NOTICE CONCERNING COPYRIGHT RESTRICTIONS

OVERVIEW OF GEOTHERMAL INVESTIGATIONS IN IDAHO, 1980 to 1992

William J. Dansart and Leland L. Mink

Idaho Water Resources Research Institute, University of Idaho, Moscow ID

ABSTRACT

In 1980, the Idaho Department of Water Resoures (IDWR) published the results of a statewide study outlining the characteristics, occurrences, and uses of thermal waters in the state of Idaho (Mitchell, Johnson, and Anderson, 1980). A substantial amount of geothermal resource investigation has occurred within Idaho during the past 12 years. The report summarizes geothermal data generated since the 1980 IDWR report.

INTRODUCTION

The Idaho Water Resources Research Institute (IWRRI) has compiled available geothermal resource data generated for the state of Idaho. Results of the compilation focus on data generated since the last published state assessment (Mitchell, Johnson, and Anderson, 1980). Sources of information include state and federal agencies, organizations under contract to the Department of Energy, and numerous other published reports. The report outlines the characteristics, occurrences, and uses of thermal waters in the state of Idaho which are documented by resource investigations conducted since 1980 and is available through the Idaho Water Resources Research Institute; an Idaho geothermal bibliography (about 700 references) is also available in hardcopy or disk format.

In addition to well data from other reports, the (IWRRI) report includes data from over 200 water wells, up to 3030 feet in depth, drilled in Idaho from 1980 to 1992. Temperatures in these wells range from 70° F to 180°F. Approximately 50% of these wells were drilled for geothermal applications (municipal and domestic heating, greenhouses, fish farming, bathing resort facilities) . Geographically most drilling has occurred in Twin Falls (62), Boise (39), Owyhee (37), and Ada (20) counties; approximately 80% of warm-water wells drilled in Idaho are located in these four counties.

Funding for this project was provided by the United States Department of Energy-Geothermal Division via contract with EG&G, Idaho.

PREVIOUS COMPILATIONS

Water Information Bulletin No. 30, part 9 (Mitchell, Johnson, and Anderson, 1980) contains information on the properties, characteristics, and origins of 899 thermal water occurrences with surface temperatures of 20° C or higher within the state. Included with this study was a statewide geothermal resource map (NOAA, 1980). The report lists chemical analyses of 357 sites. Previous published reports on statewide geothermal potential included: Stearns and others (1937); Waring (1965); Ross (1971); Nichols and others, (1972); Warner (1972) and (1975); Young and Mitchell (1973).

Since publication of Water Information Bulletin No. 30, part 9, in excess of 350 papers have been written addressing Idaho geothermal resources. Notable assessments which encompass areas hosting most geothermal occurrences in Idaho include those by Blackwell (1988) and Mabey (1983). In addition, a compilation of data from Idaho thermal water [sample] analyses performed at USGS laboratories between 1921 and 1991 is presently available (Parliman and Young, 1992),.

Regional studies include: Blackwell, Kelley, and Steele (1992) and Smith (1980), Snake River Plain; Lewis and Young (1980), Payette River Basin; Lewis and Young (1982), Boise River Basin; Young and Lewis (1982),
Salmon River Basin; Young (1985), Idaho Batholith; Batdorf and others(1980), Ralston and others (1981) and Souder (1985), SE Idaho; Young and Lewis (1982) and McClain (1980), SW Idaho.

Environmental assessments of seven Snake River Plain Known Geothermal Resource Areas (KGRA's) were conducted by EG&G, Idaho (Spencer, Russell, and Sullivan, editors, 1979). Areas evaluated are: Vulcan Hot Springs, Crane Creek, Castle Creek, Bruneau, Mountain Home, Raft River, and Island Park/Yellowstone.

Other reports are of more local coverage. Examples are listed by county.

GEOTHERMAL STUDIES SINCE 1980

Ada County

The city of Boise has been utilizing geothermal resources since the 1890's for heat and hot water. The first commercial use of water was a small domestic heating system,supplied by two 400-foot wells drilled in 1890; this venture eventually became the Boise Warm Springs Hot Water district. Use of geothermal heat began to decline in the 1930's when low cost gas and electricity became available. Major expansion of Boise's geothermal resource use began with a successful retrofit of the State Health Laboratory, as a pilot project, in 1977. In 1980, the State of Idaho drilled two wells to service the Capitol Mall heating system. The 160° F water heats 800,000 square feet of office space (Austin, 1984), flowing at a maximum rate of 800 gpm during peak heating system (Berkeley Group, 1990). In 1981, Boise Geothermal , an agency created to coordinate activities between the City of Boise and the Boise Warm Springs Water District, drilled three production wells to service a 4.5 mile heat distribution system through downtown Boise. The Boise City District Heating sytem became operational in 1983, and is capable of delivering 4000 gpm or 2.2 million therms to the heating system (Mickelson, 1985).

An extensive review of data and evaluation of the Boise Geothermal Aquifer was conducted by the Berkeley Group (1990) under contract to the Idaho Department of Water Resources. The report concluded that geothermal production wells along the Boise Front Fault communicate readily; interference occurs between production wells and effects water levels along the fault in general. The effects of development on the geothermal aquifer and aquifer longevity cannot be predicted without further hydrologic, geophysical and geochemical investigation.

An analysis of drawdown and production data by Waag and Wood (1987) suggests that the Boise Geothermal Aquifer system was at or near equilibrium prior to 1983. They recognize a decline in water levels in the vicinity of production wells. The rate of decline appeared to be increasing without a coincident increase in production.

Other evaluations of the Boise Geothermal Aquifer include those by Wood and Burnham (1983), Mayo, Muller, and Mitchell (1984), Young, Parliman, and Mariner (1988), and Mariner, Young, Parliman, and Evans (1989).

Bannock County

According to Corbett, Anderson, and Mitchell (1980) it appears that warm water sufficient at least for space heating may be available in the Tyhee area if local structural control can be identified at depth. Highest probable aquifer or subsurface temperatures that might be encountered by drilling is 80° C , with a low of 41° C represented by surface discharge temperatures in the area. Additional data collection is necessary before a realistic assessment of the geothermal resource can be made.

Trans Energy Systems (1981) studied the application of low temperature geothermal heat to a barley malting process. The study was centered around the Great Western Malting Company facility at Pocatello, Idaho. It estimated the presence of a geothermal resource yielding 1000 to 1500 gpm of 150° to 250°F in the area. Based on this estimate, the viability of seven different processing systems utilizing geothermal heat was evaluated.

Bear Lake County

A hydrogeologic investigation of geothermal systems in the vicinity of the Bear River Range was conducted by Baglio (1983). This was a reconnaissance level examination of regional geologic controls and hydrochemical characteristics of thermal and non-thermal groundwater systems in the area. Fifty three selected springs and shallow wells were characterized.

Blaine County

The geology of several hot spring sites has been mapped in varying detail by Anderson and Bideganeta (1985); Blackett (1981); Struhsacker and others (1982) and Leeman (1982). Individual systems that have been investigated are Magic Hot Springs (Struhsacker and others, 1983) and Guyer Hot Springs (Blackett, 1981; Burkett and Litke, 1989). Burkett and Litke (1989) studied the potential impact of geothermal resource development on public health and the environment in the Warm Springs Creek area near Ketchum. The research indicated that leakage from a pipeline entered the Warm Springs Creek valley aquifer, and that it had a demonstrated effect on fluoride levels in several public community drinking water systems. Burkett and Litke made recommendations for remediation of the problem.

The Idaho Department of Water Resources studied hydrothermal systems in the Wood River drainage (Anderson and Bideganeta, 1985; Street,1990). Anderson and Bidgeneta (1985) concluded that geothermal resource potential in the Wood River Drainage is limited to isolated thermal water reservoirs in the vicinity of fault controlled hot springs. None of the rock units in the area have the necessary permeability and transmissivity to serve as thermal water aquifers. Water temperatures indicate suitability for direct uses as space heating, bathing and fish culture, but elevated fluoride concentrations will complicate commercialization of the resource.

Geochemical studies of thermal springs in the Wood River Valley were conducted by Zeisloft and others (1983) and Foley and others (1983). Foley and Street (1985; 1986; 1988) discussed the nature and occurrence of the thermal resources and the elevated fluoride levels and have prepared a field guide addressing individual spring sites and regional geothermal potential.

A site-specific analysis of Ketchum was initiated by the Oregon Institute of Technology (OIT) Geo Heat Center (1982). It was later determined that the analysis could not contribute to further geothermal development due to several physical, legal, and institutional factors including limited resource quantity, ownership considerations, and environmental concerns.

Boise County

Several greenhouses, resort facilities, and numerous homes use geothermal resources to provide hot water and space heating needs in Boise County, particularly in the Garden Valley-Crouch area. Logs were filed with the Idaho Department of Water Resources for 39 warm water wells for the period 1980 to 1992. Water temperatures recorded ranged from 27 ° to 84 °C; 24 of the wells showed temperatures greater than 55 ° C.

Lewis and Young (1980) characterized 31 thermal springs in the Payette River basin. Water temperatures ranged from 34 °to 86 ° C, with estimated reservoir temperatures of 53 ° to 143 ° C. Tritium analysis indicated that sampled geothermal waters are at least 100 years and possibly more than 1000 years old.

Six hot spring areas along the South Fork of the Payette River were examined in detail by two Washington State University graduate students, Reed (1986) and Dingee (1987). Geothermometers give estimated reservoir
temperatures of 68 ° to 150 ° C. Reservoir volume and temperature appear sufficient to support localized direct-use applications.

Camas County

An evaluation of the Magic Reservoir area was conducted by University of Utah Research Institute (Struhsacker, Jewell, Zeisloft, and Evans, 1983). The authors attempted to place the Magic Reservoir volcanic rocks in the regional stratigraphic framework and heat flow regime of the Snake River Plain and indentify the structures controlling geothermal fluid circulation.

The Fairfield area was selected for a site development analysis by the Idaho Office of Enery (McClain and Eastlake, 1979) regarding potential for spaceheating public buildings and industrial applications. Three locations with good geothermal potential were identified along with recommendations for exploration and potential applications.

Canyon County

Numerous warm water wells and favorable geologic conditions indicate that the Nampa area has good potential for using geothermal energy in direct applications. Many existing warm wells are in the 75-100°F (24-38°C) temperature range.

Two analyses of potential direct resource use in theNampa area were performed by OIT Geo Heat Center (1982). One evaluation dealt with retrofitting of Parkview and Lakeview schools to use an existing

hot water source of 90°F (32°C) for heat pump conversions; in this particular instance, the conversions were not economically practical relative to cheap coal prices. The second evaluation examined a geothermal conversion for Mercy Medical Center; the economic feasiblilty looked very favorable.

The Idaho Department of Water Resources conducted an integrated geological, hydrological, geochemical and geophysical survey for the purpose of evaluating the geothermal potential of the Nampa-Caldwell area (Mitchell, 1981). Recommendations for resource definition and development were outlined.

Caribou County

Hubbell (1981) described geothermal flow systems in the vicinity of the Caribou Range in southeastern Idaho. He characterized 19 thermal springs and two wells as well as describing area geology.

Cassia County

The Raft River Geothermal site in southern Idaho has been the subject of more evaluation than any other area in Idaho. Work on the Raft River Geothermal project began in 1973 with startup of a 5MW(e) pilot geothermal plant in the fall of 1981; final shutdown occurred during June 1982 (Bliem, 1983). The plant, built by the Idaho National Engineering Laboratory, successfully demonstrated the technical feasibility of using a moderate temperature (275 to 300 °F) to generate electrical power in an environmentally acceptable manner. The plant used a dual-boiling binary cycle with isobutane as the working fluid. Seven deep geothermal wells were drilled to support the project (five production, two injection) in addition to several geothermal gradient and monitor holes. A vast amount of knowledge was obtained on the characteristics of a fracture-controlled geothermal system with respect to production and injection. Successful non-electric experiments included agriculture, aquaculture, biomass production, wetland studies, and space conditioning (Mink, 1982). A number of reports were generated concerning the Raft River Geothermal Project by EG&G, USGS, and other researchers.

Custer County

The OIT Geo Heat Center (1982) conducted a site specific development analysis of the Stanley area. It was concluded that a geothermal district heating system for Stanley was technically feasible and economically attractive. The reservoir area has significant potential for production of large amounts of thermal water; silica geothermometer estimated temperature is 167°F (75°C).

Water samples from springs in the Mackay, Idaho area were collected by the University of Utah Research Institute (UURI) to investigate potential of a direct-heat geothermal resource. Geothermometry results suggested that subsurface temperatures for spring waters is not significantly above the measured surface temperatures. The potential for finding a shallow geothermal reservoir with temperatures much above 22°C appears slight (Sibbett and Capuano, 1984).

Elmore County

The OIT Geo Heat Center(1982) conducted a site specific analysis of the Mountain Home Air Force Base. The study investigated the engineering and economic feasability of developing a heating system to service 1500 housing units on the base. The report concluded more resource assessment was needed to define the limits of resource capability.

A 4403-foot test hole was drilled by the Air Force on the Mountain Home Air Force Base for geothermal exploration. The purpose was to determine the availability of water from geothermal aquifers to supply energy for space heating of military housing and other base facilities. Maximum temperature recorded during temperature logging was 93°C (Lewis and Stone, 1988).

Evaluation of an area near Mountain Home as a hot dry rock prospect was performed by Arney, Beyer, Simon, Tonani, and Weiss (1980). A favorable target was identified. Temperatures of 200°C were projected at 3 km depth, with granitic rocks to be intersected 2 to 3 km deep .

Fremont County

Hoover, Pierce and Long (1985) postulated that the Island Park area is underlain by a solidified but still hot pluton that represents a significant hot dry rock resource. Exploration and development activities have been retarded by a lack of surface thermal features, evidence of hydrothermal systems, and environmental concerns. Deep drilling is necessary to substantiate the interpretation and provide heat-flow data.

Idaho County

Kuhns (1980) outlined the structural and chemical aspects of the Lochsa geothermal system near the northern margin of the Idaho Batholith. Heat flow data suggested a geothermal gradient of 50° C/km with circulation depth estimated at 3 to 4 km. Kuhns suggested a potential geothermal reservoir 300 to 400 cubic kilometers in size exists along the Lochsa River.

Youngs (1981) characterized the geology and geochemistry of the Running Springs geothermal area. The maximum temperatures indicated by geothermometry are in the 80-90°C range. Given the low temperature, small probable size and relative isolation of the system, there is little apparent economic development potential.

Lemhi County

An evaluation of Big Springs Hot Springs as a source of electrical power for the Blackbird Cobalt Mine was conducted (Struhsacker, 1981). Big Creek Hot Springs is one of the hottest known geothermal systems in Idaho, with a surface temperature of 93°C (199°F). Geothermometer estimates of reservoir temperature range from 137°C to 179° C (279°F- 354° F). It was concluded that Big Creek Hot Springs is an excellent geothermal prospect. A suggested exploration program, engineering and economic analyses, and appraisal of institutional factors was outlined.

The geology and geochemistry of three hot springs systems in the Shoup geothermal area was investigated by Vance (1986). Chemical geothermometers gave indicated equibration temperatures: Big Creek Hot Springs, 181°C; Owl Creek Hot Springs, 127° C; Horse Creek Springs (2 vents), 40°C and 70°C. Location of the hot springs systems make economic development impractical.

Madison County

In the summer of 1980, a 3943-foot well was drilled at the edge of Rexburg in a region that had been tested by shallower temperature gradient holes. The goal of the project was to identify a geothermal resource suitable for heating several large buildings in the Rexburg area (Kunze and Marlor, 1982) as well as supply industrial food processing energy for a large potatoe granule processing plant. Temperatures measured near 4000 feet depth were far below what was predicted or needed and drilling was halted. In 1981, attempts were made to restrict downward circulation in the well, but results were unsatisfactory. The well is a prolific producer of 70° F water (Stoker and Kunze, 1980).

Owyhee County

According to Mabey (1983), the largest hydrothermal system in Idaho is in the Bruneau-Grand View area of the western Snake River Plain with a calculated reservoir temperature of 107 °C . More information is needed to define the extent of the system and source of hot water; no evidence in the existing data indicates that large volumes of water hotter than that indicated by geothermometers will be found within 3 km of the surface.

OIT Geo Heat Center (1982) conducted an analysis of the Grandview area. A number of thermal wells ranging from 77 °F to 181 °F (25 °-83 °C) are situated within a 3-mile radius of the town. Several buildings were already heated by warm water. It was concluded that Grand View has good geothermal energy potential, but the economics of a district heating system were not very attractive.

Young and Parliman (1989) presented physical, chemical and isotopic data collected from 86 thermal-water wells and 5 springs in the Indian Bathtub area. This data was collected as part of a study to determine the cause of decreased discharge at Indian Bathtub Spring and other thermal springs along Hot Creek.

Payette County

A technical assistance grant from EG&G, Idaho, provided for a study to assess the technical and economic feasibility of using a potential geothermal source to drive a fuel grade alcohol plant. Test data from the well at the site indicated that water temperature at 8500 feet should approach 275° F. The study found the direct utilization of hot water for alcohol production based on atmospheric processes using low pressure steam to be cost effective (Austin, 1981).

Twin Falls County

The Earth Science Lab Division of the University of Utah Research Institute (UURI) provided geologic assistance to Fishbreeders of Idaho, Inc. to locate a thermal well for operation expansion. The study area was located near Banbury Hot Springs in the Hagerman Valley, about 20 miles west of Twin Falls (Blackett, 1981).

Goldman (1982) documented the development of the Leo Ray fish farming operation near Buhl, which utilizes geothermal energy. History of development is described and recommendations for future resource evaluation are presented.

UURI conducted an evaluation of exploration methods useful for low-temperature geothermal systems in the Artesian City area (Struhsacker, Smith, Capuano, 1983). Each technique was critiqued and a exploration strategy outlined.

Lewis and Young (1982) characterized geothermal resources in the Banbury Hot Spring area. An inventory of wells and 2 thermal springs was completed; water level, discharge, and chemical analyses were also carried out. Estimated age of geothermal water is at least 100 years and possibly more than 1000 years. Reservoir temperature is estimated between 70° and 100° C.

Lewis and Young (1988) also characterized the hydrothermal system in central Twin Falls County. The report described the areal extent and thickness of the hydrothermal reservoir and proposed a conceptual model of the system. It was concluded the reservoir is approximately 240 mi^3, with aquifers contained primarily in the Idavada Volcanics. Aquifer thickness ranges from 700 to 2000 feet. Estimated reservoir temperature is 70° to 80 °C; carbon-14 age dates placed samples from 1000 to 10000 years old. Net heat flux is about 2.2 HFU.

An investigation of the thermal resource in central Twin Falls County was conducted by the Idaho Department of Water Resources. The initial part of the study completed by Street and DeTar (1987), provided baseline data on geology, historic pressure and temperature fluctuations in the system, and thermal water geochemistry. The second part of the study which included continued monitoring of system temperatures and pressures, additional water chemistry and rock geochemistry was completed by Baker and Castelin (1990) and a conceptual model proposed. In addition to the Idavada volcanics, Paleozoic sedimentary rocks east of Hollister act as part of the geothermal aquifer. A north to northwest flow pattern is implied. Although water level decline is apparent in developed areas, discharge due to pumping does not exceed natural recharge.

Mariner, Young, Evans, and Parliman (1991) investigated the chemical, isotopic, and dissolved gas compositions of the hydrothermal system in Twin Falls and Jerome counties. It appears thermal waters range in age from 2000 to 26000 years. Westward-flowing older waters, north of the Snake River, may join younger northward-flowing waters; main direction of flow in the hydrothermal system seems to parallel surface drainage.

Valley County

An environmental analysis of the Vulcan Hot Springs KGRA was completed by EG&G, Idaho (Spencer and Russell, 1979) as part of a preplanning environmental program related to KGRA's in the Snake River Basin. USGS Open-file Report 80-518 consisted of a telluric profile and location map for Vulcan Hot Springs KGRA (Christopherson, Senterfit, and Dalati, 1980).

Washington County

The Crane Creek KGRA is located in Washington County, in southwestern Idaho. Estimated resource temperature is 166 ° to 176 °C. The KGRA is situated along the west side of the north-south trending Idaho Fault Zone. An environmental assessment of the area was performed by EG&G, Idaho (Spencer and Russell, 1979).

Fifteen thermal springs, two thermal wells, and eight cold springs in the Weiser and Little Salmon river drainages were sampled for deuterium and oxygen-18 analysis during the fall of 1981 by the Idaho Department of Water Resources (Mitchell and Bidgeneta, 1981). The analysis suggests that thermal waters might be Pleistocene age. Isotopic data indicate little evidence for mixing of thermal and non-thermal waters.

REFERENCES

Anderson, J.E., Bideganeta, K., and Mitchell, J.C., 1985, Geothermal investigations in Idaho: Preliminary geologic reconnaissance of the geothermal occurrences of the Wood River Drainage area; Water Information bulletin no. 30, part 13, 54 p.

Arney, B.H., Beyer, J.H., Simon, D.B., Tonani, F.B., and Weiss, R.B., 1980, Hot dry rock geothermal site evaluation, western Snake River Plain, Idaho: <in> Geothermal: Energy for the eighties, Geothermal Resouces Council Transactions, v. 4, p.197-200.

Austin, J.C., 1981, Geothermal source potential and utilization for alcohol production: EG&G report EGG-2138.

Austin, J.C., Fettkether, L.M., and Chase, B.J., 1984, Idahocapitolizes on its geothermal resources: <in> Geothermal energy: Bet on it!, Geothermal Resources Council Transactions v. 8, p. 135-138.

Baglio, J.V., 1983, Hydrogeologic investigations of geothermal systems in the vicinity of the Bear River Range, southeastern Idaho: University of Idaho M.S. thesis, 83 p.

Baker, S.J., and Castelin, P.M., 1990, Geothermal resource analysis in Twin Falls County, Idaho, part 2: Idaho Department of Water Resources, Water Information Bulletin no. 30, part 16, 50 p.

Batdorf, J.A., McClain, D.W., Gross, M., and Simmons ,G.M., 1980, Industrial application of geothermal energy in southeast Idaho: Idaho Office of Energy report DOE/ID-12010-4, 80 p.

Blackett, R.E., 1981, Preliminary investigation of the geology and geothermal resources at Guyer Hot Springs and vicinity, Blaine County, Idaho: University of Utah Research Institute, Earth Science Laboratory Rept.ID/GHS/ESL-1,(with maps) 26 p.

Blackett, R.E., 1981, A geothermal resource site evaluation near Banbury Hot Springs - Twin Falls county, Idaho: University of Utah Research Institute, Earth Science Laboratory Rept., ID/BHS/ESL-1, with maps, 14 p.

Blackwell, D.D., 1988, Heat flow and geothermal resources of Idaho: unpublished manuscript, 91 p.

Blackwell, D.D., Kelley, S., and Steele, J.L., 1992, Heat flow modeling of the Snake River Plain, Idaho: EG&G, Idaho, report EGG-C91-103450, 109 p.

Bliem, C.J. and Walrath, L.F., 1983, Raft River binary-cycle geothermal pilot plant final report: EG&G Idaho Inc. report EGG-2208.

Berkeley Group, 1990, Boise geothermal aquifer study: final report for IDWR contract #DWR-89-03-46-102-54, report no. DOE/ID/12748-3, 216 p.

Burkett, G.R., and Litke, R.T., 1989, Warm Springs Creek geothermal study: Idaho Dept. of Health and Welfare, Division of Environmental Quality, Water Quality status report no. 84, 76 p.

Christopherson, K., Senterfit, M. and Dalati, M., 1980, Telluric profiles and location map for Vulcan Hot Springs Known Geothermal Resource Area, Idaho: U.S. Geological Survey Open-File Report 80-518, 4 p.

Corbett, M.K., Anderson, J.E., and Mitchell, J.C., 1980, Geothermal investigations in Idaho, Part 10: An evaluation of thermal water occurrences in the Tyhee area, Bannock County, Idaho: Idaho Dept. of Water Resources Water Information Bulletin 30, 67 p.

Dellinger, M., Higbee, C., Justus, D. Rafferty, K. and Rivenes, R., 1982, Geothermal energy in the northwest: site specific analyses: Oregon Institute of Technology Geo Heat Center report, 188 p.

Dingee, B.E.,1987, Geology, hydrology and geochemistry of the geothermal area east of Lowman, Idaho: Washington State University M.S. thesis, 138 p.

Foley, D. and Blackett, R., 1983, Water geochemistry of hydrothermal systems, Wood River District, Idaho: University of Utah Research Institute, Earth Science Laboratory Rept. ESL-83006-TR, DOE/ID/12079-107, 23p.

Foley, D. and Street, L., 1985, Geothermal systems of the Snake River Plain, Idaho batholith and Northern Rocky Mountain transition zone: University of Utah Research Institute, Earth Science Laboratory Rept. ESL-85011-ABS.

Foley, D. and Street, L.V., 1988, Hydrothermal systems of the Wood River Area, Idaho: <in> Paul Karl Link and William R. Hackett, editors, Guidebook to the geology of central and southern Idaho: Idaho Geological Survey Bulletin 27, p. 109-126.

Foley, D. and Street, L.V., 1986, High fluoride in geothermal waters from Idaho: GSA abstracts with programs, v. 18, p. 604.

Goldman, D., 1982, Development of a low-temperature hydrothermal energy resource: University of Idaho PhD dissertation, 298 p.

Hoover, D.B., Pierce, H.A., and Long, C.L., 1985, Is Island Park a hot dry rock system?: <in> International symposium on geothermal energy, Geothermal Resources Council Transactions, v. 9, part 2, p. 25-30.

Hubbell, J.M., 1981, Description of geothermal flow systems in the vicinity of the Caribou Range, southeastern Idaho: University of Idaho M.S. thesis, 105 p.

Kuhns, R.J., 1980, Structural and chemical aspects of the Lochsa Geothermal System near the northern margin of the Idaho Batholith: Washington State University M.S. thesis, 103 p.

Kunze, J.F. and Marlor, J.K., 1982, Industrial food processing and space heating with geothermal heat: U.S. DOE rept. DOE/ET/27028-6, 117 p.

Lewis, R.E. and Young, H.W., 1980, Thermal springs in the Payette River basin, west-central Idaho: U.S. Geological Survey, Open-File Report 80-1020.

Lewis, R.E. and Young, H.W., 1982, Thermal Springs in the Boise River Basin, south-central Idaho: U.S. Geological Survey Water Resources Investigations 82-4006, 22 p.

Lewis, R.E. and Young, H.W., 1982, Geothermal resources in the Banbury Hot Springs area, Twin Falls County, Idaho: U.S.Geological Survey Water-Supply Paper 2186, 27 p.

Lewis, R.E. and Young, H.W., 1988, The hydrothermal system incentral Twin Falls County, Idaho: U.S. Geological Survey Water Resources Investigations Report 88-4152. 44 p.

Lewis, R.E. and Stone, M.A.J., 1988, Geohydrologic data from a 4403-foot test hole, Mountain Home Air Force Base, Elmore County Idaho: U.S. Geological Survey Open-File Report 88-166, 30 p.

Mabey, D.R., 1983, Geothermal resources of southern Idaho: U.S.Geological Survey Circular 866, 24 p.

Mariner, R.H., Young, H.W., Parliman, D.J., and Evans, W.C., 1989, Geochemistry of thermal water from selected wells, Boise, Idaho: <in> Geothermal Resources Council Transactions, v.13, p.173-178.

Mariner, R.H., Young, H.W., Evans, W.C., and Parliman, D.J., 1991, Chemical, isotopic, and dissolved gas compositions of the hydrothermal system in Twin Falls and Jerome counties, Idaho: <in> Geothermal Resources Council Transactions, v. 15, p. 257-265.

Mayo, A.L., Muller, A.B., and Mitchell, J.C., 1984, Geothermal investigations in Idaho, part 14, Geochemical and isotopic investigations of thermal water occurrences of the Boise Front area, Ada County, Idaho: Idaho Department of Water Resources Information bulletin no. 30, 60 p.

McClain, D.W., 1980, A site evaluation model for geothermal resource development in southwest Idaho, 146 p.

McClain, D.W., Eastlake, W.B., and Stoker, R.C., 1979, Fairfield, Idaho site specific development analysis: Idaho Office of Energy, Idaho Geothermal Report, DOE/ID/12010-7.

Mickelson, C.R., 1985, Detailed review of retail pricing strategies, marketing efforts and performance of the Boise City District Heating System, 1983-1985: <in> International symposium on geothermal energy, Geothermal Resources Council Transactions, v. 9, pt. 1, p. 39-44.

Mink, L.L., Lease, R.D., and Nichols, C.R., 1982, The Raft River, Idaho 5MW(e) binary project: Proceedings of International conference on geothermal energy, Florence, Italy, paper H8, p.283-294.

Mitchell, J.C., Johnson, L.L., and Anderson, J.E., 1980, Potential for direct heat application of geothermal resources: Geothermal investigations in Idaho, Idaho Department of Water Resources Water Information Bulletin no.30, part 9, 396 p.

Mitchell, J.C., editor, 1981, Geological, hydrological, geochemical and geophysical investigations of the Nampa-Caldwell and adjacent areas, southwestern Idaho: Geothermal investigations in Idaho, Idaho Department of Water Resources Water Information Bulletin no.30, part 11, 143 p.

Mitchell, J.C., Bideganeta, K., and Palmer, M.A., 1984, Stable isotopic evaluation of thermal water occurrences in the Weiser and the LittleSalmon River drainage basins and adjacent areas,west-central Idaho: Geothermal investigations in Idaho,Idaho Dept. of Water Resources Bulletin no. 30, part 12,45 p.

Nichols, C.R., Brockway, C.E., and Warnick, C.C., 1972, Geothermal water and power resources exploration and development for Idaho: Idaho Water Resources Research Institute publication, 48 p.

Parliman, D.J. and Young, H.W., 1992, Compilation of selected data for thermal-water wells and springs,1921 through 1991: U.S. Geological Survey Open-File Report 92-175, 201 p.

Ralston, D.R., Arrigo, J.L., Baglio, J.V., Coleman, L.M., Hubbell, J.M., and Souder, Karl C., 1981, Geothermal evaluation of the thrust zone in southeastern Idaho: Idaho Water and Energy Research Institute, University of Idaho, 110 p.

Reed, J.D., 1986, The geology, geochemistry, and hydrology of four hot springs areas along the South Fork Payette River, between Lowman and Banks, Boise County, Idaho: Washington State University M.S. thesis, 112 p.

Ross, S.H., 1971, Geothermal potential of Idaho: Idaho Bureau of Mines and Geology Pamphlet 150, 72 p.

Sibbett, B.S. and Capuano, R.M., 1984, Potential for a geothermal resource near Mackay, Idaho: University of Utah Research Institute, Earth Science Laboratory Rept. No. 137, DOE/ID/12079-120, 13 p.

Smith, R., 1980, Heat flow of the western Snake River Plain: M.S. thesis, Washington State University, 150 p.

Souder, K.C., 1985, The hydrochemistry of thermal waters of southeastern Idaho, western Wyoming and northeastern Utah: University of Idaho M.S. thesis, 139 p.

Spencer, S.G., Russell, B.F., and Sullivan, J.F., 1979, Potential use of geothermal resources in the Snake River Basin: An environmental overview. Volume I: EG&G report no. EGG-2001 (V.1), 85 p.

Stearns, N.D., Stearns, H.T., and Waring, G.A., 1937, Thermal springs in the United States: U.S.Geological Survey Water-Supply Paper 679-B, p. 59-206.

Stoker, R.C. and Kunze, J.F., 1980, Madison County Rogers Potato evaluation of the geothermal potential around Rexburg, Idaho: Department of Energy Document DOE/ET/127028-1.

Street, L.V. and DeTar, R.E., 1987, Geothermal resource analysis in Twin Falls county, Idaho: Geothermal investigations in Idaho, pt. 15, Idaho Department of Water Resources Water Information Bulletin no. 30, 46 p.

Street, L.V., 1990, Geothermal resource analysis in the Big Wood River Valley, Blaine County, Idaho: Geothermal investigationsin Idaho: Idaho Department of Water Resources, Water Information Bulletin no. 30, part 17, report no. DOE/ID/12748-1, 43 p.

Struhsacker, D.W., editor, 1981, An analysis of geothermal electrical power generation at Big Creek hot springs, Lemhi County, Idaho: U.S. Department of Energy Report DOE/10/12079-37, 71 p.

Struhsacker, E.M., Smith, C., and Capuano, R.M., 1983, An evaluation of exploration methods for low-temperature geothermal systems in the Artesian City area, Idaho: Geologic Society of America Bulletin, v. 94, no. 1, p.58-79.

Struhsacker, D.W., Jewell, P.W., Zeilsloft, J., and Evans, S.H., 1983, The geology and geothermal setting of the Magic Reservoir area, Blaine and Camas counties, Idaho; University of Utah Research Institute, Earth Science Laboratory Report No.123, DOE/ID/12079-106, 58 p.

Trans Energy Systems, Inc., 1981, Great Western Malting Company geothermal project, Pocatello, Idaho: DOE/ID/12194-T1.

Vance, D.B., 1986, The geology and geochemistry of three hot spring systems in the Shoup Geothermal Area, Lemhi County, Idaho: Washington State University M.S. thesis, 153 p.

Waag, C.J. and Wood, S.H., 1987, Analysis of historical and current drawdown and production data from the Boise Geothermal System: Idaho Water Resources Research Institute report no. USGS/G-1222-02, 58 p.

Waring, G.A., 1965, Thermal springs of the United States and other countries of the world--a summary: U.S. Geological Survey Professional Paper 492, 383 p.

Warner, M.M., 1972, Geothermal Resources of Idaho: Geothermal overviews of the western United States, 5 p.: <in> Geothermal Resources Council El Centro proceedings, 1972.

Warner, M.M., 1975, Special aspects of Cenozoic history of southern Idaho and their geothermal implications: GeologicalSociety of America Abstracts with Programs, v. 7, no. 5, p.649-650.

Wood, S.H. and Burnham, W.L., 1983, Boise, Idaho geothermal system: Geothermal Resources: Energy on Tap!: Geothermal Resources Council Transactions v. 7, p. 215-223.

Young, H.W. and Mitchell, J.C., 1973, Geothermal investigations in Idaho, part 1: Geochemistry and geologic setting of selected thermal waters: Idaho Dept.of Water Administration, Water Information Bulletin no. 30, pt. 1, 43 p.

Young, H.W. and Lewis, R.E., 1980, Hydrology and geochemistry ofthermal ground water in southwestern Idaho and north-central Nevada: U.S. Geological Survey Open-File Report 80-2043, 40 p.

Young, H.W. and Lewis, R.E., 1982, Thermal springs in the SalmonRiver Basin, central Idaho: U.S. Geological Survey Open-File Report 82-104, 27 p.

Young, H.W., 1985, Geochemistry and hydrology of thermal springs in the Idaho batholith and adjacent areas, central Idaho: U.S. Geological Survey Water Resources Investigations Report 85-4172.

Young, H.W., Parliman,D.J., and Mariner, R.H., 1988, Chemical and hydrologic data for selected thermal-water wells and nonthermal springs in the Boise area, southwestern Idaho: U.S. Geological Survey Open-File Report 88-471, 35 p.

Young, H.W. and Parliman, D.J., 1989, Hydrologic and chemical data for selected thermal-water wells and springs in the Indian Bathtub area, Owyhee county, southwestern Idaho: U.S. Geological Survey Open-File Report 89-589, 19 p.

Youngs, Steven W., 1981, Geology and geochemistry of the Running Springs geothermal area, southern Bitteroot lobe, Idaho batholith: Washington State University M.S. thesis, 125 p.

Zeisloft, J., Foley, D., and Blackett, R., 1983, Water geochemistry of hydrothermal systems, Wood River District, Idaho: Utah Univ. Research Inst. ESL report no.124, DOE/ID/12079-107, 20 p.