3	1	Birdsie Warm Spring	HS	9.2	[209]													–
4	1	Brands Ranch	W	6.4	[465]													–
5	1	Browns Canyon Warm Spring	HS	8.0	[775]	170.0	2.4	9.0			28							–
5	2	Browns Canyon (Chimney Hill)	W			170.0	2.7	7.0			47							–
5	3	Browns Grotto Warm Spring	HS	7.0	494	180.0	3.4	18.0			46							–
6	1	Canon City Hot Springs	HS	6.2	1,220	180.2	19.8	179.9	57.9	0.03	23	0.20	0.23	867	123	186	1.5	0.1
7	1	Carson #1 Well	W	8.2	789	310.0	2.8	2.7	0.3	0.07	23	0.19		–	1	14	1.5	96.4

Abbreviations

HS= Hot Spring; W= Well; ND= Not Detected

Brackets ([ ]) in the TDS column indicate Conductivity measurements; Conductivity * .58 is a good regional indicator of TDS

Table 3. Geochemical analyses of geothermal sources in Colorado (Short List) (Miligrams/Liter).

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ID	Site	Geothermal Source	Type	Use	Temp °C	Flow l/m	Well depth, m
1	1	Antelope Warm Spring	HS	N	32	11,46	
2	1	Axial	W	?	22		3.6
3	1	Birdsie Warm Spring	HS	N	30	53	
4	1	Brands Ranch	W	Bnd	34	304E	
5	1	Browns Canyon Warm Spring	HS	N	25	4	
5	2	Browns Canyon (Chimney Hill)	W	N	27		
5	3	Browns Grotto Warm Spring	HS	N	23	19	
6	1	Canon City Hot Springs	HS	N	39	4 to 19	
7	1	Carson #1 Well	W	?	38		744.8

Abbreviations

[Type: HS= Hot Spring; W= well]

[Use: Bnd= bathing, not developed; Bd= bathing, developed; N= no use; MW= mineral water; AC= Aquaculture; ACs= Aquaculture, stock tank; A= Agricultural irrigation; SH= Space Heating; GH= Greenhouse; ?= Not Known]

Table 4. General information of geothermal sources in Colorado.

ported study performed by the CGS in the late 1970s (Barrett and Pearl, 1976). Any geochemical analysis that had a cation-anion balance error greater than 15% was discarded except for the case described below.

Geochemical data derived from the U. S. Geological Survey WATSTOR database was entered into the current database; unfortunately, most of those reports do not have an analysis for HCO_3- or CO_3^{-2} which causes severe errors in the cation-anion balance. As most of these analyses are the only one for that particular site they have been retained in the database even though they do not balance within the specified limits.

DISCUSSION AND SUMMARY

The location of all the geothermal sites compiled during this assessment program is shown on Figure 1. A frequency plot of all the geothermal temperatures from each site is shown in Figure 2. The greatest number of temperature measurements fall in the 25 to 40°C categories. There is another peak in the 51 to 55°C range.

The 1992-1993 low-temperature geothermal assessment program added 10 new chemical analyses to the geochemical database of the state's geothermal waters. Other sources of geochemical data were reviewed and all good quality, that is less than 15% cation-anion balance error, geochemical analyses were entered into the long form geochemical database, Table 2. Certain areas with higher than 15% cation-anion balance were left in the database because they were the only analysis for an area or site. Usually the most significant errors in the cation-anion balance were found in the U. S. Geological Survey WATSTOR database and are due to a missing HCO_3 analysis.

Several corrections were made to locations and names of hot springs and wells described in the older literature. The CGS Information Series 6 (Barrett and Pearl, 1976) was

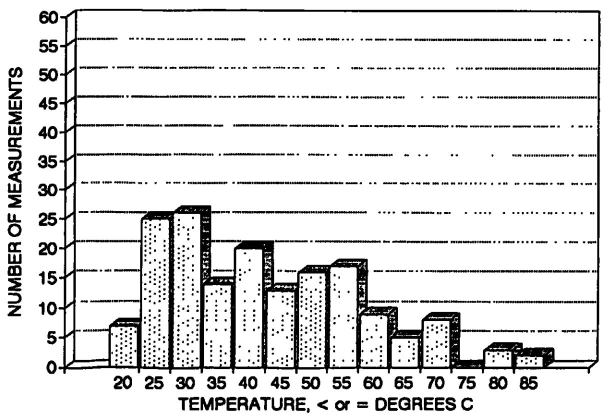

Figure 2. Frequency distripution of the Colorado geothermal sources.

updated during 1993 and the correct locations were entered into the revised publication. Corrections were also made to several location entries in the U. S. Geological Survey WATSTOR database.

A summary of the results of the 1992-1993 geothermal assessment and a comparison to the 1976-1978 geothermal assessment are shown in the following Table A:

ITEM	1993 ASSESSMENT	1976-78 ASSESSMENT	% CHANGE
GEOTHERMAL AREAS	93	56	+66%
GEOTHERMAL SITES	157	125	+26%
GEOCHEMICAL ANALYSES	382	236	+62%
SITES OF DIRECT HEAT UTILIZATION	64	64	0
SITES OF DISTRICT HEAT USE	20	?	
SITES OF GREENHOUSES, AQUACULTURE	4	?	

Table A: Summary of the results of the 1993 Low-Temperature Geothermal Assessment Program compared to the 1976-1978 geothermal assessment.

RECOMMENDATIONS

The current assessment indicates that several areas in the state continue a long history of substantial utilization of their geothermal resources. The prime areas include Glenwood Springs, Idaho Springs, Steamboat Springs, Pagosa Springs, Mount Princeton, and Ouray. All of these areas, at the minimum, utilize the geothermal resources for swimming pools and spas. Some areas such as Ouray and Pagosa Springs utilize geothermal heat for space heating in municipal and other private buildings.

There are other areas in the state that are collocated with or near population centers and are on the fringe of geothermal development. That is, they have had some development of their geothermal resources; however, there are indications that geological and geophysical studies may be used in a Second Phase geothermal assessment to increase the geothermal area and spur development in these areas. The geothermal areas that are candidates for a Second Phase are (not listed in any order of importance):

1) Trimble Hot Springs, La Plata County.
2) Orvis Hot Springs, Ouray County.
3) A large area southeast of Pagosa Springs along the Archuleta Antiform, Archuleta County.
4) Eastern San Luis Valley, Saguache and Alamosa Counties.
5) Rico and Dunton Hot Springs, Dolores County.
6) Cottonwood Hot Springs, Chaffee County.

Other areas that are geologically significant but far from a center of population are:

1) Deganahl well, Routt County.
2) Brands Ranch well, Jackson County.

3) Craig warm water well, Moffatt County.
4) Hartsel Hot Springs, Park County.

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DISCLAIMER

REFERENCES

Barrett, J. K., and Pearl, R. H., 1976, Hydrogeological data of thermal springs and wells in Colorado: Colorado Geological Survey Information Series 6, 124p.

Barrett, J. K., and Pearl, R. H., 1978, An appraisal of Colorado's geothermal resources: Colorado Geological Survey Bulletin 39, 224p.

George, R. D., Curtis, H. A., Lester, O. C., Crook, J. K., and Yeo, J. B., 1920, Mineral waters of Colorado: Colorado Geological Survey Bulletin 11, 474p.