PRELIMINARY GEOTHERMAL ASSESSMENT OF THE VERDE VALLEY, ARIZONA

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I. INTRODUCTION

Location and Access

The Verde River Valley is situated in the central part of Arizona, primarily in the transition zone between the Colorado Plateau and the Basin and Range physiographic provinces. The entire river valley, from north of Cottonwood to east of Phoenix, was investigated to ascertain whether a suitable reservoir exists that would be capable of supplying 50,000 to 150,000 acre feet of groundwater per year for 30 years. The reservoir and geothermal energy would be coupled in a desalination project to augment Arizona's water supply.

Access to the area is somewhat limited. Interstate route 17, U.S. route 89A and state routes 87, 169, 179, 279 and a few county roads traverse or are in the general vicinity of the area.

II. SUMMARY AND RECOMMENDATIONS

A study of the ground-water reservoirs in the Verde River Valley for desalination and water supply augmentation indicate that the operation would at best be marginal. In addition, there is a potential for conflict with environmental groups.

The Paradise Valley Basin has sufficient water in storage for the development of an economic desalination operation. However, the area is very well developed with cities, towns and residences. Subsidence might occur, as a result of ground water withdrawal and could pose a significant problem. In addition, the vast majority of the land is under state trust and fee ownership, making development by the federal government difficult.

III. LAND STATUS

The land status, of Paradise Valley, as concerns the Water and Power Resource Service, is negative. The land ownership in Paradise Valley is primarily fee and state surface trust lands with minor Indian lands and a very small BLM enclave, (see Map III-1). In addition, there are several cities, towns and considerable residential development in the area. The lack of significant federal acreage will in all probability prohibit the development of the desalination project in Paradise Valley.

IV. RESOURCE EVALUATION

A. Introduction

This preliminary investigation of the Verde River Valley was conducted to locate favorable areas for high temperature (>150°C) geothermal energy resources contiguous to a ground-water reservoir capable of supplying a minimum of 25,000 acre feet of water per year, and preferably 50,000 to 250,000 acre feet a year, for a minimum of thirty years.

There have been many studies for the geology and ground-water in the Verde Valley and especially in the copper mining area around Jerome. Previous investigators listed chronologically are as follows: Ross, P. P. and Farrar, C. D., 1980; Ross, P. P., 1977; Anderson, C. A., 1968; Twenter, F. R. and Metzger, D. G., 1963; Anderson, C. A. and Creasey, S. C., 1958; Lehner, R. E., 1958; Feth, J. H., White, N. D. and Hem, J. D., 1954; Price, W. E., Jr., 1950; Mahard, R. H., 1949; Lindgren, Waldemar, 1926; Jenkins, O. P., 1923; Reber, L. E., Jr., 1922 and Blake, W. P., 1890. The major source of information on the Verde Valley for this report is USGS Bulletin 1177, Geology and Ground Water in Verde Valley-the Mogollon Rim Region, Arizona by Twenter, F. R. and Metzger, D. G., 1963.

B. Verde River Valley

The Verde River Valley is situated in the central part of Arizona, in the transition zone between the Colorado Plateau and the Basin and Range physiographic provinces. The lithologies exposed in the Verde Valley are metamorphic rocks. Generally speaking, the metamorphic and igneous intrusive rocks are Precambrian in age, the unmetamorphosed igneous extrusive rocks are Tertiary in age, and the sedimentary rocks are Paleozoic, Tertiary and Quaternary in age.

In the Verde Valley area, the Precambrian lithologies and the lower Paleozoic, Cambrian and Devonian Tapeats Sandstone and Martin Limestone respectively are not water-bearing formations. The Mississippian age Redwall Limestone possibly yields some water to wells and springs but does not appear to be a copiously-producing aquifer. The Pennsylvanian-Premian Supai Formation is the seocnd most important aquifer in the Verde Valley. Water from the upper member of the Supai Formation forms springs in Oak Creek Canyon while sandstones in the lower member grudgingly supply water for wells in the Sedona area. Of the Permian Coconino Sandstone, Toroweap Formation and Kaibab Limestone, only the Coconino produces water but not in copious quantities. Of the Tertiary age lithologies, only the Pliocene Verde Formation produces significant water. The conglomerate, sandstone and limestone facies of the Verde Formation are the main aquifers in Verde Valley. The younger, Pleistocene and Recent, volcanic and sedimentary lithologies overlying the Verde Formation, generally do not produce water.

No major ground-water reservoir, suitable for supplying 25,000 to 50,000 acre feet of desalinated water, exists in the Verde Valley. The major aquifers of the Colorado Plateau, that are present in the Verde Valley have been breeched and drained by the downcutting and erision of the Verde River and its tributaries.

The hydrologic conditions of the Verde Valley are best summed by Twenter and Metzger, 1963, as follows:

> The chief means of recharge to the Verde Valley ground-water reservoir is by direct penetration of water from precipitation on the Colorado Plateaus...Only a small part of the total precipitation is a source of water for recharge, because much of it is lost to the atmosphere by evaporation or transpiration and some may be lost to sublimation. A part of the precipitation becomes runoff, and some of this runnoff percolates downward through permeable rocks to the ground-water reservoir... The Verde Valley ground water basin is in hydrologic balance; the amount of water recharged to rocks in the basin is about equal to the amount water discharged as base flow at the Chasm gaging station...The average base flow at the gaging station during the winter---225 cfs or 150,000 acre feet per year--is an approximation of the minimum quantity of water recharged to all rocks in the ground water basin...This flow represents the minimum quantity of ground water discharged from rocks in Verde Valley...

The approximate quantity of water recharged to all rocks in the ground water basin, 150,000 acre feet per year, at first glance appears quite capable of supporting a desalination plant of 50,000 to 150,000 acre feet per year that would be necessary for an economic operation. However production of water from the ground water system in this quantity would, in the opinion of the researcher, greatly affect (i.e., reduce) the discharge of springs, creeks and rivers in the area. Should water reduction take place in this area, which is highly-prized nationally for its spectacular scenic value, a hue and cry from the general public would probably ensue. Negative publicity for and potential legal battles against the Power and Water Resource Service might not be worth the benefits gained from the successful completion of the project. A smaller plant producing 12,000 to 50,000 acre feet of water a year would in all probability be a marginal operation and result in a nominal, negative public reaction, if any.

In summary, barring a national or regional emergency, the researcher recommends that this region should not be considered for a major desalination and water supply augmentation project.

The only other area along the Verde River with potential for a reservoir suitable for desalinization would be in Maricopa County. The area east of the McDowell Mountains, west of the Verde River and south of Lone Mountain and Wildcat Hill was considered for reservoir potential in light of criteria established by the Water and Power Resources Service. A study of existing gravity and magnetic maps gave indication that bedrock was reasonably close to the surface. There was no geological evidence for a basin suitable for the storage of groundwater and geothermal fluids. The study was then moved westward to Paradise Valley, west of the Verde River and McDowell Mountains in the Paradise Valley basin.

C. Paradise Valley

Paradise Valley is a northwest-southeast trending basin approximately 17 km wide and 38 km long with an overall surface area of approximately 646 km^2. It contains the cities of Paradise Valley, Scottsdale and northeast residential Phoenix and the towns of Cave Creek and Carefree. A significant portion of the Salt River Indian Reservation is situated in the southern portion of the basin. The valley is bounded on the west by the Phoenix Mountains, Squaw Peak, North Mountain, Shaw

Butte, Lookout Mountain, and Union Hill; on the north by Black Mountain, on the east by the McDowell Mountains; and on the south by Phoenix, Scottsdale, Mesa and the Salt River Indian Reservation (Map III-1).

The major reference source for the geology of Paradise Valley is the 1974 Masters thesis from Arizona State University by Charles Dean Lausten.

Structurally the Paradise Valley basin is a typical, small Basin and Range graben trending N30^{O}W, and is situated on the northeast side of the Phoenix Basin. Gravity by Lausten indicates that in the central part of the Paradise Valley basin, the east side is step-faulted downward to the southwest. The best estimate made with the gravity data suggests the basin exceeds a depth of 3,000 m (see Maps IV-2 and IV-4).

The mountains and hills surrounding the basin are composed primarily of Precambrian intrusive and metasedimentary and metavolcanic rocks. There are minor Tertiary basalt flows and Cretaceous and Tertiary sediments along the southern and western margins of Paradise Valley (see Map IV-1).

Eberly and Stanley, 1978, have divided the Cenozoic sequence in southwestern Arizona into an older Unit I and a younger Unit II. This division is based upon time stratigraphic correlations determined by the relationships of the continental clastic sediments, interbedded volcanic rocks and evaporite sequences to regional and semiregional unconformities. This correlation has been greatly facilitated by over 120 K-Ar age dates on extrusive volcanic rocks interbedded in the basin fill sediments. The boundary between older (lower)

Unit I and younger (upper) Unit II is a major, ubiquitous unconformity. The major unconformity formed from the subsidence, block faulting and erosion that commenced in late Miocene time (13-12 my B.P.), ultimately resulted in the present topography of the Basin and Range province of Arizona.

In southern Arizona the sedimentation taking place during the early Cenozoic, Unit I time, was primarily continental in origin. These continental sediments were deposited in broad depressions or basins. During the Miocene time, the advent of the extensional horst-graben faulting in southern Arizona radically altered the topography with the result that Unit II continental sediments were deposited in these northwest-southeast trending grabens.

In 1951, an oil test, Biery #1 State, was drilled in the central part of the northwest quarter of the basin. The hole was drilled to a depth of 1.64 km (5,394 feet) below surface, plugged and abandoned (see summary log by anonymous, pages 10 and 11). From the surface to a depth of 963 m (3,160 feet), the lithology is primarily arkose and sandstone. The researcher has speculated, without examination of the cuttings, that this section might well be Unit II of Eberly and Stanley. From 963 m to 1,399 m (3,160 to 4,590 feet), the lithologies are interbedded claystone, siltstone and sandstone followed from 1,399 m to 1570 m (4,590-5,150 feet) by arkosic conglomerate. The reasercher has speculated that this could be Unit I of Eberley and Stanley. From 1,570 m to 1,644 m (5,150-5,394 feet), the lithology has been logged as quartz diorite and speculated as basement by the researcher. This depth agrees fairly well with Lausten's Model 2 (1974), parts of which are reproduced

Summary Lithologic Log

Paul H. Biery - State #1
SW¼, SE¼, SW¼; Section 8, T4N, R4E
Drilled 3-51 to 4-51
Elevation 1,720 D.F.; T.D. 5396

Lithologic Description

Feet Below Surface	
0-510	Arkose, 0.5mm - 8mm (av 3-4mm), buff, angular to subround, quartz clear to amber; feldspar clear, milky white, very fresh, loose, no visible cement; scattered, fragments purple-gray, green and yellow-green metamorphics; biolite; pyrite; streaks dirty gray-white caliche. Stringers SS, 0.2mm - 0.5mm (av 0.3mm); gray, calcareous, epidote grains, tight, hard at 420-430 feet.
510-670	SS, 0.1mm - 2mm (av 0.8mm); fragments of quartz, amber chert, metamorphic rocks (green, purple and gray), gneiss, and dark volcanics; with stringers dirty gray-white caliche; loose; grains subround; fragments (about 1mm diameter) of finer SS (av 0.2mm grains) gray, calcareous, tight, at 640-650.
670-870	SS, 0.1mm - 0.6mm (0.3mm av), buff, calcareous, tight, micaceous, abundant black ferromagnesian grains, friable, with scattered fragments metamorphic material; partly conglomeratic in lower part; (POROSITY POOR).
870-1820	Arkose, 0.5mm - 4mm (av 1mm), conglomeratic, brown and gray; fragments of quartz, metamorphics, feldspars, chert, all subangular to subround. Many fragments dark green metamorphic minerals; garnet, becomes finer, better sorted, 0.5mm - 1.5mm (av 1mm) from 1,490-1,820.
1820-2250	Arkose SS, as above, with increase in metamorphic fragments to about 30%.
2250-2280	Argillaceous SS, pink-buff, calcareous, very poorly sorted, micaceous, dirty, very tight; probably occurs as stringers or lenses in arkosic sandstone described above.

Summary Lithologic Log

Paul H. Biery - State #1 cont.

2280-2250 Arkose, with metamorphic fragments as above, partly conglomeratic.

2550-2960 Arkose, and argillaceous sandstone, as above, interbedded. Argillaceous SS, 0.2mm - 1mm (0.4 av). Arkose, 0.5mm - 4mm (1mm av).

Samples from 2,960-5,396 feet not available at time of examination, but driller's log is summarized as follows:

2,960-3,160	Arkose, and argillaceous SS, interbedded. UNIT II (?)
3,160-4,590	Interbedded alluvial claystone, siltstone & sandstone. UNIT I (?)
4,590-5,150	Arkosic Conglomerate
5,150-5,394	Quartz diorite - T.D. BASEMENT (?)

Modified by Hahman, 1980

on Map IV-3.

It should be pointed out at this time that the interpretation of the drill log regarding the location of Unit II and Unit I are speculative. If the current basin was an area of nondeposition during pre-Unit II basin formation time, then Unit I would not be present. An examination of the detailed, cuttings log compiled by the American Stratigraphic Company, shows that the log apparently does not reflect the great thickness of Superstition volcanic rock of Unit I present in other basins in the Phoenix area. In order to ascertain the true stratigraphic relationship with respect to Unit I and Unit II the cuttings would have to be relogged and the volcanic units age dated radiometrically.

Thirty-three water samples with one duplicate were collected and analyzed. The results of the analyses (Table IV-1) show there are no obvious geothermal waters. The Na-K-Ca and SiO_2 (chalcedony) geothermometers (Table IV-2 and Maps IV-5 & IV-6), indicate that the maximum reservoir temperature that may be expected is approximately 110°C. The geothermometers indicate the presence of a probable reservoir suitable for space heating and cooling. The preliminary study of the geothermal resource in Paradise Valley does not indicate temperatures suitable for desalination (150-200°C).

The following section on the estimate of the reservoir is written by Alice Campbell, engineering geologist and hydrogeologist.

D. Hydrogeology of Paradise Valley

Paradise Valley is a small, distinct groundwater basin that forms a part of the Salt River Valley groundwater basin.

Table IV-1: Chemical quality of selected subsurface waters from the Verde Valley area, Arizona

	Ca	Mg	K	Li	Na	Cl	B	HCO3	SiO2	SO4	F	TDS	pH
# 1	45	44	4.9	0.09	54	219	0.84	162	36	68	1.2	825	8.60
# 2	44	46	5.3	0.12	75	285	1.0	196	41	85	1.1	956	8.39
# 3	20	25	3.2	0.03	17	51	1.0	160	34	37	1.2	345	8.68
# 4	31	26	5.0	0.15	97	285	1.08	174	31	92	1.0	885	8.47
# 5	13	20	2.2	0.03	12	14	0.84	163	23	18	1.1	269	8.78
# 6	76	66	8.0	0.19	132	478	1.26	225	46	108	0.7	1688	8.31
# 7	13	18	2.6	0.03	10	16	1.30	145	26	18	1.1	246	8.62
# 8	14	21	2.3	0.03	11	19	0.90	160	30	23	1.1	261	8.69
# 9	3	9	1.7	0.11	59	44	1.16	156	30	61	7.0	396	8.85
#10	5	20	2.2	0.12	34	32	1.08	179	50	67	3.3	373	8.83
#11	25	22	1.9	0.10	28	32	1.16	297	102	78	3.3	589	8.63
#12	340	40	4.4	0.15	71	279	1.16	310	96	75	1.9	1469	8.60
#13	18	11	1.9	0.04	12	29	1.08	108	32	24	1.2	267	8.49
#15	25	15	4.4	0.09	44	57	0.90	186	34	90	3.3	491	8.85
#16	15	25	3.3	0.11	32	51	0.88	255	80	19	2.2	472	8.72
#17	23	38	2.8	0.12	37	117	0.90	247	85	68	2.1	631	8.47
#18	29	28	2.8	0.09	47	101	0.86	316	83	47	1.7	615	8.61
#19	8	17	2.4	0.08	27	35	0.76	188	55	6	1.8	330	8.63
#20	25	18	2.5	0.06	31	32	0.90	290	69	28	1.6	481	8.64
#21	29	19	2.1	0.07	37	51	0.78	247	66	75	1.3	524	8.91
#22	20	25	2.0	0.05	20	38	0.90	225	78	24	1.4	436	8.91
#23	5	9	3.5	0.18	57	95	1.16	149	36	36	1.6	427	8.88
#24	1	1	1.1	0.04	57	38	0.86	185	54	6	1.7	382	8.87
#25	12	23	2.7	0.03	26	32	0.92	327	54	27	1.5	423	8.85

Table continued...

	Ca	Mg	K	Li	Na	Cl	B	HCO3	S102	S04	F	TDS	pH
#26	16	42	3.8	0.05	51	70	0.90	350	59	51	1.9	624	8.93
#27	7	40	12.5	0.08	25	38	0.78	271	83	6	1.6	457	8.86
#28	6	21	3.2	0.05	42	35	0.92	250	74	3	1.8	431	8.90
#29	6	40	3.0	0.11	23	63	0.83	182	60	10	1.7	289	8.68
#30A	19	38	2.9	0.11	44	111	1.16	285	93	49	2.2	668	8.80
#30B	71	71	3.6	0.10	60	272	1.06	292	90	170	2.0	1298	8.30
#31	28	42	3.0	0.06	32	95	0.78	265	73	78	1.7	584	8.89
#32	11	19	2.9	0.05	10	25	0.68	157	64	3	1.8	173	8.77
#33	12	7	2.4	0.14	56	60	0.86	257	32	14	1.0	441	8.74

All data except pH reported as milligrams per liter.

Location of water samples are found on Map .

Table IV-2: Chemical geothermometers for Verde Valley area, Arizona.

Sample	Na-K-Ca (β=4/3)	SiO_2 (Chalcedony)
1	52.9	56.1
2	58.6	62.2
3	45.4	53.6
4	66.4	49.4
5	40.1	36.9
6	65.6	67.7
7	42.9	41.9
8	39.2	48.0
9	76.2	48.0
10	67.8	71.8
11	32.5	111.7
12	18.6	107.9
13	31.0	50.8
15	59.0	53.6
16	57.5	97.1
17	46.3	100.6
18	44.3	99.2
19	58.8	76.7
20	40.3	88.8
21	34.8	86.3
22	34.7	95.7
23	88.5	56.1
24	85.6	75.7
25	54.0	75.7
26	65.0	80.3
27	117.3	99.2
28	78.0	92.7
29	69.6	81.2
30A	52.4	106.0
30B	37.4	104.0
31	43.4	91.9
32	48.8	84.7
33	58.0	50.8

Location of water samples are found on Maps IV-3 and IV-4.

The alluvial surface of this basin, exclusive of the pediment, covers about 480 km^2, and gravity data suggest it exceeds 3,000 m in depth. One oil test hole, Biery #1 state, was drilled to a depth of about 1.64 km and provides some stratigraphic control for the materials within the groundwater basin. Water in the upper part of the basin is extensively pumped for agricultural and municipal supply, so the upper 300 m of the groundwater basin has been excluded from the reservoir estimate.

Based on the description of Basin and Range structure and stratigraphy presented in Everly and Stanley (1978) and gravity and other data in a thesis by Lausten (1974), the basin contains a thickness of about 1,650 m of uncemented continental deposits, some thin volcanic units probably 0-200 m thick, and approximately 1,000 m of older, possibly deformed and cemented continental deposits. The porosity and specific yield for these units have been estimated using reasonable average values for these materials.

The total volume of water in storage in the basin (excluding the upper 300 m) amounts to 63,600 cubic hectometres (hm^3). Of this volume about half, or 30,000 hm^3, would be recoverable by wells. Most of this water is contained in the upper, uncemented continental sediments. See Table IV-3 for an analysis of the estimate.

Water stored in the lower portions of the groundwater basin probably occurs under confined to semiconfined conditions. Mining of large volumes of water from some portions of the aquifer could produce geotechnical problems similar to problems encountered by the agricultural mining of ground water. For example, subsidence resulting from ground water pumping of confined or semiconfined aquifers has been well documented in many parts of the Southwest.

Another geotechnical problem involves protection of potable ground water supplies from degradation by saline geothermal waters. However, the potable water supplies can be adequately protected utilizing reasonable care and currently available technology. The extent and magnitude of any subsidence problems resulting from geothermal development cannot be ascertained from the data available.

Table IV-3

Paradise Valley Reservoir Estimate

Sediment Type	Thickness	Area	Porosity	Specific Yield
continental	1,645 m	170 km^2	20%	10%
volcanics	100 m	119 km^2	5%	1%
older continental	1,000 m	70 km^2	10%	3%

	Water in Storage	Recoverable Water
upper continental unit (excluding upper 300 m)	56,000 hm^3	28,000 hm^3
volcanic rocks	600 hm^3	120 hm^3
lower continental unit	7,000 hm^3	2,100 hm^3

V. ENVIRONMENTAL ASPECTS

The Paradise Valley area has undergone considerable development, in addition to being an exclusive residential area. The high population density has resulted in a proliferation of roads, buildings and residences. The mining of ground water for the large scale development of a geothermal resource could well result in some surface subsidence and the erection of surface structures necessary to develop the geothermal reservoir. The surface construction might necessitate the relocation of some of the residents. Exploration and production drilling might create a temporary noise problem and cause minor damage to the land surface. The land surface could be repaired once the drilling was completed.

There would be a net groundwater loss, should an economic resource be developed. The amount of withdrawal and subsequent impact on the area would be dependent upon the scope of the project. In any event, the necessary technology is available to curtail and/or prohibit subsidence and protect the potable water aquifers.

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