NEW MEXICO THERMAL WATERS

W. K. Summers

PURPOSE AND SCOPE

In our anxiety to generate electricity using the natural heat of the earth, we tend to think about natural thermal waters in two contexts. (1) We look at the known occurrences of warm and hot water in the context of their exploration potential hoping that these surficial occurrences will lead us to a steam field. (2) We project our thoughts forward to a management context... anticipating the problem of the winning, using, and disposing of geothermal fluids.

This paper considers New Mexico's thermal waters in a third context -- their present value. That is what sort of answers evolve if we ask "What are New Mexico's thermal water good for"?

To answer this question we must merge two sorts of data. On the one hand we must know what the thermal waters are like--their occurrences, their physical and chemical properties, and the quantities available. On the other hand, value implies use so we must be aware of the criteria that should be satisfied before a given thermal water can be approved in terms of a given use.

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This paper consists then of three parts: a descriptive survey of New Mexico's thermal waters, a summary of the criteria established for some selected uses and an evaluation of the use potential of the thermal waters in the light of these criteria.

The descriptive survey is derived from a report entitled Catalogue of New Mexico's Thermal Waters, which the New Mexico Bureau of Mines and Mineral Resources is preparing for publication later this year.

Thermal water in New Mexico can be divided into two categories--normal and anomalous. Temperatures generally increase with depth so under normal conditions it's possible to find warm or hot water at some depth in almost any sedimentary basin. For example, temperatures of more than 300° F have been reported from depths in excess of 20,000 feet in the Permian Basin, southeastern New Mexico, and temperatures of more than 100° F are commonly reported in wells in the San Juan Basin.

Anomalous temperatures are those which are distinctly warmer than normal. For New Mexico, water temperatures of 90° F or more to depths of 500 feet are anomalous. For water from depths below 500 feet to be considered anomalous the temperatures (T) must be at least 90° F and larger than $A + 4 + .027 Z$, where A is the mean annual air temperature and Z is the average depth of the contributing interval of the well.

This paper deals with anomalously warm water.

In this report a thermal area is one in which there is some justification for believing the temperatures between discharge points is continously anomalous, i.e., the Truth or Consequences area. As more information becomes available occurrences counted singularly here will undoubtedly be integrated in the future.

Using these criteria 67 thermal areas have been identified. Of these I have visited 50 and sampled 40. Of the 27 areas I have not sampled 20 are reports from unquestionably reliable sources and 7 are from probably reliable sources.

SUMMARY OF HYDROTHERMAL OCCURRENCES

Thermal water occurs in the mountainous parts of New Mexico and in the intermountain basins. They seem to be related to structural highs that border the state's structural troughs or grabens (i.e. the Rio Grande Valley, the Animas Valley). They occur in areas of volcanism.

Specifically thermal waters were noted in 12 of New Mexico's 32 counties: Catron, Dona Ana, Grant, Hidalgo, Luna, Otero, Sandoval, San Juan, San Miguel, Sierra, Socorro, and Taos.

No thermal waters are likely to be discovered in the following eastern counties: Chaves, Colfax, Curry, DeBaca, Eddy, Guadalupe, Harding, Lea, Quay Roosevelt, or Union.

The prospects for discovering thermal water in the remaining nine counties range from slight (where no warm springs occur) to excellent (where warm springs are numerous).

The frequency of occurrence of thermal areas by drainage basin is as follows:

Basin	No. of areas
Gila River Basin	
Upper Gila Basin	12
Cliff-Gila-Riverside Area	1
Animas Valley	3
San Francisco River Basin	3
	19
Rio Grande Basin	
Upper Rio Grande Basin	5
Jemez River Basin	12
Middle Rio Grande Basin	2
Jornado del Muerto Basin	1
Lower Rio Grande Basin	16
	36
Mimbres River Basin	7
Playas Lake Basin	1
Pecos River Basin	1
Tularosa Basin	1
San Juan River Basin	2
	67

GEOLOGIC AND HYDROLOGIC CHARACTERISTICS OF THERMAL AREAS

Geologic Age

Thermal waters discharge from rocks of all ages, as follows:

Age	Number of Occurrences
1. Precambrian	2
2. Paleozoic	8
3. Mesozoic	2
4. Cenozoic	35
5. Precambrian and Cenozoic	1
6. Paleozoic and Cenozoic	3
7. Precambrian and Paleozoic	1
8. Paleozoic and Mesozoic	1
9. Paleozoic, Mesozoic, and Cenozoic	1
10. Unspecified or unknown	6

The age of the rock, per se, from which the thermal water discharges is apparently of secondary importance. These rocks are not the source of the water nor are they just conduits. They form part of the ground water reservoir. The fact that they contain thermal water merely indicates that hot water moves through them. Both the heat and water originate else-where The head presumably comes from great depths. The water appears to be largely circulating meteoric water.

Lithology

Thermal waters occur in association with various rock types and lithologies. These occurrences are classified as follows:

Rock Type	Number of Occurrences
1. Extrusive igneous rocks (not including areally extensive massive rock)	10
2. Consolidated sedimentary rocks	11
3. Unconsolidated sedimentary rocks	15
4. Massive igneous and metamorphic rocks	8
5. Extrusive igneous and consolidated sedimentary rocks	6
6. Extrusive igneous and unconsolidated sedimentary rocks	1
7. Unconsolidated and consolidated sedimentary rocks	3
8. Unspecified or unknown	6

The arbitrary division of the igneous rocks and the grouping of massive igneous rocks with metamorphic rocks came about for two reasons:

First, hydraulically the massive igneous and metamorphic rocks are similar in that they transmit water almost entirely through fractures, whereas the extrusive igneous rocks include both particulate rocks and fractured rocks.

Second, where massive igneous rocks or metamorphic rocks occur they are fairly extensive and homogeneous, whereas extrusive igneous rocks tend to vary radically in composition and hydraulic character in short distances.

In terms of volume of water discharged, the Magdalena limestone of Pennsylvanian age discharge more thermal water than any other stratigraphic unit.

Many thermal waters are seen only in unconsolidated sedimentary rocks (alluvium, pediment gravels, etc.). Where this condition exists, we have a clear indication that much remains to be learned about the cause and effect of the thermal water at the site.

Geologic structure

Of 50 thermal areas visited, faults were the primary structural feature at only 5; 21 were associated with volcanic structures, including faults; and 23 occurred in situations where (1) distinct structure was lacking or (2) the structural setting was hidden beneath alluvimm or pediment gravels. In a few instances regionally significant faults cut volcanic structures and the thermal waters occurred nearby, so that clear-cut distinctions are not possible.

Faults are probably not important in themselves, but mark zones of fracture and sones in which rock types have been offset. That is to say the old cliche that "Thermal water rises along fault zones" is not universally evident. The waters are associated with fracture systems which in some cases are also related to faults and the exact relation between the thermal waters and the fault is not a singular one.

Similarly the relation of volcanic structures and thermal waters may be extremely complex. The heat and the rock may have originated from a common source, but have done so at widely separated times. Or they may have their origin in two completely separate sources. In all probability, the simultaneous occurrence of relatively young volcanic rocks and thermal water are the product of the same heat source, whereas older volcanic rocks and present-day thermal waters are probably related to differenct heat sources.

The occurrences of thermal water that are most difficult to explain are those where no "volcanics" occur, such as Truth or Consequences thermal water basin, Montezuma Hot Springs, and Ponce de Leon Hot Springs, for in these areas no obvious heat source exists.

Outlets

Thermal water discharges from several distinct outlets. These are:

Type	Number of Occurrences
Fractures	12
Talus slope	5
Interstitial porosity of particulate rocks	5
Calcareous tufa	2
Some combination of the above	7
Wells (including 4 areas with springs)	33

Water discharges from fractures where the rocks have low porosity. These rocks range from granite to breccias. In some places the fractures have been enlarged by the discharging waters; in others they have been partially closed by preceipitated minerals.

Interstitial granular porosity may also be reduced by the disposition of minerals--especially silica as chert and calcite as tufa. Free sulphur occurs at Sulphur Springs and Soda Dam Springs.

Where talus covers the bedrock the exposed lithology suggests that the discharge would be from fractures if the talus were to be removed.

Water discharges directly from calcareous tufa only at Faywood Hot Springs. However, calcareous tufa is an important deposit at Soda Dam Springs and Jemez Hot Springs. It is extensively deposited in the area of the Rio Salado-Jemez River confluence, but not at the rivers.

Some deposits occur in the Socorro thermal area and may mark the location of former thermal springs. Deposits near Ojo Caliente in Taos County probably mark the earliest outlet of the thermal waters there. Similar deposits occur near Truth or Consequences and in the Animas Valley. However, calcareous tufa may form from cooler waters, so its presence does not prove the existence of earlier thermal waters.

Discharge mode

Thermal waters discharge in a variety of ways, which have been subdivided as follows:

Mode of discharge

I. Springs:
    A. Above stream
        Wells up (boils)
        Cascades
        Wells up and cascades
    B. At stream level
    C. No stream near

II. Wells

  A. Flowing

  B. Pumped

  C. Not equipped with operable
     pump and does not discharge

  D. Destroyed

Under ideal effluent conditions ground water discharges to streams. This discharge occurs at springs and seeps along the stream bank and bed.

If the stream bed is very permeable, the individual points at which ground water flows in are not discernible. If the permeability of the stream bed and banks varies, more inflow occurs in the zones of large permeability than occurs along the banks even where the entire reach of the stream contributes to the total flow.

Where permeability contracts are large, the discharge may occur from a valley wall.

Where the rocks involved are fractured and permeability contrasts are related to the fracture pattern and the degree of fracture, the first appearance of the ground water may be a cascade. If the valley wall is steep, a talus cover may hide the actual mode of discharge.

If the discharge is from a low permeability aquifer onto high permeability alluvium, the water from a perennial spring will form an influent stream. In the more arid regions, the discharging spring may be several miles from the nearest perennial stream.

CHEMICAL CHARACTERISTICS OF THERMAL WATER

Dissolved Constituents

For 54 thermal areas 384 chemical analyses from many different laboratories have been assembed. These analyses reveal the following:

(1) Relatively few analyses are complete and the heavy metals have received so little attention that fewer than 20 samples have been analyzed for more than 5 heavy metals.

(2) In 28 areas water discharges from more than one place. In 7 of these areas the water temperature and chemistry vary radically with the source.

(3) The total dissolved solids in thermal water are independent of the temperatures as are most individual constituents. The following tabulation shows the frequency of total dissolved solids for 51 areas. This tabulation is based upon average values and in the 7 areas where concentrations vary upon the maximum values.

Total dissolved solids concentration range (ppm)	No. of areas	Cumulative total	Cumulative percent
0 - 250	8	8	15.7
250 - 500	13	21	41.2
500 - 750	6	27	52.9
750 - 1000	0	27	52.9
1000 - 1500	6	33	64.7
1500 - 2000	0	33	64.7
2000 - 2500	5	3	74.5
2500 - 5000	8	46	90.2
5000 - 10000	2	48	94.1
10000 - 20000	3	51	100.0
?	3	54	

As the preceeding tabulation shows about two-thirds of the thermal water contains 1500 ppm of total dissolved solids.

(4) Most constituents that make up the dissolved solids show no singular relation to the fact that the waters are thermal. The notable exceptions are silica, sodium and potassium, and fluorine. The solubility of silica increases with temperature. So the concentration of silica is generally larger than the average for cooler waters from similar terranes. Sodium and potassium are the dominant cations in thermal waters everywhere regardless of the total mineral content of the water. Fluoride is not unique to thermal but as the following tabulation shows, more than half of New Mexico's 54 thermal water areas contain fluoride concentrations in excess of 3 ppm. The probability that 54 areas chosen on any parameter other than temperature would have such a large concentration is diminishingly small.

Fluoride concentration (ppm)	No. of areas	Cumulative total	Cumulative percent
0 - 1	6	6	12.8
1 - 2	9	15	32.9
2 - 3	4	19	40.4
3 - 4	11	30	63.8
4 - 5	3	33	70.2
5 - 6	2	35	74.5
6 - 7	3	38	80.9
7 - 8	1	39	83.0
8 - 9	1	40	85.1
9 - 10	0	40	85.1
10 - 15	3	43	91.5
15 - 20	3	46	97.9
20 - 25	1	47	100.0
?	7	54	

(5) Boron is usually high only in thermal waters of the Jemez region.

(6) A review of samples from the same sources suggests that the chemistry of the discharging thermal water has not changed enough to measure since 1915.

Associated gases

Only the thermal water of the Jemez River Basin discharges significant volumes of gas. However, most of the thermal springs bubble occasionally. The primary exceptions are those that discharge from beneath a talus slope.

A few springs (Mimbres Hot Springs and Montezuma Hot Springs, for example) give up an occasional odor of hydrogen sulfide. Field tests for hydrogen sulfide however, were negative suggesting that the discharge of hydrogen sulfide was intermittment and of short duration.

Gases associated with thermal water in the Jemez area are:

	CO_2	O_2	H_2O	H_2	N_2	He
	Percent by volume					
Sulphur Springs (Men's)	85.9	1.1	7.1	--	5.9	0
(Alum)	77.9	1.1	20.1	--	.9	0
Soda Dam	82.8	3.3	.0	--	13.9	0
Jemez Spring	91.0	.6	--	2.8	5.2	-
Phillips Springs (Swimming Pool)	70.4	8.3	.0	--	21.3	-
San Ysidro Springs	97.5	.5	.0	--	2.0	0
do	96.3	.6	.0	--	2.7	0

Clearly, the dominant component of the gas associated with the thermal waters of Jemez River Basin is carbon dioxide, with minor amounts of hydrogen sulfide. The other constituents may be contaminants. Duke (1967) obtained similar results for the gas discharges at Mimbres Hot Springs.

Radioactivity

Scott and Barker (1962) reported uranium and radium in groundwater in the United States. They note (p. 15) that thermal waters "...commonly have large amounts of radium..." They also indicate (p.12) an anomaly threshold for both radium and uranium.

Unfortunately only a few samples of thermal water from New Mexico (Table 1) have been analyzed for radio-activity. Of these barely one of six analyzed for radium and only two of seven analyzed for uranium are above the anomaly threshold established by Scott and Barker for the area.

We conclude, therefore, that New Mexico's thermal waters are much like the non-thermal groundwater with respect to radioactivity. Recent work, as yet unpublished, of the U. S. Environmental Protection Agency shows that the radon-222 content of New Mexico's thermal water is also in the same range as normal groundwater (R. Kaufman Personal Communication March 31, 1975).

PRESENT USES OF THERMAL WATER

Currently thermal waters in New Mexico are being used as follows:

Use	No. of areas
Municipal or domestic supply	15
Spas	4
Industrial	2
Space heating	2
Irrigation	1
Stock and wildlife only	22
Destroyed wells--no use possible	7
Wells not in use	6
Steam wells	1

In the past spas operated in at least five other thermal areas. Based on the New Mexico experience a successful spa, based on thermal water, must satisfy these requirements (in addition to good business management):

(1) Easy and convenient access by the public. All existing spas are on or near main highways.

(2) Water temperature in excess of 100°F. Water warmer than 125°F is cooled before it is used. Water cooler than 100° F apparently will not sustain a clientele.

(3) A constant discharge of thermal water of 15 gpm or more.

Table 1.--Radioactivity of thermal water samples from New Mexico

	Beta gamma activity (pc/l)	Radium (pc/l)	Uranium (ppb)	Radon+ 222 (pc/l)
Animas Hot Spot	12	.3	.2	---
Soda Dam	--	--	40.0	450
Socorro Thermal Area	11	.2	1.8	520
Gila Hot Springs	12.2	<.1	1.4±.01	640,68
Truth or Consequences (Yucca)	100	7	3.3	1400
Radium Springs	170	.6	1.8	5800
Faywood	19	29	.1	5600
range for region*	--	.1-29	.1-37	---
median for region*	--	.1	1.2	---
anomaly threshold for region*	--	5.9	54	---
maximum observation in Japan**	--	111.1	---	---

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*Scott and Barker (1902, p.12)
**Uzumasa (1965, p.116)
+preliminary results of U.S.EPA

POSSIBLE CONVENTIONAL USES OF THERMAL WATER

To determine to what use thermal waters might be put, two facts have to be considered. First, the chemical character of the water as compared to a standard for a use; and second, the amount of water required for that use.

To assay the chemical character of the water as a function of use a table of requirements for specific uses was first compiled. Then the chemical analyses of the thermal water were compared to these requirements.

The possible uses of thermal water were divided into fifteen broad categories:

(1) Domestic water supply. Standards for this category included those for cooking and laundering.

(2) Stock and wildlife supply. Standards for this category included those established for cattle, horses, swine, poultry and rats.

(3) Fish and other aquatic life. This category includes both fresh and sea water when requirements are exceedingly flexible. In general this category considers the requirements of game fish.

(4) Irrigation

(5) Cooling water and air conditioning

(6) Boiler feed water. The quality of water for steam boilers varies with the pressure, only low pressure (150-250 psi) was considered.

(7) Industrial water supply, general. Standards for this category were assembled from standards published from the following specific industries which seem to be essentially the same: ceramic, electroplating, glass manufacture, nitrocellulose production, organic chemical industries paint production, photographic processing, plastic manufacturing, both synthetic and natural rubber manufacturing, soap and steel manufacturing, and tanning.

(8) Textile manufacturing. Standards for this category were compiled from those for textiles in general, bandage manufacturing, cotton manufacturing, dyeing, and wool scouring.

(9) Rayon and synthetic fibers

(10) Dyeing

(11) Pulp and paper making. Standards for this category are a blend of those for alkaline pulps, high grade pulps, low grade pulps, ground wood pulp, fine papers, bleached and unbleached draft paper, and soda and sulfate paper.

(12) Brewing and distilling

(13) Food processing. The standards for this category are those established for food processing in general, plus those for baking, equipment washing, mild and dairy industry, sugar manufacture, and sugar. In general, the water is not a part of the finished product.

(14) Food products. The standard uses in this category are those established for carbonated beverages, fruit juices, and ice manufacture. The water is a part of the product.

(15) Food canning and freezing.

The chemical character of thermal water ranges from suitable for most purposes to unsuitable for any purpose. The most common potential problems are excessive concentrations of iron, manganese, carbonate, bicarbonate, chloride, and sulphate and fluorine. Silica also tends to be high. The pH of many thermal waters tends to fall outside the acceptable range for most uses.

Table 2 summarizes the range of maximum values for these uses. In some cases the range is fairly large because a specific use within a category is sensitive to a particular ion.

Table 3 indicates the potential problem causers in the thermal waters for which some chemical analyses were available. "Potential" problems are specified because (1) a specific use within the catagory may call for substantially lower maximum values than the majority of uses, (2) only one or perhaps a few of several analyses from a source showed values above the "lowest maximum", (3) only one source in a particular area may show above maximum values for a particular constituent.

Three other factors which restrict the use of thermal water for the specified purposes are temperature, discharge rate, and location.

Of the fifteen uses listed, the first five require the water to be cool to some extent, except for laundering. Uses six to fifteen may or may not be sensitive to temperature depending upon specific applications. Temperature of the water is only a minor factor since for many purposes hot water can be cooled to air temperature fairly easily.

Discharge rate is perhaps the most critical factor in determining whether a specific area might lend itself to one of the fifteen possible uses. Discharge rates vary from almost 0.0 gpm at the seep on the Middle Fork of the Gila River (128.14W.2.100) to 1500 gpm at Truth or Consequences. In practice only a few areas can be expected to produce 500 gpm or more of thermal water.

These include:

(1) Hot wells, Animas Valley (25S.19W.7.000)

(2) Flowing wells at Warm Springs (16N.1W.410)

(3) Socorro thermal area

(4) Truth or Consequences (13S.4W.33.400;14S.4W.4.100)

(5) Kennecott Warm Springs

(6) Apache Tejo

Areas, which might be developed to produce 500 gpms or more of thermal water, can only be surmised for there have been no adequate tests to determine potential yield of the groundwater reservoir at these sites. However, experience

TABLE 2.--RANGE OF CONCENTRATION OF PROBLEM CAUSING CONSTITUENTS OF NATURAL WATER AS SPECIFIED FOR SELECTED USES

	See text for description														
Constituent	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SiO_2									25		20-100	50			
Fe	.3-1				.1-.5		.1	.05	0.0-.2		.3-1		.1-1.0	.2	
Mn	.05-.5	10.0	1.0	.50			00-.5	.2-.25	.0-.03	0.0	0.0-0.5	.1-.2	1.2	.2	.2
As	.05 .01	1.0	1.0	1.0											
Ca	10-200	1000						10.0				200-500	20.0		
Mg	10-150							5.0			12.0	30	10.0		
K	2000														
Se	.01-.1														
HCO_3	60-150	50				0-100	160	200	100			100-200	100	100-300	300
CO_3	20					20-200						60	20-60		
SO_4	200-400	500				1-40		100				250	20-250	250	
Cl	250-600	3000		100			50-75	100			75-200	100			
F	3														
NO_3	45											10.0			
NO_2	2.0											0.0			
B	1.0	20.0		1.0											
DS	500-1500	2500	2000			50-3000	200-1300		200		80-500	500-1500	850	100-850	850
pH	6.0-9.2					8.0-9.6	6.8-7.0		7.9-8.3	q		6.5-7.0			7.5
Zn	5.0-15.0														
Ag	0.05														
NH_3	.5														.5
Cu	.02-1.5	.5-1							5.0					20-20	7.0

Table 3. -- Potential problem causing constituents by use

	USE (THE CORRESPONDING NUMBER IN TEXT)														
LOCATION NO.	1	2	3	4	5		7	8	9	10	11	12	13	14	15
								GILA RIVER BASIN							
UPPER GILA RIVER DRAINAGE															
11S.14W.35.400	G	G	G	G	G	G	G	CA	G	G	G	G	G	G	G
12S.13W. 7.340	MN HCO3 PH CA F	G	G	G	G	HCO3 DS PH	MN PH	MN CA	MN SIO2 DS	MN	MN SIO2 DS	MN SIO2 PH	MN	MN DS	MN
12S.13W.31.100	MN HCO3 PH CA F	G	G	G	G	HCO3 DS PH	MN DS CL PH	MN CA	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 PH	MN CL	MN DS	MN
12S.13W.30.009	MN HCO3 PH CA F	----	----	----	----	----	----	----	HCO3 SO4 CL DS	----	----	----	----	----	----
13S.13W. 5.241	MN HCO3 PH CA F	G	G	G	MN	HCO3 SO4 DS PH	MN DS CL PH	MN CA	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 PH	MN SO4 CL	MN DS	MN
13S.13W.10.121	MN HCO3 CL PH CA F	G	G	CL	MN	HCO3 SO4 DS PH	MN DS CL PH	MN CA CL	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 CL PH	MN CL	MN DS	MN
13S.13W.11.000	MN HCO3 CL PH CA F	G	G	CL	MN	MN HCO3 DS PH	MN DS CL PH	MN CA CL	MN SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN SIO2 HCO3 CL PH	MN CL	MN DS	MN
13S.13W.20.430	CA HCO3 CL DS PH F	G	G	CL	G	HCO3 SO4 DS PH	MN DS CL PH	CA CL	SIO2 HCO3 DS	MN	MN SIO2 CL DS	SIO2 CL PH	CL	DS	G
CLIFF—GILA—RIVERSIDE AREA															
16S.17W. .	FE MN HCO3 PH CA	G	G	G	FE MN	HCO3 SO4 DS PH	FE MN PH	FE MN HCO3	FE MN HCO3 SIO2 DS	MN	FE MN SIO2 CL DS	FE MN HCO3 CA PH	FE MN HCO3 SO4	FE MN DS	FE MN
ANIMAS VALLEY															
25S.19W. 7.000	CA HCO3 SO4 PH DS MN CL	G	G	CL	MN	HCO3 SO4 DS PH	MN FE SO4 CL PH DS	MN CL CA SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 CL DS	MN SIO2 HCO3 CL PH DS	FE MN HCO3 CL SO4 DS	FE MN SO4 DS	FE DS
SAN FRANCISCO RIVER DRAINAGE															
5S.19W.34.200	HCO3 PH	G	G	G	G	DS PH	DS PH	G	SIO2 HCO3 DS PH	G	SIO2 DS	SIO2 PH	G	DS	G
7S.21W.8.442	FE MN HCO3 DS PH	G	MN DS	G	G	HCO3 SO4 DS PH	MN PH	G	MN SIO2 G	E	SIO2 DS	SIO2 PH	G	DS	G
12S.20W.23.120	FE MN HCO3 DS PH	G	G	G	G	HCO3 CL DS PH	FE MN SO4 CL DS PH	FE CL	FE MN HCO3 SIO2 DS	MN	FE MN SIO2 CL DS	MN SIO2 CL HCO3 DS PH	FE MN CL DS	FE CL DS	FE DS
								RIO GRANDE BASIN							
UPPER RIO GRANDE DRAINAGE															
26N.11E. 1.000	CA HCO3 CL DS PH	G	G	G	G	HCO3 SO4 DS PH	MN CL DS PH	CA	MN SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	CL HCO3 SO4 DS	HCO3 DS	G
24N.13E. 7.000	MN HCO3 CA PH	G	G	G	G	HCO3 SO4 DS PH	MN CL DS PH	CA	MN SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	SO4 CL	DS	G
24N. 8E.24.100	FE MN HCO3 PH	DS	DS	CL	G	HCO3 SO4 DS PH	MN CL DS PH	MN CA SIO2 HCO3	SIO2 HCO3 DS PH	MN	SIO2 CL DS PH	MN SIO2 HCO3 CL DS PH	SO4 CL	MN HCO3 DS	HCO3
JEMEZ RIVER BASIN															
20N. 4E. 7.000	MN HCO CL DS PH	G	G	G	G	HCO3 SO4 DS PH	MN DS	G	SIO2 HCO3 DS	MN	MN SIO2 DS	SIO2	G	DS	G
20N. 3E.29.000	----	G	G	G	G	HCO3 DS PH	MN	G	SIO HCO3 DS	MN	MN SIO2 DS	SIO2 HCO3 PH	G	SIO2 HCO3 PH	G

Table 3.--Potential problem causing constituents by use (cont)

	USE (SEE CORRESPONDING NUMBER IN TEXT)														
LOCATION NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
20N. 3E.35.000	MN HCO3 CA SO4 DS F	DS	DS	CL	FE MN	HCO3 SO4 DS PH	FE MN SIO2 DS	FE MN 6EA CL SO4	MN HCO3 DS	MN	MN CA	FE MN CL HCO3 PH	MN FE DS	SO4 DS	MN HCO3 DS
19N. 3E. 4.000	FE MN DS CL MG SE SO4 DS PH	FE MN SO4 DS	FE MN DS	FE MN	FE DS	SO4 MN PH	FE MN DS PH	FE FE CA MG SO4	SIO2 SIO2 MN PH MG DS	MN SIO2 HCO3 PH MG	MN DS SIO2 HCO3 PH	G	DS	FE MN SO4 DS	FE MN DS PH
19N. 3E.28+32	HCO3	G	G	G	G	DS	FE	G	MN SIO2 HCO3 PH	MN	MN SIO2 DS	SIO2 HCO3 PH	G	DS	G
18N. 2E.14.000	CA HCO3 CL DS F	G	CA HCO3	G	G	CA HCO3 DS PH	CA HCO3	FE CA HCO3	FE SIO2 CA HCO3		FE SIO2 CA	CA HCO3	FE CA HCO3	FE HCO3	FE CA HCO3
18N. 2E.23.000	MN CA HCO3 F	G	CA HCO3	G	G	HCO3 SO4 DS	PH MN	FE MN CA HCO3	MN SIO2 HCO3	MN	MN SIO2 DS	MN SIO2 CA HCO3 DS	CA HCO3 SO4	MN DS	MN
16N. 2E.29.142	FE MN HCO3 PH F	CA HCO3	G	G	FE	CA SO4 PH	FE MN HCO3	FE CA	FE SIO2 HCO3	MN	FE SIO2	FE SIO2 HCO3	FE CA	FE MN HCO3	FE HCO3
16N. 1W. 1.410	FA CA HCO3 CL SO4 DS F	HCO3 CL SO4 DS	DS	CL	FE	G	FE HCO3 CL SO4 DS	FE CA HCO3 CL SO4	MN SIO2 HCO3 CL SO4 DS	G DS	MN SIO2 CL SO4 DS	FE HCO3 CL SO4 DS	FE CA HCO3 CL SO4 DS	FE HCO3 SO4 DS	FE HCO3 DS
MIDDLE RIO GRANDE DRAINAGE															
10N. 2E.21.343	CA HCO3	---	---	---	---	HCO3 CO3 SO4 DS	PH	CA	SIO2 HCO3	---	SIO2 DS	HCO3 PH	HCO3 CO3 SO4	HCO3 DS	PH
9N. 5W.12.442	HCO3 CL SO4 DS	HCO3 CL SO4 DS	DS	CL	G	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 CL SO4 DS	G	CL	HCO3 CL SO4 DS	HCO3 CL SO4 DS	HCO3 SO4 DS	HCO3 DS
3S. 1W.16+22	FE MN CA	HCO3		G	G	HCO3 CL	FE MN PH	FE MN CA	SIO2 FE MN HCO3 PH	MN	SIO2 MN DS	HCO3 PH	FE CA HCO31	HCO3	HCO3 PH
JORNADO DEL MUERTO															
10S. 1W.25.100	HCO3 SO4 DS	---	---	CL	---	HCO3 SO4	HCO3 DS PH	HCO3 SO4	HCO3 DS PH	---	DS	HCO3 SO4 DS PH	HCO3 SO4 DS	HCO3 SO4 DS	HCO3 SO4 DS PH
LOWER RIO GRANDE DRAINAGE															
13S. 4W. 4.000 14S. 4W. 4.000	FE MN CA HCO3 CL DS F	CL DS	DS	DS	CL	HCO3 SO4 CL DS PH	FE MN DS PH	MN FE CA CL HCO3 SO4 DS	FE MN SIO2 HCO3 CL DS	G	FE MN SIO2 CL DS	FE MN HCO3 CL DS PH	MN FE CA CL HCO3 SO4 DS	FE MN DS	FE HCO3 DS
14S. 5W.25.410	MN CA HCO3 SO4 DS PH F	DS	DS	CL	MN	HCO3 SO4 CL DS PH	FE MN DS PH	MN CA CL DS	FE MN DS	MN	FE MN SIO2 CL DS	MN CA CL DS	MN FE CL DS	MN DS	MN
17S. 4W.29.340	MN CA HCO3 SO4 DS PH	G	G	CL	MN	HCO3 SO4 DS PH	FE MN SIO2 CL DS	FE CA CL SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	MN SIO2 CL HCO3 DS PH	CL SO4 DS	MN SO4 DS	FE HCO3
19S. 2W. 9.120	FE MN HCO3 DS PH F	G	G	CL	FE	HCO3 SO4 DS PH	FE MN SIO2 CL DS	FE CA CL SO4	FE MN SIO2 HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 CL HCO3 DS PH	SO4 CL DS	FE DS	FE DS
23S. 1W.10.213	MN CA HCO3 CL SO4 DS PH F	CL DS	DS	CL	FE MN	HCO3 CL SO4 DS PH	FE MN SIO2 CL DS	FE MN CA HCO3 CL SO4 DS	FE MN SIO2 CL HCO3 DS	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 CL HCO3 DS PH	SO4 CL DS	SO4 DS	FE MN HCO3
23S. 2E.34.000	FE MN CA HCO3 CL SO4 DS PH	G	G	CL	FE MN	HCO3 SO4 DS PH	MN FE HCO3 CL DS PH	FE MN CA HCO3 CL SO4	FE MN SIO2	MN	FE MN SIO2 HCO3 CL DS	FE MN SIO2 HCO3 CL DS PH	FE MN CA HCO3 CL DS	FE MN HCO3	FE MN DS

Table 3.--Potential problem causing constituents by use (cont)

	USE (SEE CORRESPONDING NUMBER IN TEXT)														
LOCATION NO.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
23S. 2W.36.133	FE MN CA SO4 HCO3 CL PH F	SO4	G	CL	MN	HCO3 SO4 DS PH	MN CL DS PH	MN CL SO4 DS	SIO2 HCO3 DS	MN	MN SIO2 CL DS	MN CL DS PH	MN CL SO4 DS	MN CL SO4 DS	MN
23S. 1W.31.432	FE MN CA HCO3 CL SO4 DS PH	DS	DS	CL	G	HCO3 SO4 DS PH	CL DS	FE CA CL SO4 DS	FE DS	G	CL DS	CL DS	FE CA CL SO4 DS	CL DS	DS
28S. 2W.24.213	HCO3 SO4 CL DS	DS	DS	CL	---	HCO3 SO4 DS	HCO3 CL DS	HCO3 SO4 CL	DS	---	DS	HCO3 SO4 CL DS	HCO3 SO4 CL DS	04 DS	DS
MIMBRES RIVER BASIN															
18S.10W.18.100	FE MN AS SE HCO3 F	HCO3	FE MN	FE	FE MN	HCO3 PH DS	FE MN PH	FE MN	SIO2 FE MN PH	MN	SIO2 FE MN	SIO2 FE MN PH	FE MN	FE MN	MN PH
20S.11W.20.243	FE MN AS CA HCO3 F	HCO3	G	G	FE	HCO3 SO4 DS PH	FE MN HCO3 PH	FE MN CA MG	SIO2 FE MN HCO3 PH	MN	SIO2 FE MN CA DS	SIO2 FE MN HCO3 PH	FE MN HCO3 SO4	FE MN HCO3	SO4 DS MN PH
20S.11W.18.310	MN CA MG HCO3	HCO3	G	G	G	HCO3 SO4 DS	HCO3	FE CA	SIO2 FE MN HCO3 DS PH	MN	SIO2 MN CA MG DS	SIO2 MN HCO3 PH	FE MN CA MG SO4	HCO3 DS	G
19S.12W.19.000	MN CA MG SE HCO3	HCO3	G	G	G	HCO3 SO4	HCO3	MN CA	SIO2 MN HCO3 DS PH	MN	SIO2 MN DS	MN HCO3 PH	MN CA MG SO4	MN HCO3 DS	MN PH
PECOS RIVER BASIN															
GALLINAS RIVER BASIN															
16N.16E. 6.000	FE MN CA HCO3 DS	HCO3	FE	FE	FE	FE HCO3 SO4 DS	FE MN HCO3 DS PH	FE CA	SIO2 FE MN DS PH	MN	SIO2 FE MN DS	SIO2 FE DS PH	FE CA HCO3 SO4	FE DS	PH
TULAROSA BASIN															
18S. 8E. 5.144	FE MN AS CA DS MG HCO3 SO4 CL	HCO3 SO4 CL DS	FE MN DS	FE CL	FE MN	HCO3 SO4 CL DS	FE MN HCO3 SO4 DS	FE MN CA MG HCO3 SO4 CL	SIO2 FE MN HCO3 DS	MN	SIO2 FE MN MG CL DS	FE MN CA MG SO4 CL DS PH	FE MN CA MG SO4 CL DS	FE MN SO4 CL DS	MN DS
SAN JUAN RIVER BASIN															
19N.17W.29.000	HCO3 PH	G	G	G	G	HCO3 SO4 DS PH	HCO3 PH	SO4 HCO3	FE HCO3 DS	G	MN SIO2 DS	MN HCO3 SIO2 DS	SO4 HCO3	G	G

plus observations made during visits suggest the following areas might have production possibilities in excess of 500 gpm.

(1) Gila Hot Springs (13S.13W.5.140)

(2) Lyon Hunting Lodge Hot Springs (13S.13W.10.000)

(3) Cliff-Gila-Riverside area

(4) Lower Frisco Hot Springs (12S.20N.23.120)

(5) The Jemez River drainage

(6) Jornado del Muerto

(7) Las Alturas Subdivision (23S.2W.35.133)

(8) Mimbres Hot Springs (18S.10W.13.110)

(9) Faywood Hot Springs

(10) Garton well (18S.8E.5.144)

(11) Pure oil test Navajo #1 (19N.17W.29.000)

The remaining areas may also one day be made to yield more thermal water than present-day evidence suggests. Without substantial additional testing, we can only say that the geologic setting and known history of discharge suggests that the amount of hot water which can be obtained economically is less than 500 gpm and probably less than 100 gpm.

Access to the thermal water is perhaps the most critical factor of all. Many thermal areas occur in ground water basins which the New Mexico State Engineer has closed to further appropriations. Several are in the Gila National Wilderness area which is closed to any development. Several are in mountainous areas, some distance from existing roads with only limited accessibilities. The majority of the occurrences of thermal water are on privately owned land.

The use of thermal water for irrigation requires special consideration because several factors combine to determine whether a particular water is suitable for irrigation. These include the boron concentration, the sodium adsorption ratio, the per cent sodium and the specific conductance of the water. These data for thermal water show that the bulk of it is not suited for use by irrigators, although particular waters may be so used.

DISCUSSION

From the preceeding discussion two facts are clear. First, much of New Mexico's anomalously thermal water resource is already being used for conventional purposes to the limit of its availability and quality. Second, of the unused portion, either its location, its quality, its probable quantity or cost to obtain preclude its use for space heating, water supply, or other ordinary purposes.

Therefore, I believe that, excepting one or two occurrences, the use of thermal water in New Mexico for prosaic purposes will not be increased by any significant volume in the near future.

As a result of these observations, a third conclusion follows: Future research efforts on anomalously thermal waters should focus on the significance of these waters with respect to exploration for and development of natural thermal waters for generating electricity.

RECOMMENDATIONS FOR FUTURE PROGRAMS

Several research programs on geothermal research are underway; these recommendations are offered in light of these extant programs.

(1) This paper was based on a somewhat arbitraty definition of "anomalous" thermal water. A study of New Mexico's subsurface temperature regime should be conducted to determine with greater precision the distribution of "normal" thermal waters. That is, we should have better criteria for determining when we cross the line that separates normal from anomalous.

(2) The volume of and the feasibility of using "normal" thermal waters should be evaluated. Many "dry" oil wells discharge warm or hot water. In some instances these waters may be warm enough to use for space heating or in a heat exchanger to generate electricity. Today these wells are abandoned as failures.

(3) The anomalous thermal water should be better understood in terms of its role in the hydrologic cycle. A program to measure the stable isotopes in groundwater, including anomalously thermal water, would give insight into a hydrologic regimen. A program to evaluate the trace elements and especially the heavy metals in groundwaters would help us not only to understand the hydrologic regimen of thermal water but also the role of natural waters in the evolution and destruction of ore bodies. Such a program might also lead to the discovery of new ore bodies.

(4) Steam fields, without exception, discharge CO_2 and H_2S. A program should be instituted to learn (a) the nature and volume of the noncondensible gases associated with thermal waters in New Mexico, and (b) the nature and volume of the dissolved gases. This program should include the determination of isotopic content of the gases.

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