BIBLIOGRAPHY OF GEOTHERMAL RESOURCES IN THE SAN CARLOS-SAFFORD-DUNCAN NONPOINT-SOURCE MANAGEMENT ZONE, ARIZONA

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The San Carlos-Safford-Duncan Nonpoint-Source Management Zone (Figure 1) is known to contain significant quantities of geothermal energy resources. Following the energy crisis in the 1970s, these resources were studied in detail. This report includes references pertaining to geothermal energy resources, hot springs and wells, heat flow measurements, and geothermal gradients.

Two geothermal reservoirs are located in Greenlee County. One of Arizona's most important Known Geothermal Resource Areas (KGRA) is at Clifton. References pertaining to geothermal resource evaluations for Greenlee County and the Clifton KGRA include Witcher (1979a), Arizona Geothermal Commercialization Team(1979), Witcher and Stone (1980), Witcher (1981), and Hahman (1979a, b).

The Safford basin, in Graham County, contains at least four proven and potential geothermal reservoirs of less than 1.2 km depth and three inferred moderate to high-temperature reservoirs less than 2.5 km depth (Arizona Geothermal Commercialization Team, 1979). Studies by Witcher, 1979b, 1981, 1982) Hahman, (1979a) and Hahman and others (1979) focused on characterizing the nature and extent of geothermal anomalies in the Safford area.

One of the surface manifestations of geothermal reservoirs is the presence of hot springs and hot artesian wells. The relation of natural hot springs and hot wells to water quality in the upper Gila River was discussed in Harris (1997). The following is excerpted and modified from that report:

Hot Springs

Several hot springs occur within the Management Zone that are known to produce salty water. Perhaps the best known is the Clifton Hot Springs (D-4-30-19,30). These springs issue at temperatures up to 49°C (120°F) from Tertiary volcanic rocks. Total dissolved solids (TDS) is up to 14,548 mg/l and chloride runs 5800 ppm (Eaton and others, 1972) to 6500 mg/l (Witcher, 1981a) in these thermal waters (ppm is used mostly in older literature and is approximately equal to mg/l). An estimated average of 54 tons of dissolved solids per day (19,710 tons per year) is discharged from the springs to the San Francisco River (Hem, 1950).

Eagle Creek Hot Springs (D-4-28-35abb) may be on the same fault zone as Clifton Hot Springs (Witcher, 1981a). Eagle Creek springs discharge water at about 42°C (108°F), with TDS of less than 1000 mg/l. The water is of a mixed sodium bicarbonate-chloride type.

Gillard Hot Springs (D-5-29-27aad), along the Gila River where it cuts through the Gila Mountains east of Safford, is reported to be the hottest springs in Arizona, at 80° to 84°C (176 to 183°F) (Witcher, 1981a). The output of hot, saline water from the springs (TDS 1200-1500 mg/l) is sufficient to raise the temperature of Gila River water about 2°C (3.6°F), and raise the chloride content of the river from 25 mg/l upstream from the springs to 30 mg/l below the springs (Hem, 1950; Witcher, 1981a).

Indian Hot Springs (D-5-24-17add), northwest of Safford, produces about 1000 liters per minute of water at 45 to 48°C (113 to 118°F) (Witcher, 1981b). The water is a sodium chloride type and travertine (calcium carbonate) deposits are present at the springs. TDS ranges from 2570 mg/l to 3004 mg/l. A high level of sulfate in the spring water indicates the presence of gypsum in the sediments.

Indian Hot Springs is on an alignment of faults trending NW on the north side of the Gila River flood plain. This zone of faulting extends from Bylas to northwest of Safford and is thought to responsible for an alignment of hot springs and hot wells in that area (Witcher, 1981b). Traces of fault segments and associated deformation of sedimentary units are exposed at several localities (Houser, 1990; Houser and others, 1985)

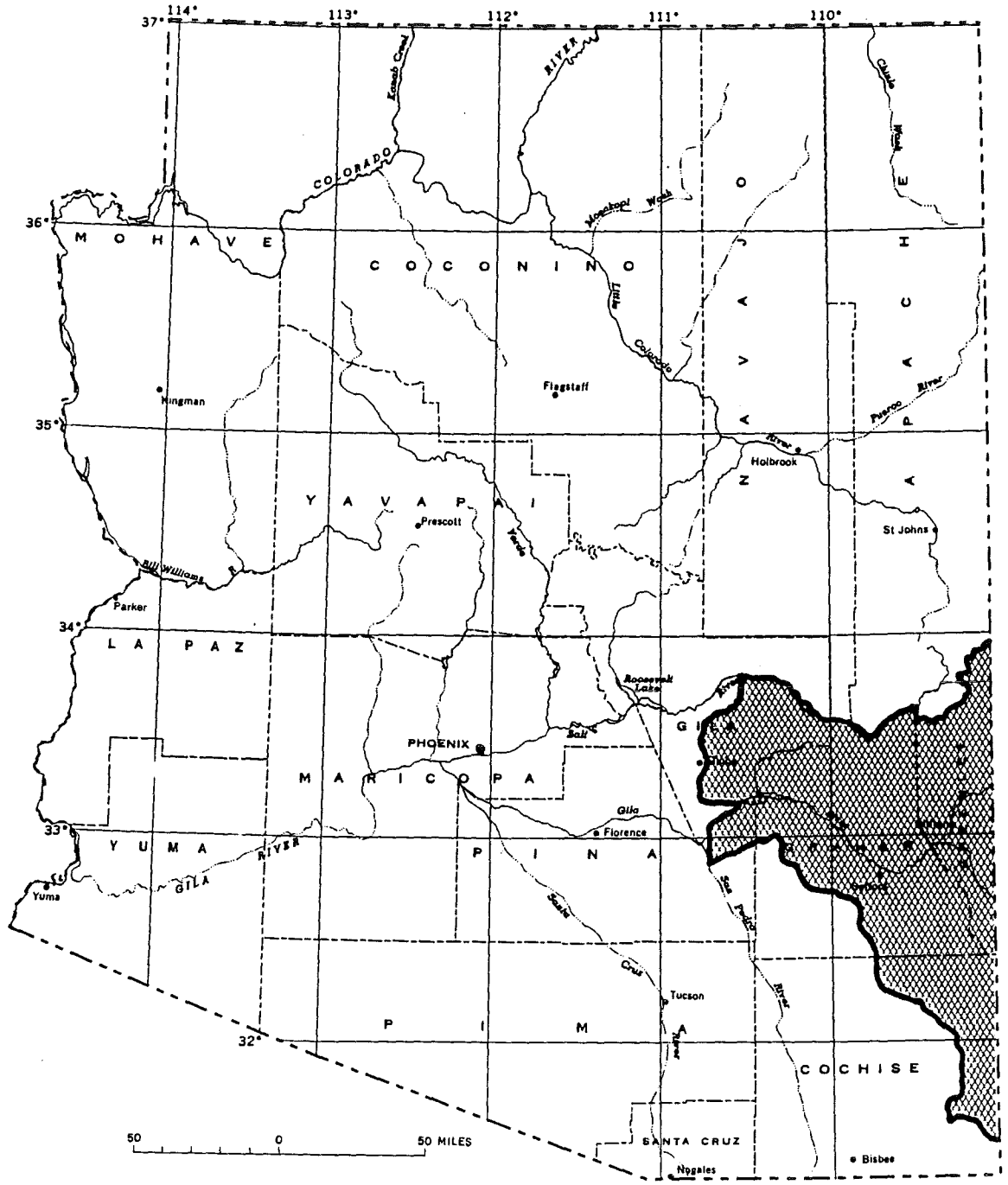

Figure 1. Location of San Carlos-Safford-Duncan Nonpoint-Source Management Zone.

Deep wells

The 3767 foot deep Underwriters Syndicate 1 Mack oil exploration well (D-6-24-13ab; location of wells shown on Plate 1), also known as the Mary Mack well, discharged water similar in chemistry to that of the nearby Indian Hot Springs. (This well is near the fault-controlled alignment of hot springs along the north side of the Gila River.) TDS was measured by Knechtel (1938) at 3351 ppm, and the water temperature was 59°C (138°F). In 1933, the well was flowing at 2250 gpm, but the well is no longer flowing (Witcher 1981b; Stone and Witcher, 1982).

Knechtel (1938) reports that the 2,645-foot deep Gila Oil Syndicate #1 well near Ashurst (D-5-24-30ac) produced substantial artesian flow of hot, mineralized water. Well logs (AZGS oil and gas files; Knechtel, 1938) describe salt water at 590 and 750 feet, but the actual amount was not measured.

Artesian flow of salt water (21 gpm) was noted in a well at Geronimo (D-4-23-19) from the bottom of a 405-foot thick layer of hard clay and lime 90 to 495 feet below surface (Knechtel, 1938). The 28°C (82°F) water had a very high TDS of 14,035 ppm, with a sodium content of 5,076 ppm, chloride content of 6,656 ppm, and sulfate of 1,838 ppm. The well produced fresh water to a depth of 45 feet.

The Smithville Canal well, also known as the Mt. Graham Mineral Bath well (D-6-25-36cbb), produced 601 gpm of sodium chloride type water under artesian flow at 46°C (115°F) (Witcher, 1981b). Witcher reports TDS ranging from 4,431 to 8,292 mg/l, and Muller and others (1973) measured total chloride of 480 to 1504 ppm. [Note: the Smithville Canal well was plugged and abandoned in 1997]

About five miles south of Safford, the Idle Oil-Healy #1 well (D-8-26-6bd) produced what Knechtel (1938) called "scalding hot salty water". This artesian well flowed at 1/2 gpm and the main water-bearing bed was at 1600 feet.

This bibliography is derived in part from the comprehensive bibliography for the Management Zone by Trapp and Harris (1996), with additional references.

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