UTAH'S HIGH TEMPERATURE GEOTHERMAL RESOURCE POTENTIAL – ANALYSIS OF SELECTED SITES

by

Robert E. Blackett[1], Glade M. Sowards[2], and Edie Trimmer[3]

[1]Utah Geological Survey
[2]Utah Energy Office
[3]Utah Division of Forestry, Fire & State Lands

July 2004
UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES
in cooperation with
U.S. Department of Energy, National Renewable Energy Lab

DISCLAIMER

This open-file release makes information available to the public during the review and production period necessary for a formal UGS publication. It is in the review process and may not conform to UGS standards, therefore it may be premature for an individual or group to take action based on its content.

Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, express or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

EXECUTIVE SUMMARY

Geothermal sites in Utah, either suitable or potentially suitable for electric power generation, are limited in number given current economics and technology. For this study, we reviewed several hundred geothermal wells and springs in Utah, choosing nine geothermal areas or sites for more detailed review. Two of the areas – Roosevelt hot springs and Cove Fort-Sulphurdale - have been developed for geothermal power since the 1980s, and both will undergo expansion and power plant modification in the near future. Three other sites – Thermo hot springs, Newcastle, and Drum Mountains – experienced significant geothermal exploration in the past, but much more data are needed to fully evaluate them. The remaining four sites in northern Utah are virtually unexplored and were selected on the basis of geothermometry applied to geothermal water issuing at the sites. An overall comparative matrix of the study areas is presented in appendix D.

The original intent of this effort was to rank the sites based upon an economic analysis of their electric power development potential. After entering this process, however, we realized that the required elements for such a ranking (reservoir temperature, depth, flow rates, and volume, among other factors), except in one case, are not known. As a result, for this analysis we classify these nine sites into three tiers based on levels of past exploration and industry interest noted above. Following are discussions of the sites themselves with respect to the classification scheme.

<u>First Tier</u> – Resource undergoing active development, well defined.

Roosevelt hot springs KGRA
Cove Fort-Sulphurdale KGRA

<u>Second Tier</u> – Resource explored, not defined.

Newcastle
Thermo hot springs
Drum Mountains-Whirlwind Valley

Third Tier – Resource essentially not explored, indication of potential resource exists.

Utah hot springs
Ogden hot springs
Hooper hot springs
Crystal-Madsen hot springs

First Tier Sites

Roosevelt Hot Springs – Pacificorp (Utah Power) operates the single-flash Blundell plant (26 MW gross) with current plans to upgrade the plant by adding 13 MW reportedly from a "bottoming cycle" using binary power technology. Pacificorp's recent Integrated Resource Plan identified portfolios containing significant upgrades to the Blundell plant, or building a nearby new plant; no new plant portfolio was selected, however. The geothermal field is controlled by a separate supplier entity – Intermountain Geothermal, a subsidiary of California Energy Company – maintaining the fluid supply to the Blundell plant through several production and injection wells. We are aware of no problems related to existing infrastructure and access that would encumber development. No environmental conflicts would appear to restrict future development, although the area is within mapped habitat for the Greater Sage Grouse, and may include several other listed species. Citizen groups propose part of the Mineral Range to the southeast as "wilderness" under some scenarios.

Cove Fort-Sulphurdale – The Cove Fort-Sulphurdale geothermal field, controlled by Provo City, along with Utah Municipal Power Agency's Bonnett geothermal plant (10 MW gross) was recently sold to private developers (Recurrent Resources). The new owners reportedly plan to decommission the old facility, consisting of a combination of flash and binary power plants, drill new production and injection wells, and construct a new 30 MW (gross) facility using binary technology. Surface land ownership is mixed, primarily USFS and private. No environmental conflicts would appear to restrict future development, although the area is within mapped habitat for the Greater Sage Grouse, a listed species. No wilderness areas are near here and none are recommended for future designation.

Second Tier Sites

Newcastle – The Newcastle area is undergoing active geothermal development for large-scale space heating of commercial greenhouses covering more than 10 ha (25 ac). This area was the recent focus of a U.S. Department of Energy-sponsored project to develop geothermal distributed power systems in the west. However, exploratory drilling in the outflow plume yielded temperatures less than required for commercial power generation. The suspected source-location of the geothermal fluids remains untested to date. Land ownership is mostly private within the current geothermal production area, although the suspected source location lies primarily on land administered by the BLM. No imminent environmental concerns have been identified. Present studies suggest a maximum resource temperature in a range around 130ºC (266ºF).

Thermo Hot Springs II KGRA – The region surrounding Thermo hot springs has been of interest to prospective geothermal developers, although no developable resource is identified. Republic Geothermal and others drilled a number of exploratory boreholes and performed geophysical surveys in the area, measuring a maximum temperature of about 174ºC (345ºF) at a depth of about 2,000 m (6,600 ft). No environmental concerns are present that would outwardly restrict development, although the area is remote and contains several listed species including the Greater Sage Grouse.

Drum Mountains Geothermal Prospect – Amax Geothermal and Phillips Petroleum Company explored the Drum Mountains-Whirlwind Valley area during the late 1970s and early 1980s. They identified no developable geothermal resource from this exploration, although they measured temperatures as high as 70ºC (158ºF) in shallow (generally 150 meters or less) boreholes. As a result, we include the area in our second tier classification even though a resource has yet to be discovered. The area is remote, and locally may contain only one listed species. A BLM wilderness study area (WSA) covers much of the Swasey Mountains directly southwest of Whirlwind Valley.

Third Tier Sites

Utah Hot Springs – The Utah hot springs site is one of three sites situated in the urbanized region along the Wasatch Front of northern Utah. We have identified this and the other two sites mainly on the basis of geothermometry, which suggests that the temperature of resource fluids at depth may exceed 190ºC (374ºF). Utah hot springs is within an urban-industrial setting adjacent to a utility corridor, highway, and Interstate 15. The springs were used for a time at a now-defunct resort, and are currently used to heat a small commercial greenhouse. Minor geothermal exploration was conducted in the early 1980s, but the resource is poorly defined. Although the area is industrial, large-scale development could be problematic due to the number of listed species (10) possibly in the area. Zoning restrictions may also impede development.

Ogden Hot Springs -- This site is also within the urbanized Wasatch Front region. It was identified mainly on the basis of geothermometry, which suggests that the temperature of resource fluids at depth may exceed 190ºC (374ºF). Ogden hot springs is situated near the mouth of Ogden Canyon, near residential neighborhoods, utility lines, water sources, and roads. The springs have no history of extended use other than local recreation and bathing. Moreover, no geothermal exploration beyond surface spring sampling has been reported. Similar to Utah hot springs, large-scale development could be problematic due to the number of listed species (10) possibly in the area. Zoning restrictions may also complicate development.

Hooper Hot Springs -- Hooper hot springs and Southwest Hooper warm springs are located about 16 km (10 mi) southwest of Ogden near the eastern shore of Great Salt Lake in an urbanizing portion of Davis County. Geothermometry suggests resource temperatures at depth near 135ºC (275ºF), although no exploration has been performed to date. The area is within a Utah Wildlife Refuge, which could be problematic for industrial development. This area also contains the largest number of listed species of all geothermal areas considered in this study. Land ownership is a mixture of Utah Sovereign Lands, Utah Wildlife Resources, and private.

Crystal-Madsen Hot Springs – The Crystal-Madsen site is the northernmost of the geothermal areas studied. The area has been extensively developed as a resort, operating commercially at least for the past 75 years. The area is logistically attractive as there is ready access to roads and transmission lines. The resource is virtually unexplored, as only fluids have been sampled and the results reported One thermal-gradient borehole penetrated 67 m (220 ft) at the site and yielded a bottom-hole temperature of 61ºC (148ºF). Land ownership is entirely private, although the USFS designated a wilderness area about 3.2 km (2 mi) east from the site. Utah Wildlife Resources indicates that four listed species are found in the region.

CONTENTS

FIGURES

TABLES

APPENDICES

CONVERSION FACTORS

Length:	1 centimeter (cm) = 0.3937 inch (in) 1 meter (m) = 3.281 feet (ft) 1 kilometer (km) = 0.6214 mile (mi)
Area:	1 m^2 = 10.76 ft^2 1 km^2 = 0.3861 mi^2 1 hectare (ha) = 2.471 acres (ac) 1 ac = 43,560 ft^2
Volume:	1 liter (L) = 0.2642 gallon (gal) 1 km^3 = 0.2399 mi^3
Mass:	1 kilogram (kg) = 2.205 pounds (lb)
Flow Rate:	1 L/s = 15.85 gal/min
Temperature:	degrees Celsius (ºC) = 5/9 (degrees Fahrenheit [ºF]-32) kelvins (K) = ºC + 273.15
Temperature Gradient:	1ºC/km = 0.05486ºF/100 ft
Energy:	1 joule (J) = 0.2390 calorie (cal) 1 J = 9.485×10^{-4} British thermal unit (Btu) 1 J = 2.777×10^{-4} watt-hour (W•hr) 10^{18} J = 0.9485 quad (10^{15} Btu) 1 MW_t for 30 yr = 9.461×10^{14} J
Power or work:	1 watt (W) = J/s 1 megawatt (MW) = 3.154×10^{13} J/yr
Heat flow:	1 mW/m^2 = 2.390×10^{-8} cal/cm•s 1 mW/m^2 = 2.390×10^{-2} heat-flow unit (HFU)
Thermal Conductivity:	1 W/m•K = 2.390 mcal/cm•s•ºC

INTRODUCTION

Background

In 2002, the Utah Geological Survey (UGS) and Utah Energy Office (UEO) completed compiling various datasets of geothermal resource information for Utah on compact disk (Blackett and Wakefield, 2002). The "Geothermal Resources of Utah" CD replaced an out-of-date and unavailable geothermal map of Utah, published in 1980 (Utah Geological and Mineral Survey, 1980), and contained data, documents, images, and various GIS layers. This report describes the results of a U.S. Department of Energy (DOE)-sponsored study prepared, in part, using information included in the aforementioned project, and results in a new, enhanced version of the CD. The DOE-sponsored study, described in this document, focuses on evaluating and ranking geothermal resource areas in Utah for electric power development potential.

Presently in Utah, utilities generate electricity from two geothermal resource areas, while businesses extract heat from 13 other geothermal sites for a variety of purposes ranging from greenhouse space heating and aquaculture to spas and SCUBA diving schools. Statewide geothermal resource assessments revealed more than 1,100 wells and springs that produce water at temperatures greater than 20EC (68EF). More than 200 of these sources produce water at or above 30EC (86EF), and 74 of these produce water with temperatures at or above 50EC (122EF). Potentially, some of the unused geothermal sources may be commercially viable as geothermal direct-use projects. A few of these sites may also be developable for electrical generation.

Purpose and Scope

The purpose of this project is to increase awareness of Utah geothermal development potential by using available geothermal resource, socioeconomic, and infrastructure data to profile selected moderate to high temperature (>120ºC [248ºF]) geothermal areas in Utah. We use the profiles and other criteria to qualitatively evaluate areas for geothermal electric power development potential. The effort includes reviews of existing published information plus unpublished, available thermal-gradient data for Utah's high and moderate temperature geothermal areas in the Sevier, Black Rock, and Escalante Deserts of southwestern Utah, and several areas within the Wasatch Front region of northern Utah. Several areas of possible development potential are also described, but not analyzed (figure 1).

Our original objective was to characterize the sites with respect to capital and operating costs for various types of geothermal power plants, and rank them based upon the quality of the resource, availability of land and water, proximity to existing infrastructure (power grid), and economic likelihood of their future development. Since the original conception of the project, however, it became evident that many of the potential areas lacked adequate resource definition to model critical economic parameters. Critical attributes lacking at most potential sites include measured resource temperature, reservoir depth, and volume/flow rates that might be expected from wells. In our initial screening process we made assumptions for these parameters based upon the known geologic setting and geothermometry applied to local thermal waters in order to identify those geothermal areas of prospective value for electric power development. From the original 1,100 geothermal sources in Utah, we identified nine areas where geothermal reservoirs are either known or could potentially be developed. In this document we review each of these nine sites, describing various resource and institutional attributes. The nine sites selected are noted on figure 1 and summarized in table 1.

Information sources include spatial data sets available from the Utah Geological Survey (Black and others, 2003), Utah Automated Geographic Reference Center, U.S. Bureau of Land Management (BLM), the U.S. Geological Survey Water Resources Division, the Utah Division of Water Rights (Water Rights), the University of Utah Department of Geology and Geophysics, and Southern Methodist University's Geothermal Laboratory. These spatial data sets are supplemented by economic and demographic data sets from the U.S. Bureau of Economic Analysis (BEA).

Since the first version of the digital geothermal atlas of Utah (Blackett and Wakefield, 2002) was developed, our effort has focused on incorporating more detailed geothermal resource, institutional, and economic information as part of a U.S. Department of Energy (DOE) sponsored project to enhance the atlas. As part of the enhanced version of the digital geothermal atlas of Utah, this document includes: (1) a summary of legal and institutional issues governing water and geothermal development; (2) county-level economic and demographic data such as income, employment, and population estimates; and (3) thermal-gradient data obtained from published and unpublished sources.

Geothermal Energy For Electric Power

Geothermal-hydrothermal systems are of two main types. Vapor-dominated systems, like those at The Geysers in northern California and Lardarello, Italy, are rare and most valuable. These systems yield nearly pure, high-temperature (> 235°C, or 455°F) steam through production wells from 1 to 4 km (3,300 to 13,000 ft) deep. The steam is processed to remove particulates and non-essential fluid, and then is piped to turbines that spin generators to create electricity. More common are high-temperature systems containing hot water (liquid-dominated) at temperatures from 150°C to 300°C (300°F to 570°F). For these, flash-steam power plants are required. Again, the geothermal fluids are brought to the surface from production wells as much as 4 km (13,000 ft) deep. At these depths, the fluids are highly pressurized, but as pressure is reduced in transit to the power plant, 10 to 40 percent of the water flashes (boils and steam forms from some of the water). The steam is separated from the remaining hot water and fed to a turbine/generator unit to produce electricity. The residual water is usually returned to the reservoir through injection wells to help maintain pressure and prolong productivity.

For intermediate-temperature geothermal reservoirs (those between approximately 120°C and 150°C [248ºF and 300ºF), binary-cycle power plants are the preferred installations. In a binary plant, geothermal water passes through a heat exchanger to heat a secondary, organic, working fluid (for example, isopentane) that vaporizes at temperatures lower than the boiling point of water. In a closed-loop cycle, the working-fluid vapor spins the turbine generator then condenses to liquid before vaporizing again at the heat exchanger. As in a flash-steam cycle, the spent (heat-depleted) geothermal fluid is injected back into the geothermal reservoir.

Flash and binary cycles can be combined in sequence for the most efficient conversion of thermal to electrical energy. In these hybrid power plants, hot water from production wells first flashes to steam, turning a primary turbine generator unit. Steam condensate from the flash cycle then mixes with the residual water and is routed to a binary unit for further generation of electricity.

Geothermal electric-power plants are typically available for generation 95 percent of the time. They are modular and can be installed incrementally on an as-needed basis. Moreover, construction of these plants is a relatively rapid procedure – taking as little as six months to install 0.5 to 10 megawatt units, and 1 to 2 years for clusters of plants with capacities of 250 megawatts or more.

A 2003 draft report by the California Energy Commission (CEC) estimates levelized costs for several, competing "central-station electricity generation technologies" (table 2). CEC found that geothermal flash power plants, at $0.0471/kWh, were nearly competitive on a direct, levelized cost basis with combined-cycle, natural-gas plants, at $0.0458/kWh, for a baseload operative mode. Geothermal flash plants compete favorably with wind and hydropower plants, which had direct, levelized costs of $0.0544/kWh and $0.0720/kWh, respectively (California Energy Commission, 2003). While these estimates are encouraging for geothermal electricity, CEC cautions against comparing competing technologies and fuels on a levelized cost basis alone for several reasons. For example, different technologies and fuels provide different services to end users. Some technologies may have favorable operative mode characteristics or may offer environmental benefits over competing technologies. In addition, depending upon how power generated is sold, lower costs associated with a particular technology may not always be passed along to consumers. On a related note, depending upon how economic risks are shared between ratepayers and investors, changes in fuel costs may or may not be passed along to consumers. Surprisingly, rising fuel costs may even affect prices for renewable electricity sources such as geothermal power as a result of how contracts are structured. Still, CEC notes that "… adoption of a renewable energy project may be viewed as part of a greater fuel diversification strategy, and the State may deem higher cost renewable projects to be an acceptable investment to pay for… price risk mitigation."

PacifiCorp undertakes a similar comparison of electric power generating technology costs in its 2003 Integrated Resource Plan (IRP). In addition to considering capital (unit and transmission) and operating & maintenance (O&M) costs, the company also includes such factors as reserve margin contributions, outage rates, annual heat rates, environmental adders, and fuel costs in its analysis of real levelized costs among competing technologies. The results (table 3) show that the cost of generation from an additional flash generator and bottoming cycle at the company's Blundell geothermal plant is competitive with the costs of other alternatives, including natural-gas, combined-cycle, combustion turbines and pulverized-coal systems. This outcome is reflected in the IRP action plan, which calls for "1,400 MW of primarily wind resources, but also potential geothermal resources" (PacifiCorp, 2003, p. 11). As in the CEC analysis described earlier, however, these estimates should only be considered approximations of the relative costs of competing generation technologies. Real generating costs can be heavily influenced by changes in fuel prices, environmental regulations, and technology.

CHARACTERISTICS OF UTAH GEOTHERMAL SYSTEMS

Resource Economic Factors

The original intent of this study was to rank the various geothermal areas in Utah that are either known to contain high temperature geothermal resources, or are suspected to hold high temperature resources for potential electric power development. Primary factors controlling the economics of geothermal development for electrical power include: (1) availability of land and water, (2) distance from transmission lines and load centers (as well as transmission line capacity), (3) the characteristics of the resource, and (4) the cost of competing electric power sources. However, because critical resource parameters are not known for several of the prospect areas, a ranking based on economic considerations was not possible. Instead, we attempt to characterize the areas in more general terms, discussing both positive and negative attributes of the resource and location with respect to political boundaries, land ownership, infrastructure, environmental concerns, and regional demographics.

Land availability is always the primary consideration in development of a geothermal system. Resources may exist, but if access is restricted or prohibited such as the case with geothermal systems within "withdrawn" land units (national parks, monuments, and wilderness areas), then the system is effectively removed from the available geothermal resource base.

Water availability in the form of water rights is necessary to legally develop a geothermal resource. Because geothermal resources are in many cases considered a special type of ground-water resource, having a right to make "beneficial use" of the water through the state system of water appropriation is of paramount importance. Some water basins are "over appropriated" and thereby closed to additional development. In these cases geothermal developers would need to acquire water rights from private parties, or to establish that geothermal rights are at depth or of such quality that their use for geothermal development would not impact appropriated ground water.

Transmission lines and load center location with respect to geothermal resources may also be important in estimating the viability of a geothermal power system. Producing electricity from geothermal resources involves a mature technology. The time from which a site is confirmed as having development potential (with sufficient water at temperatures high enough to drive turbine blades using a binary or flash system) to the time a facility can produce electricity is short, less than three years. However, due to the often remote locations of geothermal resources, the cost of transmission may make the venture more expensive than a facility that does not need miles of new transmission lines. Constructing transmission lines requires extensive environmental permits, the acquisition of which may stretch out for years before a permit is granted. Available transmission line capacity could also dictate whether or not new lines are needed in order to develop a particular resource.

Resource characteristics include mainly (1) depth of the resource, (2) production capacity (flow rate and volume) of the geothermal reservoir, and (3) temperature of the resource. Production capacity is dependent on a number of physical properties of the reservoir mostly related to porosity, permeability, and reservoir pressure. The chemistry of the fluid may also affect the production capabilities of a reservoir. Regardless of institutional and physical barriers to geothermal development, evaluation of resource characteristics is of primary importance when assessing the development potential of a geothermal prospect. The "footprint" of a typical geothermal-hydrothermal system is small (point source) and usually expressed at the surface as hot springs, fumaroles, and alteration minerals. Geothermal developers rely mostly on geologic mapping, near-surface temperature surveys, and geochemical evidence collected from springs and shallow water wells to first delineate a geothermal prospect. Following this, detailed surface geophysical surveys may be used to establish targets for temperature-gradient drilling, which in turn are used for drilling deeper exploratory wells.

Unfortunately, many geothermal areas in Utah remain unexplored or underexplored with respect to determining resource characteristics. In these cases, it is problematic to estimate those important parameters, like depth and temperature, for input into an economic model. Regardless, nine geothermal source areas are considered in this analysis – some with identified high-temperature resources, others with suspected moderate- to high-temperature resources.

Resource Depth

Typically, hot springs and alteration are merely surface expressions of a deeper geothermal resource. Developers conduct exploration using geological, geochemical, and geophysical methods in order to develop target models. This is followed by exploratory and production drilling. Resource depth is an important factor when considering the economic viability of a geothermal source for electric power generation, as depth determines the cost of production wells, well casing, pump design/selection, and other capital costs.

Estimating resource depth for unexplored geothermal systems is difficult. We approach this problem by proposing an estimated average within a range of depths for unexplored resources based upon known factors including local geology and thermal gradients. Geologic information is available to varying degrees for all of the resource areas in question. Some of these areas have exploratory (thermal gradient) drill holes nearby that permit more accurate estimations of resource depth. Information on statewide thermal-gradient drill holes and individual geothermal areas was obtained from the website of Southern Methodist University's Geothermal Lab (Blackwell and others, 1999), data supplied by Henrikson and Chapman (2002), and data compiled as part of this project.

Resource Flow Rates (Permeability)

Because of the broad variability of physical factors controlling geothermal reservoirs, geothermal reservoir capacity and resource flow rates cannot be estimated without flow data from test wells. These reservoir parameters include reservoir temperature, pressure, permeability (hydraulic conductivity), resource volume, and others. The following discussion of reservoir permeability and porosity is paraphrased from Wright and Culver (1991).

Production from most geothermal reservoirs results from fracture permeability. *Permeability* is a measure of a material's capacity to transmit fluid as a result of pressure differences. Where *permeability* is a property of the medium, *hydraulic conductivity* involves the properties of the medium plus the fluid. In rocks, fluids flow through voids (pores) between mineral grains and along open fractures, often caused by faulting or regional stress. *Porosity* refers to the fraction of void space in a volume of rock. *Effective porosity* refers to the amount of void spaces that are interconnected, allowing fluid to flow through the material. Permeability and porosity can be primary (forming as fractures or voids between grains), or secondary (forming by dissolution of the rock matrix). Primary porosity in sedimentary rocks (sandstone, limestone, or shale) is intergranular, usually decreasing with depth because of compaction and pores filling with cementing minerals. In volcanic rocks, primary intergranular porosity and permeability exists in open spaces and at contacts between individual flows. Features that form secondary porosity and permeability include open fault zones, fractures and fracture intersections, intrusive dikes, and breccia zones.

Permeability in rocks ranges over 12 orders of magnitude. Permeability in pristine, unfractured crystalline rock is commonly low. Local fractured and faulted sites, however, can have permeability enhanced by 4 to 6 orders of magnitude. Most attractive geothermal sources are fracture controlled. Fracture permeability may increase where fracturing and faulting occur in response to both local and regional stresses. Deep, local stresses can occur in response to emplacement of an intrusive body or in response to collapse due to volcanism or dissolution. Regional stresses occur as a result of broad tectonic influences. Thus, an understanding of the geologic structure and tectonic history in a prospect area leads to inferences about higher permeability at depth, thereby helping identify an exploration target. The problem, therefore, is more in locating permeable zones rather than in locating anomalous temperatures. Fractures sufficient to make a geothermal well a good producer need be only a few millimeters in width, but they must be connected into a general fracture network in the rock in order to sustain production of large fluid volumes.

Flow rates reported in the Utah geothermal well and spring database (Blackett and Wakefield, 2002) mainly represent flows occurring at the time of a particular hydrologic survey; they are generally not representative of sustained production flows. As a result, for this study we did not include flow rate in the resource criteria used to determine economic viability. Rather, we assumed a minimum flow necessary to permit a development based on the range of resource temperature and depth indicated from measured temperatures, geothermometry, thermal gradients, and geologic factors.

Flow and volume of a geothermal reservoir are economically important factors when considering a geothermal, power-generation project. The production capacity (flow and volume) will most affect plant capacity, which will indirectly affect the unit cost of electricity. Larger plant capacity often means lower unit cost of electricity.

Resource Temperatures

In general, resource temperatures are inversely correlated with capital costs per kilowatt-hour (Entingh and others, 1994; DiPippo, 1999) and appear to have little effect on O&M costs. According to DiPippo (1999), the former relationship stems from the fact that resource temperature influences the number of wells that must be drilled for a given plant capacity. Entingh and others (1994) note that, "reservoir temperature is the physical factor to which overall project costs are most sensitive."

The actual reservoir or resource temperature of a geothermal system is difficult to estimate when no deep, temperature measurements are available. Geothermometers can provide some temperature estimates where measured temperatures are not available. Geothermometers, or geoindicators, are computations applied to natural waters from springs or wells based on empirically derived formulae using dissolved chemical species. Geothermometers are used in geothermal exploration to estimate the temperature and composition of the original reservoir fluid at depth prior to cooling by conduction and mixing with shallow ground water at the sample collection point (well or spring). Geothermometers indicate a hotter fluid reservoir somewhere in the system, usually at greater depth, that might reasonably be tapped for delivery to the surface. Geothermometers described in appendix A were applied to the statewide geothermal well and spring database. The results shown in appendix B are sorted with respect to the statewide map number (MAPNO field, based on county code), and represent where the K-Mg geothermometer or measured temperature is 100ºC (212ºF) or greater.

As expected, wells and springs within the two developed, high-temperature geothermal areas – Roosevelt hot springs and Cove Fort-Sulphurdale – ranked as some of the highest-temperature sources on the list, yielding temperatures from 207ºC to 298ºC (405ºF to 568ºF). Somewhat surprising, though, was the high rating predicted by several less-well-known areas. In northern Utah, chemical data from Ogden hot springs and Utah hot springs yielded equilibration K-Mg temperatures of nearly 190ºC (374ºF). The K-Mg geothermometer should be the most reliable for these spring waters (Rick Allis, UGS written communication, March 25, 2000). Although the method may not apply to water samples from deep wells, wells in the Sanpete Valley (J. Paulsen) of central Utah and the Uinta Basin (Ashley Valley) of eastern Utah yielded

K-Mg equilibrium temperatures of 207ºC and 182ºC (405ºF and 360ºF), respectively. Other areas yielding anomalously high equilibrium temperatures include the Hooper hot springs and Southwest Hooper warm springs (120ºC to 135ºC [248ºF to 275ºF]), and Crystal-Madsen hot springs (153ºC [307ºF]).

In some cases, geothermometry for areas originally thought to have high potential resource temperatures yielded equilibrium temperatures only slightly higher than the spring or well temperature. These areas included the Abraham hot springs (90ºC [194ºF]) and the Meadow-Hatton hot springs area (110ºC [230ºF]). This is not to say that higher temperature resources do not exist at depth near these systems. For example, a deep exploratory well "Escalante 57-29," drilled near Thermo hot springs to a depth of 7,287 ft (2,221 m), yielded a measured bottom-hole temperature of 160ºC (320ºF) corroborating a K-Mg equilibrium temperature of 166ºC (331ºF) (quartz temperatures range from 217ºC to 241ºC (423ºF to 466ºF). Thermo hot springs water yielded K-Mg temperatures of only 110ºC to 115ºC (230ºF to 239ºF).

Highly saline well water from the Great Salt Lake desert of Box Elder and Tooele Counties yielded anomalously high temperatures using the K-Mg geothermometer while other indicators did not. As a result, we conclude that the K-Mg indicator yields erroneous results when applied to solutions of very high ionic strength, containing high levels of potassium. We therefore eliminated sources with high K-Mg indicated temperatures from consideration if potassium concentrations were greater than 1,000 mg/L.

FIRST TIER GEOTHERMAL RESOURCE AREAS

This study focused on analysis of infrastructure and resource characteristics of selected geothermal areas in Utah that have either known or potential moderate- to high-temperature (> 120°C [248ºF]) geothermal resources. The following sections describe the nine geothermal areas selected for analyses, and seven areas considered but not analyzed. Table 1 lists the various general parameters for each area studied. The study area locations are shown on figure 1. Because most of the geothermal areas lacked sufficient resource information to analyze within the context of a quantitative economic model, we present qualitative information in a three-tiered format. Tier-one areas include the developed Known Geothermal Resource Areas at Roosevelt

Hot Springs and Cove Fort-Sulphurdale. Tier-two areas incorporate geothermal sites where exploration has been performed, but where resources are still largely undefined. These include Thermo hot springs, the Newcastle area, and the Drum Mountains-Whirlwind Valley region. Tier-three sites involve thermal sources where virtually no exploration has taken place, but where geochemical indicators suggest a high temperature resource may be present. Tier-three sites include Utah, Ogden, Hooper, and Crystal-Madsen hot springs.

Roosevelt Hot Springs

Location and Resource Parameters

Long: 112.8503 W; Lat: 38.5019 N; NW¼, SW¼, SE¼, section 34,T.26S., R.09W., SLBM; Beaver County; Measured Temp: 268°C (514ºF); Resource Temp: 270°C (518ºF); Depth: 1,000 to 2,000 m (2,381 to 6,562 ft); Resource Type: high-temp liquid; TDS: 7,000-7,800 mg/L

Area Description and Development Outlook

The Roosevelt hot springs geothermal area is situated on the west flank of the Mineral Range in Beaver County, roughly 16 km (10 mi) northwest of the town of Milford (figure 2). It is the most studied geothermal system in Utah. Ward and others (1978) and Ross and others (1982) presented geological, geophysical, and geochemical data for the Roosevelt hot springs geothermal area. Mabey and Budding (1987) summarized the findings of previous workers. The Mineral Range is primarily a complex of Tertiary-age intrusions and Precambrian metamorphic rocks crosscut by a low-angle, west-dipping detachment zone and Basin-and-Range faults. The active geothermal system is associated with relatively young igneous activity, expressed as Quaternary rhyolite domes (0.5-0.8 Ma) within the Mineral Range, recent Basin and Range-style north-south faulting on the west side of the range, an older east-west fault system, and a still older system of near-vertical faults associated with the low-angle detachment zone. The Opal Mound fault, an important conduit for geothermal fluids, defines the western boundary of a small graben that contains much of the geothermal resource. Production from the Roosevelt geothermal area is primarily from highly fractured Tertiary granite and Precambrian metamorphic rocks. Geothermal resources at Roosevelt hot springs have been of commercial interest since the early 1970s, and have been actively developed for power generation since the late 1970s (Moore and Nielson, 1994).

Heat-flow studies identified an area of anomalous heat flow extending about 5 km (3 mi) wide and 20 km (12 mi) long over the Roosevelt hot springs geothermal area (Wilson and Chapman, 1980). Heat-flow values in excess of 1,000 mW/m^2 enclose an area roughly 2 km (1.2 mi) wide by 8 km (5 mi) long that is thought to coincide with the near-surface part of the geothermal system. Geophysicists infer that a deep, cylindrical body approximately 10-15 km (6-9 mi) in diameter situated about 5 km (3 mi) beneath the geothermal field, is a young igneous intrusion.

Utah Power operates the single-flash (26 MW gross) Blundell geothermal power station at Roosevelt. Intermountain Geothermal Company, the field developer, produces geothermal brine for the plant from four wells that tap a production zone in fractured, crystalline rock. The hot brine is flashed to steam in surface separators. The steam is sent to the power plant and the spent geothermal brine is channeled back into the reservoir through three, gravity-fed, injection wells. The production zone depths range generally between 382 and 2,232 m (1,253 and 7,321 ft). Reservoir temperatures are typically between 240°C and 268°C (464°F and 514°F).

The Blundell geothermal power station generated an average of 166,737 MWh per year from 1992 through 2002 (table 4). Blundell generation has rebounded somewhat over the past two years after a period of decline that began after 1996. The plant generated 184,447 MWh in 2002 (U.S. Department of Energy, 2003. The current plant is scheduled for retirement in 2021, based upon the length of the steam-purchase contract period of 30 years, which began in 1991 (Pacificorp, 2003).

Three alternative portfolios in PacifiCorp's (2003) Integrated Resource Plan (IRP) include a 2007 upgrade at Blundell that would provide an additional 50 MW of capacity for a total of 76 MW. This additional block of electricity would result from adding bottoming cycle to the current Blundell Plant, and adding an additional flash and bottoming cycle system. The assumed total capital cost of the proposed Blundell upgrade is $1,880 $/kW or $94,000,000. Although none of the three portfolios including the Blundell upgrade was eventually selected, the 2003 IRP notes that the upgrade, "… is a very realistic option currently under review by PacifiCorp." PacifiCorp also notes that there is at least one additional site with some development work completed and a known potential plant capacity of 50 MW near the current Blundell plant (Pacificorp, 2003, page 71). During a more recent meeting of geothermal advocates, Pacificorp representatives reported that they plan to add the bottom-cycle (binary) power unit to their existing facility at the Blundell plant. This will expand capacity by about 13 MW (Harold Cunningham, Pacificorp, verbal communication, September 2003).

Pacificorp plans to upgrade the single-flash Blundell plant (26 MW gross) by adding 13 MW reportedly from a "bottoming cycle" using binary power technology. Pacificorp's recent IRP identified portfolios containing significant upgrades to the Blundell plant, or building a nearby new plant; no new plant portfolio was selected, however. The geothermal field is controlled by a separate supplier entity – Intermountain Geothermal Co., a subsidiary of California Energy Company – maintaining the fluid supply to the Blundell plant through several production and injection wells. We are aware of no problems related to existing infrastructure and access that would encumber development. No environmental conflicts would appear to restrict future development, although the area is within mapped habitat for the Greater Sage Grouse, and may include several other listed species. Citizen groups propose part of the Mineral Range to the southeast as "wilderness" under some scenarios.

Cove Fort-Sulphurdale

Location and Resource Parameters

Long: 112.5668 W; Lat: 38.5685 N; T.26S., R06W., sec.07,SE/NE/NW SLB&M; Beaver County; Measured Temp: 150°C; Resource Temp: 150°C; Depth: 180 to 400 m (shallow reservoir); 600-900 m (deep reservoir); Resource Type: dry steam in shallow reservoir, high-temp liquid in deeper reservoir; TDS (mg/L): 9,400 (deep reservoir)

Area Description and Development Outlook

The Cove Fort-Sulphurdale geothermal area lies on the northwest side of the Tushar Mountains, and is roughly 32 km (20 mi) north along Interstate Highway 15 from the town of Beaver (figure 3). The geothermal system results from a combination of complex geologic structures that localize the geothermal source. The oldest structures are Cretaceous-age (Sevier orogeny) thrust faults. Younger Basin and Range structures consist of numerous north-northeast-striking high-angle normal faults. More recent gravity-slide blocks, shed from the northwest flank of the Tushar Mountains, act as low permeability layers that cap portions of the geothermal system. At the surface, the trends of faults are delineated by local alignments of sulfur deposits, acid-altered alluvium, and gas seeps. Surface manifestations occur throughout an area of about 47 km^2 (18 mi^2), and probably reflect boiling and degassing of chloride-rich brine from a thermal water table 400 m (1,300 ft) below the surface. Dry steam at about 150°C (300°F) is produced from relatively shallow production wells (180 to 400 m [600 to 1,300 ft] deep) completed into fractured Paleozoic sandstone (Moore and others, 1979; Ross and Moore, 1985).

The Utah Municipal Power Agency (UMPA) operates four, binary-cycle, power units with a combined capacity of 3 MW (gross), a turbine generator (2 MW gross) placed upstream from the binary units, and a condensing turbine rated at 8.5 MW (gross). UMPA operates the facility known as Cove Fort Station No. 1 for the City of Provo. Because H_2S is produced as a non-condensable gas, the facility includes a sulfur abatement plant designed to produce 1.36 metric tons (1.5 tons) per day of sulfur.

Six production wells (three 18-cm- [7-in] diameter wells and three 33-cm [13-in] diameter wells) supply steam to the three power units. Steam supply wells reportedly produce from the shallow, vapor-dominated part of the geothermal system, at depths between 335 and 366 m (1,100 and 1,200 ft). Reductions of reservoir pressures necessitated completion of new production wells into the deeper, liquid-dominated portion of the system. One deep well was completed into the deeper system and now produces geothermal fluid for the condensing turbine. Spent fluid is channeled back into the deep reservoir through one of the early exploratory wells, which was converted to an injector well. The estimated net output from the three power units is about 10 MW. UMPA is operating the plant somewhat below capacity (4 to 6 MW).

Although the Cove Fort geothermal plant has generated an average of 34,591 MWh per year from 1992 through 2002, annual generation has fluctuated greatly from as high as 47,024 MWh in 1992 to as low as 28,422 MWh in 1995 (table 5). The plant generated 29,681 MWh in 2002.

At the time of this writing, Provo City had reportedly sold their interests at the Cove Fort-Sulphurdale area. The new owners (Recurrent Resources) had not announced future plans for the development of the geothermal field, but reportedly the new operators intend to decommission the existing plant, reconstruct the well field, and build a new power station (30 MW gross) incorporating binary technology (Ray Connors, Sunrise Engineering, verbal communication, September 2003). Surface land ownership is mixed, primarily USFS and private. No environmental conflicts would appear to restrict future development, although the area is within mapped habitat for the Greater Sage Grouse, a listed species. No wilderness areas are near here and none are recommended for future designation.

SECOND TIER GEOTHERMAL RESOURCE AREAS

Newcastle

Location and Resource Parameters

Long: 113.5651 W; Lat: 37.6591 N; T.36S., R.15W., sec. 20, SW/NW/NW SLB&M; Iron County; Measured Temp: 118°C; Resource Temp: 130°C; Depth: 150 to 274 m (from Milgro drilling results); Resource Type: moderate-temp liquid; TDS (mg/L): 1,000 to 1,100

Area Description and Development Outlook

Newcastle is a small, unincorporated rural community located near the south end of the Escalante Valley adjacent to the northwest side of the Antelope Range in Iron County (figure 4). Newcastle is located along State Highway 56. Cedar City and connection to Interstate 15 lie about 48 km (30 mi) to the east along SR-56. A number of small communities in the Escalante Valley to the west from Newcastle are also connected by SR-56. Commercial greenhouse operators use geothermal production wells to tap an unconfined, alluvial aquifer, which covers an area of several square miles. Geothermal water also heats a Church of Jesus Christ of Latter-Day Saints' chapel in the town of Newcastle.

A maximum temperature of 130°C (266°F) was measured in a 1981 geothermal exploration well, which penetrated the outflow plume of the geothermal aquifer (Blackett and others, 1990; Blackett and Shubat, 1992). However, more recent thermal-gradient exploratory holes drilled nearby, record a maximum temperature of about 118°C (244°F) within the outflow plume. Production wells at the greenhouses generally produce fluids in the range of 75°C to 95°C (167°F to 203°F).

Based on shallow borehole data, and detailed self-potential (SP) and resistivity surveys (Ross and others, 1990), thermal water is thought to originate from a buried point source (upflow zone) near a Quaternary range-front fault southeast of Newcastle. The geothermal fluid then spills into the unconfined aquifer, creating a concealed outflow plume. The fluids move northwest within the aquifer cooling by conduction and probably mixing with cooler ground-water at the system margins. Shallow production wells (~ 150 m [500 ft]) tap this aquifer, supplying hot water for greenhouse space heating. Gawlik and Kutcher (2000) reviewed resource and economic parameters associated with a proposed small-scale geothermal power development at Newcastle and suggested that the resource was not large enough to support additional development beyond the existing greenhouse space heating. However, the probable source of the geothermal fluid, near the Antelope Range fault, remains unexplored. Only a few shallow (< 20 m) thermal-gradient boreholes have been drilled near the "throat" of the system. Deeper exploratory drilling into the source (150 to 300 m?) would be necessary to better evaluate the development potential for electric power generation.

The main part of the outflow plume extends northwestward from the Antelope Range fault beneath the privately owned valley floor. The suspected geothermal source area lies along the irregular boundary between private and BLM-administered lands along the foothills southeast of Newcastle. The main part of the suspected source area resides within BLM-administered lands.

The Newcastle area is undergoing active geothermal development for large-scale space heating of commercial greenhouses covering more than 10 ha (25 ac). This area was the recent focus of a U.S. Department of Energy-sponsored project to develop geothermal distributed power systems in the west. However, exploratory drilling in the outflow plume yielded temperatures less than required for commercial power generation. The suspected source-location of the geothermal fluids remains untested to date. Land ownership is mostly private within the current geothermal production area, although the suspected source location lies primarily on land administered by the BLM. Questions about the production temperature and capacity of the resource, however, remain as paramount obstacles to the extent of future development. No imminent environmental concerns have been identified. Present studies suggest a maximum resource temperature in a range around 130ºC (266ºF).

Thermo Hot Springs

Location and Resource Parameters

Long: 113.2036; Lat: 38.1731; T.30S., R12W., sec 28, SE/SE/NE; Beaver County
Measured Temp (°C): 174; Resource Temp: 160 to 217°C; Depth: 2,050 m; Resource Type: high-temp liquid; TDS (mg/L): 1,300 to 3,300 (data from Republic well Escalante 57-29)

Area Description and Development Outlook

The Thermo hot springs geothermal area is located within the northeast part of the Escalante Desert in southern Beaver County (figure 5). Thermal water discharges from two large spring mounds, situated near the axial drainage of the Escalante Desert valley. The Shauntie Hills, northwest of the hot springs, and the Black Mountains to the southeast consist of mainly Tertiary lava flows and volcaniclastic deposits (Rowley, 1978).

Northeast-oriented normal faults displace Quaternary valley-fill units and form a broad zone of faulting in and around the hot spring mounds. Faults mapped within the volcanic units of the low hills southeast of the thermal area, and within the Black Mountains, exhibit a dominant northwest orientation. The orientation of these two sets of structures and the position of the hot springs suggest that a structural intersection localizes the geothermal system. Regional gravity data suggest that a subsurface fault with several hundred feet of displacement (down to the west) passes through the hot springs area (Mabey and Budding, 1987). Blackett and Ross (1992) reported an interesting negative self-potential (SP) anomaly about 1 kilometer (0.6 mi) southeast of the spring mounds, which suggests the possibility of nearby upward-flowing geothermal fluid.

Republic Geothermal, Inc. (1977) contributed temperature-gradient, geophysical, and geochemical data resulting from geothermal studies in the area. The data package includes temperature-gradient borehole data (27 boreholes), water analyses, and production-test and temperature data from a deep (2,221 m [7,288 ft]) exploratory drill hole (Escalante 57-29). Mabey and Budding (1987) reported written communication from Republic indicating that this drill hole penetrated alluvium to about 350 m (1,148 ft), volcanic rock to 960 m (3,150 ft), and sedimentary-metamorphic rocks to 1,500 m (4,921) ft) where granite was encountered. The granite extended to total depth. Republic measured static temperatures on January 6, 1978 revealing a maximum temperature of 173.7ºC (344.7ºF) at a depth of 2,043 m (6,700 ft) – the maximum depth of recorded temperatures.

Although indicators suggest that a moderate- to high-temperature resource exists at Thermo, no developable resource has been defined to date – due mainly to lack of permeability. Maximum measured water temperature in the springs is 89.5ºC (193.1ºF) and estimates of the discharge range from about 30 to 120 l/min (8 to 32 gpm). Rush (1983) estimated the reservoir temperature between 140ºC and 200ºC (284ºF - 392ºF). Geothermometers applied to three water analyses of the hot springs yielded equilibrium temperatures ranging from 110º to 148ºC, while fluid samples from Escalante 57-29 yielded temperatures ranging from 166º to 241ºC (appendix B).

The region surrounding Thermo hot springs has been of interest to prospective geothermal developers, although no developable resource is identified. Republic Geothermal and others drilled a number of exploratory boreholes and performed geophysical surveys in the area, measuring a maximum temperature of about 174ºC (345ºF) at a depth of about 2,000 m (6,600 ft). No environmental concerns are present that would outwardly restrict development, although the area is remote and contains several listed species including the Greater Sage Grouse.

Drum Mountains Geothermal Prospect

Location and Resource Parameters

Long: 113.1533 W; Lat: 39.4900 N; T.14-15S., R.12-13W. SLB&M; Juab & Millard Counties; Measured Temp: ?; Resource Temp: ?; Depth: ?; TDS: ?.

Area Description and Development Outlook

The Drum Mountains geothermal prospect is located roughly 64 km (40 mi) WNW of the town of Delta, Utah (figure 6). Near the head of the Whirlwind Valley, the prospect extends across a broad area astride the Juab-Millard County line. Geothermal companies (primarily Phillips and Chevron) focused exploration on this area during the 1970s and 1980s, drilling nearly 80 thermal-gradient boreholes, and performing geophysical and geochemical surveys. The Little Drum Mountains, flanking the east side of the valley, consist mainly of Eocene-Oligocene intermediate volcanic rocks associated with a deeply eroded volcano complex. To the west lie the Swasey Mountains and the House Range consisting of Cambrian Tintic or Prospect Mountain Quartzite and series of overlying Cambrian clastic and carbonate rock units.

Rowley (1998) describes broad transverse zones and related Cenozoic igneous belts in the Great Basin. These east-west aligned zones include numerous geologic structures, igneous centers, mineralized districts, and hot springs that appear related in space and time. Rowley deduces that hot springs and hydrothermally altered rock may be concentrated along transverse zones because of long-lived faults, providing pathways for ground water and magma bodies. The Drum Mountains geothermal prospect lies within one of Rowley's igneous belts (Ely-Tintic igneous belt) and near two (Payson and Sand Pass) transverse zones. Later overprinting of Basin and Range faulting produced a number of north-south oriented faults (Drum Mountains fault zone).

The nearby Crater Springs geothermal area surrounds a Quaternary eruptive center known as Fumarole Butte (figure 6). See the section on "Crater Springs" in this report for more information.

Sass and others (1999) present summaries of exploratory drill-hole data for the Drum Mountain area acquired by the U.S. Geological Survey from several companies (primarily Phillips Petroleum and Chevron) that explored the region during the 1970s and early 1980s. These data were further summarized, combined with other data sets and made available through the Internet by the Geothermal Laboratory at Southern Methodist University (Blackwell and others, 1999). The Internet address is: http://www.smu.edu/geothermal/.

Figure 6 shows the distribution of these drill holes and the relative magnitudes of measured temperature gradients in the Drum Mountains area. Borehole data indicate mostly moderate to high thermal gradients relative to average Basin and Range values. Boreholes in this area vary in depth generally from 96 to 153 m (315 to 502 ft). One borehole was completed to a depth of 372 m (1,220 ft). The highest bottom-hole temperature was 70°C (158°F) at a depth of 150 m (492 ft) measured in a borehole drilled in section 30, T.15S., R.11W., near the east edge of the Whirlwind Valley and west side of the Little Drum Mountains. Beyond these data, no identified moderate-high temperature geothermal system has been publicly reported. The presence of young volcanic activity, young faults and geothermal springs, however, suggests that the area may contain significant geothermal resources.

Amax Geothermal and Phillips Petroleum Company explored the Drum Mountains-Whirlwind Valley area during the late 1970s and early 1980s. They identified no developable geothermal resource from this exploration, although they measured temperatures as high as 70ºC (158ºF) in shallow (generally 150 meters or less) boreholes. As a result, we include the area in our second tier classification even though a resource has yet to be discovered. The area is remote, and locally may contain only one listed species. A BLM WSA covers much of the Swasey Mountains directly southwest of Whirlwind Valley.

THIRD TIER GEOTHERMAL RESOURCE AREAS

Utah Hot Springs

Location and Resource Parameters

Long: 112.0278 W; Lat: 41.3375 N; T.07N., R.02W., sec 14, SW/SE/SE SLB&M; Weber County; Measured Temp: 59°C; Resource Temp: 192°C (from K/Mg geothermometer); Depth 1,800 m(?); Resource Type: high-temp liquid (?); TDS: 22,000 mg/L.

Area Description and Development Outlook

Utah hot springs issue from several orifices in Pleistocene valley fill sediments at the western edge of the Pleasant View spur, or salient, about 90 m (300 ft) west of U.S. 89 on the Box Elder-Weber County line (figure 7). The area is located within a utility and transportation corridor where the discharge, in the past, was channeled to baths, pools, and greenhouses. A small commercial greenhouse presently uses the fluids for heating during winter months. The maximum temperature reported is 63°C (145°F), although temperatures reported in most studies ranged between 57°C and 58.5°C (135°F and 137°F) (Murphy and Gwynn, 1979).

Total dissolved solids content of Utah hot springs water ranges between 18,900 and 25,200 mg/L, consisting mainly of sodium chloride. In addition to the high salinity, the water contains 3 to 5 mg/L dissolved iron that oxidizes and precipitates when the water is aerated. The iron compounds have reportedly led to scale buildup in piping and heat exchangers within the greenhouses. Felmlee and Cadigan (1978) have reported that the water also contains measurable quantities of radium (66 µµg/L) and uranium (0.04 µg/L). Cole (1983) included Utah hot springs as part of a geothermal-geochemical research project, and suggested that the hot spring discharge fluids appear to have circulated to depths in excess of 5 km (3 mi), thermally equilibrating with reservoir rock at temperatures above 200ºC (392ºF).

A shallow temperature survey (1 to 1.5 m depth) reported by Murphy and Gwynn (1979), indicated the temperature anomaly is centered on the main spring. Shallow temperatures decrease rapidly with distance northward from the main spring as the 25ºC isotherm is encountered about 75 m (250 ft) north. Southward from the main spring, temperatures decrease less with distance as another spring orifice (measured temperature 40ºC) occurs about 150 m (500 ft) to the southeast. The 25°C isotherm extends westward about 200 m (650 ft) to the Allen Plant Co. greenhouses.

The Wasatch Range to the east is a complex of Cretaceous-age (Sevier orogeny) thrust sheets involving Precambrian and early Paleozoic rocks. The Pleasant View spur (Gilbert, 1928) or salient, a prominent bedrock block projecting westward from the Wasatch Range north of Ogden, is part of the mountain mass displaced by normal faulting down and west from the main massif. The bedrock block within the salient remains high relative to the Basin-and-Range grabens to the west. Cluff and others (1970) note that the bounding structures of the Pleasant View spur are mostly concealed and not fully understood. A normal fault separates the eastern edge of the spur from the main Wasatch Range. A fault scarp, which marks the southwestern edge of the spur, is mapped near Utah hot springs (figure 7). Cluff and others (1970) identified two sets of lineaments, roughly perpendicular to one another, within the Pleasant View salient. One set of lineaments strikes northwestward, parallel to the Wasatch Range, while the other strikes to the northeast. Near the western edge of the salient at least two of the northeast striking lineaments appear to intersect the fault scarp at the salient's western edge. The northernmost intersection is close to Utah hot springs. Based on limited information, Murphy and Gwynn (1979) postulate that displacement on most of the internal structures of the salient does not appear large.

Utah hot springs are situated nearly due west of the boundary between the Weber and Brigham City segments of the Wasatch fault, where Personius (1990) describes surficial deposits and structural geology along these two fault segments. His work shows that at least three Holocene faults on the west flank of the Pleasant View spur postdate Bonneville lake cycle (between 30 and 10 ka) deposits and trend roughly at right angles to the Brigham City segment of the Wasatch Fault. The three faults are marked by 3-5 m high scarps formed in Bonneville-lake-cycle lacustrine gravels. The northernmost scarp also appears to cut Holocene fluvial and lacustrine deposits near the hot springs. He also notes that the springs appear localized at the intersection of this young fault and an older buried fault, described by Davis (1985), that flanks the west side of the spur.

Murphy and Gwynn (1979) also reported the results of temperature-gradient drill hole UT/GH-B. As part of a small DOE-funded project, the borehole was drilled to 30.5 m (100 ft).

They reported the hole would not stay open unless casing was installed as drilling proceeded. At a depth of 22 m (72 ft) a small volume of artesian flow was noted. In the 27 to 30 m (90 to 100 ft) interval, artesian flow increased to 227 L/min (60 gpm) and drilling ended. Grouting controlled flow from the hole. Borehole UT/GH-B encountered a series of sandy clay layers interbedded with sand and gravel layers. The overlying sandy clay confines the water in the sand and gravel layers, creating artesian conditions. An undetermined volume of thermal water is transported away from the springs in the sand and gravel aquifer. Temperature of water flowing from UT/GH-B (prior to grouting?) was 59ºC (138°F). Murphy and Gwynn (1979) measured conductivity at 4.05×10^4 μmohs/cm at 25°C (77°F). At 21 m (69 ft) pieces of saturated wood were blown from the borehole; samples sent to the U.S. Geological Survey's radiocarbon lab in Reston, Virginia yielded an age of 27,100 ± 600 years BP. Temperature profile for UT/GH-B is a simple curve showing temperature increasing with depth to a maximum of 59°C (138°F) at total depth (30.5 m, 100 ft).

The Utah hot springs site is one of three sites situated in the urbanized region along the Wasatch Front of northern Utah. We have identified this and the other two sites mainly on the basis of geothermometry. Geothermometry suggests that the temperature of resource fluids at depth may exceed 190ºC (374ºF). Utah hot springs is within an urban-industrial setting adjacent to a utility corridor, highway, and Interstate 15. The springs were used for a time at a now-defunct resort, and are currently used to heat a small commercial greenhouse operation. Minor geothermal exploration was conducted in the early 1980s, but the resource is poorly defined. Although the area is industrial, large-scale development could be problematic due to the number of listed species (10) possibly in the area. Small-scale geothermal power development, however, would likely blend well with other uses. Zoning restrictions in this "urban-fringe" area could impede some types of future development.

Ogden Hot Springs

Location and Resource Parameters

Long: 111.9233 W; Lat: 41.2356 N;T.06N, R.01W., sec. 23, SE/SW/SW SLB&M; Weber County; Measured Temp: 57°C; Resource Temp: 190°C (from K/Mg geothermometer); Depth: 1,800 m; Resource Type: high-temp liquid (?); TDS (mg/L): 8,800

Area Description and Development Outlook

Ogden hot springs, located at the mouth of Ogden Canyon on the east side of Ogden in Weber County, issue from fractures in Proterozoic (?) rocks along the Ogden River (figure 8). Nelson and Personius (1993) show the surface trace of the Wasatch fault a few hundred feet west of the springs. Undoubtedly, some (or even most) of the bedrock fractures near the springs are associated with the Wasatch fault. Since the late 1800s, workers have reported temperatures for the springs ranging from 49°C to 66°C (121°F to 150°F), but averaging about 57°C (135°F) (Mundorff, 1970). Flow rates recorded for the springs have been as high as 379 L/min (100 gpm), although most records indicate that the flow rate is about 132 L/min (35 gpm). TDS content of the sodium-chloride-type water from the springs generally varies from 8,650 to 8,820 mg/L. Concentration of manganese is high, and the chemical and thermal characteristics are similar to those for Hooper hot spring about 24 km (15 mi) to the southwest. Cole (1982, 1983) included Ogden hot springs as part of a geothermal-geochemical research project, and suggested that the hot spring discharge fluids appear to have circulated to depths in excess of 5 km (3 mi), equilibrating at temperatures above 200ºC (392ºF).

This site also occurs within the urbanized Wasatch Front region. It was identified mainly on the basis of geothermometry, which suggests that the temperature of resource fluids at depth may exceed 190ºC (374ºF). Ogden hot springs is situated near the mouth of Ogden Canyon, near residential neighborhoods, utility lines, water sources, and roads. The springs have no history of extended use other than local recreation and bathing. Moreover, no geothermal exploration beyond surface spring sampling has been reported. Similar to Utah hot springs, large-scale development could be problematic due to the number of listed species (10) possibly in the area. Zoning restrictions in this “urban-fringe” area may also complicate certain types of development.

Hooper Hot Springs

Location and Resource Parameters

Long: 112.1753 W; Lat: 41.1370 N; T.05N., R.03W., sec 27 SE/NW/SW SLB&M; Davis County; Measured Temp: 57°C; Resource Temp: 135°C; Depth: 1,500 m (from temp grad 91.6°C/km); Resource Type: low- to mod-temp liquid; TDS (mg/L): 8,600

Area Description and Development Outlook

Hooper hot springs and Southwest Hooper warm springs are located about 16 km (10 mi) southwest of Ogden near the eastern shore of the Great Salt Lake in Davis County (figure 9). The springs issue from Quaternary sedimentary deposits, and lie about 0.4 km (0.24 mi) west from an inferred fault. In addition to the main hot springs, several small springs and seeps are in the immediate area. Southwest Hooper warm springs are located about 0.6 km (0.4 mi) west of the main spring. Temperature at Hooper hot springs is about 57°C (135°F) with TDS content of about 8,600 mg/L. Temperature of Southwest Hooper warm springs is 32°C (90°F) with a TDS content of about 27,800 mg/L. The water is of sodium chloride-type in both springs. Although calcium concentrations are about the same for both springs, Mundorff (1970) noted that magnesium and potassium concentrations are much higher at Southwest Hooper warm springs. They suggest that the thermal waters at both springs are of the same origin, but water from Southwest Hooper warm springs is a mixture of both thermal and shallow ground water (Great Salt Lake brine). Geothermometers indicate equilibrium temperatures of about 135ºC (275ºF).

Geothermometry suggests resource temperatures at depth near 135ºC (275ºF), although no exploration has been performed to date. The area is within a Utah Wildlife Refuge, which could be problematic for industrial development. This area also contains the largest number of listed species of all geothermal areas considered in this study. Surface ownership and administration include mainly State Sovereign Lands and Division of Wildlife Resources lands along the eastern Great Salt Lake shoreline (figure 9). Both of these land divisions appear established as wildlife preserves. The geothermal resource area coincides with a Utah Division of Wildlife Resources designated wildlife refuge. Private lands extend eastward from these Sovereign and Division of Wildlife Resources lands.

Crystal-Madsen Hot Springs

Location and Resource Parameters

Long: 112.0864 W; Lat: 41.6600 N; T.11N., R.02W., sec. 29 SE/NE/SE SLB&M; Box Elder County; Measured Temp: 54°C; Resource Temp: 153°C; Depth 3,580 m (from temp grad ~ 40°C/km); Resource Type: mod- to high-temp liquid; TDS: 43,600 mg/L.

Area Description and Development Outlook

Crystal (Madsen) hot springs, located about 2 km (1.3 mi) north of Honeyville in Box Elder County, flow from the base of a small salient extending west from the Wellsville Mountains (northern extension of the Wasatch fault zone) (figure 10). Springs flow from fractured Paleozoic rocks at temperatures between 49.5°C and 57°C (121°F and 135°F). Although there are a number of warm springs and seeps in the area, the original main spring orifice is no longer visible, since it was enclosed in a box about 75 years ago. A nearby cold spring 11°C (52°F), along with water from the hot springs, is used to fill a 1.14-million-liter- (300,000-gallon-) pool, while the hot springs alone are used to fill therapeutic hot tubs and mineral pools (Blackett and Wakefield, 2002). Swimming pool temperatures range from 29° to 44°C (85° to 112°F). Roughly 610 m (2,000 ft) south of the main spring, a series of low-flowing warm springs and seeps are present in a small branch of Salt Creek, a tributary of the Bear River (Murphy and Gwynn, 1979).

The flow from all springs and seeps drains southwest along Salt Creek and has been estimated at about 15,300 L/min (4,000 gpm). The main hot spring discharges at a rate of about 6,370 L/min (1,680 gpm).

Dissolved constituents of the thermal water are the highest of any spring in Utah with TDS values above 46,000 mg/L. Over 90 percent of the ions in solution are sodium and chloride. Milligan and others (1966) estimated that the Crystal-Madsen system produces 450 tons (408 mt) of salt per day. In addition to high TDS values, the springs reportedly contain elevated levels of radium (220 µµg/L) and uranium (1.5 µg/L) (Felmlee and Cadigan, 1978). Geothermometry suggest equilibration temperatures near 150ºC (300ºF), although these values might be questionable given the high TDS of the spring waters.

The Wellsville Mountains (north extension of the Wasatch Range) consist mostly of faulted Paleozoic sedimentary rocks dipping northeastward from 20 to 60 degrees. These carbonate rocks contain some quartzite and shale. Displacement across the northeast-trending fractures within the range is generally small, but fractures dissect the range into a number of small fault blocks. The range is bound on the east and west by basin-and-range normal faults.

Murphy and Gwynn (1979) describe the bedrock and alluvium mantle of the Madsen salient. The only known bedrock exposures are found at the western edge of the salient, east and southeast of the springs. Exposed rocks are primarily bluish gray, Paleozoic limestone striking N 40° W and dipping 60 to 85 degrees eastward. Remnants of a more extensive Tertiary (?) conglomerate are scattered across the western edge of the salient, unconformable atop Paleozoic bedrock. Quaternary and recent alluvium covers much of the salient and varies in thickness up to several tens of meters. Alluvium is thickest where the salient and Wellsville Mountains meet, and along the north and west edges. Murphy and Gwynn (1979) identify a large landslide mass northeast of the springs exposing a "scarp of alluvium" (?) about 30 m (100 ft) thick. Black and others (2003), using mapping by Oviatt (1986), show several northeast-southwest Quaternary faults intersecting the Collinston segment of the Wasatch fault near the hot springs.

The Salt Creek drainage exposes a 20 cm (7 in) thick layer of hot-spring tufa. This thermal spring deposit is brown with a fibrous, vuggy texture. The tufa appears laterally extensive and may have been penetrated by borehole C(M)/GH-A at 6.7 m (22 ft).

Crystal-Madsen hot springs issue along faults at the western edge of the Madsen salient or spur. The salient is small relative to the Pleasant View or Salt Lake salients, but, in similar fashion, is a fault block intermediate in elevation between the Wellsville Mountains to the east and the graben to the west.

The Crystal-Madsen site is the northernmost of the geothermal areas studied. The area has been extensively developed as a resort, operating commercially at least for the past 75 years. The area is logistically attractive for development as there is ready access to roads and transmission lines. The resource is virtually unexplored, as only fluids have been sampled and their analytical results reported. One thermal-gradient borehole penetrated 67 m (220 ft) at the site yielding bottom-hole temperature of 61ºC (148ºF). Land ownership is entirely private, although the USFS designated a wilderness area about 3 km (2 mi) east of the site. Utah Wildlife Resources indicates that four listed species are found in the region.

GEOTHERMAL AREAS CONSIDERED BUT NOT ANALYZED

Several areas described below were considered for inclusion in this study, but were not analyzed because resource temperatures appear too low and reservoirs are undefined. In most cases, geothermometry (geo-indicators described in appendix A) suggested resource temperatures below the threshold (120ºC [248ºF]) established for this study. In nearly all cases, though, reservoir parameters, such as depth, volume, and flow capacity of the resource, were also undetermined. These resource areas, however, should be considered in future studies of potential sites for geothermal direct use.

Beryl Area

Location and Resource Parameters

Long: 113.6870 W; Lat: 37.8390 N; T.34S., R.16W., sec. 18, SW/SE/SW SLB&M; Iron County; Measured Temp: 149ºC; Resource Temp: 149ºC (?); Depth: 2,134 m (?); TDS: ~ 4,000 mg/L.

Area Description

The Beryl area is located within the southern Escalante Valley of Iron County, south of the Wah Wah and Indian Peak Ranges, near the rail sidings of Beryl and Zane (figure 1). Goode (1978) reported a temperature of 149°C (300°F) from a depth of 2,134 m (7,000 ft) measured within a 3,748 m- (12,295 ft-) deep well that he termed "De Armand #1." Goode also reported that, upon testing, the well flowed at a rate of 3,785 L/min (1,000 gpm) and that the water contained less than 4,000 mg/L dissolved solids. No flowing temperature was given.

According to records obtained from Water Rights, three companies -- McCulloch Oil Corporation (MCR Geothermal Corp.), Geothermal Kinetics, Inc., and Utah Power & Light Company -- formed a partnership to drill and complete a well referred to as "MCO-GKI-UPL-DeArman #1." The well was located in the SW¼SE¼SW¼ section 18, T. 34 S., R. 16 W., and was drilled during the spring of 1976. Documents filed with Water Rights during December 1981 and correspondence dated November 12, 1985, suggest that the well was drilled to a depth of at least 2,361 m (7,745 ft) and that it did not comply with state-regulated abandonment procedures at that time.

Klauk and Gourley (1983) made no mention of the above-referenced ("DeArman") well, but reported a temperature of 60°C (140°F) measured at a depth of 2,461 m (8,072 ft) within an unnamed geothermal test well located in the NE¼NE¼NW¼ section 22, T. 34 S., R. 16 W. This location corresponds to a well reportedly drilled in 1976 by MCR Geothermal Corp., and referred to as "State #1" (letter from Water Rights to Insurance Company of North America, dated November 12, 1985).

Wood's Ranch is located just south of the Wah Wah Mountains in the northwest part of the Escalante Valley in Iron County, roughly 16 km (10 mi) NNW of the DeArman #1 well. One of two wells, a 61-m- (200-ft-) deep water well drilled for irrigation on the ranch produces 36.5°C (97.7°F) water. No hot springs are present. A self-potential survey performed at Wood's Ranch by workers from the University of Utah and the UGS (Ross and others, 1991) revealed a broad, negative SP anomaly interpreted as thermal up-flow. Beyond the SP survey and one water analysis, the property remains unexplored. Chemical geothermometers suggest reservoir temperatures in the range of 100°C to 115°C (212°F to 239°F). The warm water produced from the well may be a mixture of thermal water and non-thermal ground water from the Escalante Valley aquifer. The area is somewhat remote with no incorporated communities nearby. The Union Pacific rail line crosses the Escalante Valley within 1.6 km (1 mi) of Wood's Ranch. Access roads into the area are both improved county and BLM roads, and jeep trails. Land ownership in the vicinity of the thermal wells is privately owned. Surrounding lands are federal and state owned.

The Beryl area has been included in projections of possible geothermal resource areas in Utah for the production of geothermal electric power. We did not include the area as part of this effort, however, due to the depth (2.36 km) versus the temperature (149ºC) of the resource. This yields an uncorrected geothermal gradient of about 59ºC/km – a relatively normal gradient for the region. This area may still be valuable as a target for future exploration.

Uinta Basin – Ashley Valley

Location and Resource Parameters

Long: 109.4160 W; Lat: 40.3650 N; T.05S., R.22E., sec. 23 SLB&M; Uintah County; Measured Temp: 40ºC to 56ºC; Resource Temp: ?; Depth: 1,300 m; TDS: 2,000 mg/L.

Area Description

The Uinta Basin in northeastern Utah is a broad, east-west trending basin that sub-parallels the Proterozoic-rock-cored Uinta Mountains to the north. It encompasses more than 26,000 km^2 (10,000 mi^2), most of northeastern Utah (figure 1). Structurally, it is a broad east-west asymmetrical syncline with a steep north limb and a gently dipping south limb. The basin is a Laramide orogenic feature, filled primarily with Tertiary alluvial, fluvial, and lacustrine deposits. A number of oil reservoirs occur in the basin as well as other hydrocarbon deposits (gilsonite, oil shale, and bituminous sandstone). Several significant faults near the south flank of the Uinta Mountains run subparallel to the axis of the basin, and may act as conduits for vertical movement of thermal water.

In his detailed report on the thermal waters of Utah, Goode (1978) summarized geothermal occurrences in the Uinta Basin. Thermal water is produced as a by-product of oil production within the Uinta Basin. At the Ashley Valley field, Goode reported that low-TDS water (1,500 mg/L) at temperatures between 43° and 55°C (109° and 131°F) was produced with oil, separated in settling ponds, and diverted into the local irrigation system. Wells are about 1,300 m (4,265 ft) deep. No attempt to use the heat in geothermal applications has been reported.

Crater Springs

Location and Resource Parameters

Long: 112.7281 W; Lat: 39.6125 N; T.14S., R.08W., sec. 10, NE/SW/SE SLB&M; Juab County; Measured Temp: 75º - 85ºC; Resource Temp: 87º to 116ºC; Depth: ?; TDS: 3,600 to 4,000 mg/L.

Area Description

The Crater Springs geothermal area surrounds a Quaternary eruptive center known as Fumarole Butte in the northern Sevier Desert of Juab County (figures 1 and 6). Early Pleistocene basalt flows (0.9 Ma) erupted from the vent area and formed a broad volcanic apron now known as Crater Bench. The Drum Mountains fault zone, a north-northeast trending zone of high-angle normal faults, offsets basalt flows along the west-central side of Crater Bench at Fumarole Butte. Warm vapor rises from several fissures in the vicinity of Fumarole Butte. Abraham hot springs, also referred to in literature as "Crater Springs" or "Baker hot springs," issues 8 km (5 mi) to the east of Fumarole Butte along the east margin of the Crater Bench basalt flows. Mabey and Budding (1987) postulated that the vapor venting from Fumarole Butte and the thermal waters at Abraham hot springs are part of the same geothermal system.

Temperatures at Abraham hot springs range up to 87°C (189°F). Rush (1983) estimated total flow rates from about 40 spring orifices at between 5,400 and 8,400 L/min (1,400 and 2,200 gpm). The thermal water is sodium and calcium-chloride type. The geologic structure controlling the system is unknown, and the reservoir temperature is uncertain. Samples of cold springs issuing from the same site were collected for analyses as part of this study in order to develop more accurate mixing models. Analyses of the cold water, however, revealed that this water is very similar in composition to that of the hot springs, and suggests that the cold springs are merely cooled hot water. Geothermometers suggest equilibration temperatures in the range 87°C to 116°C (189°F to 241°F).

Meadow and Hatton Hot Springs

Location and Resource Parameters

Long: 112.4900 W; Lat: 38.8500 N; T.22S., R.06W., sec. 35, NW/SE/SE SLB&M; Millard County; Measured Temp: 29º to 66ºC; Resource Temp: ~ 110ºC; Depth: ?; TDS: 4,450 mg/L.

Area Description

The Meadow-Hatton area (figure 1) is located less than 2 km (1.3 mi) west of Interstate 15 in Millard County. Fillmore, the county seat with a population of 2,000 people, is located about 10 km (7 mi) to the northeast. The small community of Meadow (population 250) is situated on Interstate15, less than 2 km (1.3 mi) from the thermal area. The Pavant Valley and the Black Rock Desert comprise mostly irrigated croplands. Land ownership in the Pavant Valley and Black Rock Desert is a combination of private, state, and federal parcels administered by the BLM.

The Meadow-Hatton geothermal area consists of a large travertine mound, marshland, and thermal springs located about 16 km (10 mi) southwest of the town of Fillmore on the east side of the Black Rock Desert in Millard County. The Black Rock Desert contains some of the state's youngest volcanic rocks -- some being only a few hundred years old. Hatton hot spring issues from the south end of a large, northeast-trending travertine mound at a temperature of 63°C (145°F). Meadow hot springs, comprising several thermal springs in a northeast alignment and located in a marshy area about 2 km (1.3 mi) northwest of the Hatton travertine mound, issue at temperatures up to 41°C (106°F). Flow rates from the springs are low and reportedly vary from 0 to 240 L/min (63 gpm). The spring waters are probably coupled to the regional ground-water flow system of the Pavant Valley and Black Rock Desert.

Ross and others (1993) described two fluid samples from the Meadow hot springs area in conjunction with the results of self-potential surveys completed in the area. Self-potential surveys revealed a high-amplitude, negative anomaly beneath the southern part of the travertine mound. More recent chemical data show very different values for potassium, silica, and fluoride concentrations compared to earlier data, suggesting temporal variations in spring chemistry.

Standard geothermometers range between 205°C (401°F) (Na-K-Ca) and 86°C (187°F) (Na-K-Ca-Mg), with most likely equilibration temperatures around 108°C (226°F) (quartz conductive). Based on the results of the new chemical analyses, the fluids appear to be highly evolved with a very complex thermal history (Ross and others, 1993).

Monroe-Joseph Area

Location and Resource Parameters

Long: 112.1070 W; Lat: 38.6330 N; T.25S., R.03W., sec. 10, NE/SE/SE SLB&M; Sevier County; Measured Temp: 70ºC to 76ºC; Resource Temp: 94ºC to 110ºC; Depth: ?; TDS: 2,650.

Area Description

Monroe hot springs and Red Hill hot springs are situated less than a 0.8 km (0.5 mi) east of the town of Monroe, a community of about 1,470 people located about 5 km (3 mi) east of Interstate 70 in Sevier County (figure 1). Richfield (population - 5,590), the county seat of Sevier County, is located a few miles to the north along Interstate 70. The Sevier-Sanpete Valley is an agricultural region extending for about 129 km (80 mi) northeastward from the Monroe area. Land ownership in the Sevier Valley is mostly private.

Monroe was the site of a number of geoscience and exploratory drilling studies sponsored by the DOE in the late 1970s and early 1980s to assess resource potential. Mabey and Budding (1987) summarized the results of various workers. Although feasibility studies based upon fluid temperatures and flow rates from a DOE-sponsored production well showed that a district-heating system was not economical, the area could be attractive for process or agricultural direct-heat applications. At Monroe hot springs, Mystic Hot Springs Resort uses geothermal water to heat a swimming pool, several therapeutic baths, and for tropical fish ponds.

The Monroe and Red Hill hot springs issue at about 77°C (170°F) near the surface trace of the Sevier fault, adjacent to the Sevier Plateau. The Sevier fault is a 482-km- (300-mi-) long zone of rupture extending from the Grand Canyon northward into central Utah. Chemical geothermometers suggest maximum resource temperatures of about 110°C (230°F). Maximum measured temperature is 77°C (171°F) at Red Hill hot springs and 76°C (169°F) at Monroe hot springs. Combined flows for the Monroe-Red Hill system have been estimated at about 1,200 L/min (320 gpm).

Joseph hot spring discharges from a spring mound near the Dry Wash fault, which parallels the Sevier River along the northwest edge of a group of hills that are part of the Antelope Range. The springs issue at 63°C (145°F) with flow rates approaching 121 L/min (32 gpm).

North Sanpete Valley Wells

Location and Resource Parameters

Long: 111.5653 W; Lat: 39.3628 N; T.07S., R.03W., sec. 03, SE/NW/SE SLB&M; Sanpete County; Measured Temp: 38°C, Resource Temp: ?; Depth: (?); Resource Type: (?); TDS: 8,260 mg/L.

Area Description

The Sanpete and Sevier Valleys form a long, narrow, northeast-southwest depression in central Utah (North Sanpete Valley on figure 1). The area may appear geologically simple, but surface deposits mask a structurally complex area of subsidence caused by faulting, folding, and dissolution of salt from Jurassic formations. Warm springs and wells are present throughout both valleys, although the hotter springs are located at the southern margin of the Sevier Valley. In the Sanpete Valley, several warm wells suggest the possibility of a hidden (blind) geothermal system somewhere below the valley floor. Geothermometers applied to chemical analyses of the J. Paulsen well suggest the possibility of a high temperature geothermal system at depth, although measured temperatures are relatively low. High TDS values within ground water from in Jurassic evaporite deposits in this region may yield anomalously high geothermometer temperatures, however.

GEOTHERMAL RESOURCE REGULATION AND OWNERSHIP IN UTAH

General Description

Ownership or control of geothermal resources in Utah has historically followed both ownership of land and water rights. Beginning in the mid-1970s, rapid escalation of energy prices resulted in increased interest in exploiting geothermal resources throughout the United States. The Geothermal Steam Act of 1970 governs leasing and development of geothermal resources on Federal land. In Utah, statutes were not enacted until 1981, addressing the regulation of geothermal resource development at the state level, particularly with regard to water rights issues. Geothermal resource regulation in Utah is detailed in the following section. Similar regulations for several of the surrounding western states and the Federal Government are summarized in appendix C.

When the Roosevelt hot springs area was explored and developed in the mid-1970s, high-temperature, geothermal-water-rights issues involved a long process partly because there was no statute at the time addressing this unique resource. The state had no procedures to administer the exploration, construction, testing, and allocation of deep and/or high pressure geothermal waters. The enactment of the Utah Geothermal Resource Conservation Act of 1981 defined such geothermal resources as heat contained in water for those resources with temperatures greater than 120ºC (248°F) and designated the Utah Division of Water Rights as the administering agency.

The statute also assigned Water Rights the ability to declare unit agreements to assure the sharing of the geothermal resource. This could be done at the request of an interest owner or by the Division's initiative. The unit for Roosevelt hot springs was, however, guided by BLM rules modeled on federal oil and gas units. (BLM has rules for units for oil and gas, and the Utah Division of Oil, Gas and Mining Board can review those decisions to assure that the resource is conserved and all owners fairly represented.) The Roosevelt hot springs unit is the only geothermal production unit established in Utah thus far. Issues of ownership of water rights, which are connected to geothermal resources, are resolved through a hearing process before Water Rights, rather than the Division of Oil, Gas and Mining.

All water projects regardless of temperature require an application to appropriate water. Such applications currently involve a four to six month process if there are no problems or challenges. Water users in closed basins are the most concerned when water rights for geothermal projects are advertised, even if the use is non-consumptive due to re-injection of geothermal fluids. Existing users are commonly concerned that geothermal development will have an adverse affect on water availability and quality. In these cases, such as the sites along the urban areas of the Wasatch Front, Water Rights requires evidence of adequate separation of the deep strata bearing geothermal resources from the surface and shallow ground water resources to prevent any impact to existing rights, to return the water to protect the geothermal resource, and to prevent interference between water rights. Geothermal waters are often at depth, from "ancient" waters and of poor quality, but the burden is on the geothermal resource developer to prove there will be no impact.

Obtaining water rights and geothermal rights might be even more difficult in the future in closed basins. There are several Utah water basins with full allocation and some with over-allocation of water as a result of early rights being used to their full extent and more consumptive crops and operations are being employed. Some basins are experiencing falling water tables, partly caused by the recent extended drought (1998 to present). In spite of this, non-consumptive projects such as space heating and aquaculture operations have been approved. High-temperature projects, even existing ones, have been limited due to economics in the power industry, rather than difficulty in obtaining the necessary water right. Low-temperature geothermal (below 120ºC [248ºF]) resources can be treated as a "special" water resource at the Utah State Engineer's discretion, which allows the consideration of other factors besides priority date of water right.

Utah Geothermal Resource Conservation Act

The Utah State Legislature enacted the Utah Geothermal Resource Conservation Act (Utah Code Title 73, Chapter 22) in 1981 (amended in 1987 and 1988) to:

- Promote the discovery, development, production, utilization, and disposal of geothermal resources in the State of Utah in such manner as will prevent waste, protect correlative rights, and safeguard the natural environment and the public welfare;

- Authorize, encourage, and provide for the development and operation of geothermal resource properties so that the maximum ultimate economic recovery of geothermal resources may be obtained through, among other things, agreements for cooperative development, production, injection, and pressure maintenance operations.

Definitions in the Utah Act

Correlative rights mean the rights of each geothermal owner in a geothermal area to produce without waste his just and equitable share of the geothermal resource underlying the geothermal area.

Division means the Division of Water Rights, Utah Department of Natural Resources – the agency given the responsibility of regulating geothermal development in Utah.

Geothermal fluid means water and steam at temperatures greater than 120ºC (248ºF) naturally present in a geothermal system.

Geothermal system means any strata, pool, reservoir, or other geologic formation containing geothermal resources.

Geothermal resource means (a) the natural heat of the earth at temperatures greater than 120ºC (248ºF); and (b) the energy, in whatever form, including pressure, present in, resulting from, created by, or which may be extracted from that natural heat, directly or through a material medium. Geothermal resource does not include geothermal fluids.

Material medium means geothermal fluids, or water and other substances artificially introduced into a geothermal system to serve as a heat transfer medium.

Waste means any inefficient, excessive, or improper production, use, or dissipation of geothermal resources. Wasteful practices include, but are not limited to: (a) transporting or storage methods that cause or tend to cause unnecessary surface loss of geothermal resources; or

(b) locating, spacing, constructing, equipping, operating, producing, or venting of any well in a manner that results or tends to result in unnecessary surface loss or in reducing the ultimate economic recovery of geothermal resources.

Well means any hole drilled, converted, or reactivated for the discovery, testing, production, or subsurface injection of geothermal resources.

Features of the Utah Act

Ownership of a geothermal resource derives from an interest in land and not from an appropriative right to geothermal fluids. However, the mass transfer of heat is normally dependant on the withdrawal of water (or steam) from the geothermal system, which implies that a developer should obtain a water right though the appropriative process. The exception may be whereby a "material medium" (or working fluid) is used to extract the heat energy, such as the case with a hot dry rock project. This definition of geothermal resource ownership applies to all lands in the State of Utah, including federal and Indian lands to the extent allowed by law. When these lands are committed to a unit agreement involving lands subject to federal or Indian jurisdiction, Water Rights may, with respect to the unit agreement, deem this chapter complied with if the unit operations are regulated by the United States and Water Rights finds that conservation of geothermal resources and prevention of waste are accomplished under the unit agreement.

Geothermal fluids are deemed to be a special kind of underground water resource, related to and potentially affecting other water resources of the state. The utilization or distribution for their thermal content and subsurface injection or disposal constitutes a beneficial use of the water resources of the state. Therefore, geothermal owners are required to file an application with Water Rights in order to appropriate geothermal fluids that will be extracted from geothermal wells.

Cooperative or unit operation of geothermal areas may be formed following an adjudicative proceeding to consider the need for "unitizing" a geothermal area. Any affected person or organization may request Water Rights to initiate this process. Water Rights shall order the operating unit if it finds that a geothermal resource exists, and unitizing a field is necessary to prevent waste, to protect correlative rights, or to prevent the drilling of unnecessary wells, and it will not reduce the ultimate economic recovery of geothermal resources. As of January 2004, no persons or organizations have approached Water Rights to unitize geothermal fields in Utah.

Rights to geothermal resources and to geothermal fluids to be extracted in the course of production of geothermal resources are based on the principle of correlative rights. Correlative rights refer to the right of each landowner in a geothermal area to produce "without waste" their just and equitable share of the geothermal resource underlying a geothermal area.

Jurisdiction of the Division of Water Rights includes the authority over all persons and property, public and private, necessary to enforce the provisions of [the act]. Water Rights has issued rules (R655) governing geothermal resource development.

Geothermal Steam Act of 1970

Overview – The Geothermal Steam Act of 1970 (Act) governs development of geothermal steam and related resources on public land in the United States.

Selected Definitions – Geothermal lease, a lease issued under the authority of this Act; Geothermal steam and associated geothermal resources, (1) all products of geothermal processes, embracing indigenous steam, hot water, and hot brines; (2) steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formations; (3) heat or other associated energy found in geothermal formations; and (4) any byproduct derived from them. Secretary, Secretary of the Interior.

Lands Subject to Leasing - The Act authorizes the Secretary to issue leases for development and utilization of geothermal steam and associated geothermal resources in lands administered by the Secretary including: public, withdrawn and acquired lands; national forests or other lands administered by the USFS, including public, withdrawn and acquired lands; and lands conveyed by the U.S. subject to a reservation to the U.S. of geothermal steam and associated geothermal resources. Geothermal leases for lands withdrawn or acquired to aid functions of the Departments of Interior and Agriculture may be issued only under terms and conditions that ensure the lands are used for their intended purposes. The Act prohibits issuance of geothermal leases on, (1) lands in the National Park System; (2) lands in a fish hatchery administered by the Secretary, wildlife refuge, wildlife range, game range, wildlife management area, waterfowl production area or lands acquired or reserved for the protection and conservation of fish and wildlife threatened with extinction; and (4) tribally or individually owned Indian trust or restricted lands. The Secretary also is prohibited from issuing leases on lands not subject to leasing under § 226-3 of the Mineral Leasing Act of 1920 (wilderness study areas).

Geothermal Leases - The Act sets forth detailed provisions governing the issuance and administration of geothermal steam leases, including: (1) competitive bidding for leases; rents and royalties; (2) lease duration, acreage and termination; and (3) disposition of moneys from sales, bonuses, royalties, and rentals. A lessee may use as much of the surface of the land covered by the lease as the Secretary finds necessary for the production, utilization, and conservation of geothermal resources. The Act must be administered under the principles of multiple-use of lands and resources.

Significant Thermal Features - The Act directs the Secretary to maintain a list of significant thermal features within National Park System units, including 16 specified units. The Secretary must maintain a monitoring program for these features and establish a research program on geothermal resources within units with these features. If the Secretary determines that exploration, development, or utilization of lands subject to a lease application is reasonably likely to have a significant adverse effect on a significant thermal feature within a National Park System unit, the Secretary is prohibited from issuing the lease. If these activities are reasonably likely to have an adverse effect, the Secretary must include specified stipulations in leases or drilling permits to protect the significant thermal features.

Regulations - The Secretary must prescribe regulations to carry out the Act. The regulations may include provisions for, (1) prevention of waste; (2) development and conservation of geothermal and other natural resources; (3) protection of the public interest; (4) protection of water quality and other environmental qualities.

The BLM released the final rule, published in the Federal Register on September 30, 1998 (Bureau of Land Management, 1998) governing geothermal resources leasing and operations on public lands. The final rule amends the regulations, which implement the Geothermal Steam Act of 1970. The rulemaking addresses leasing, permitting and operational requirements for geothermal exploration, drilling, and utilization operations. The final rule (1) rewrites all the geothermal resource development regulations in a plain language style, (2) reduces and streamlines permitting and information requirements, (3) provides the BLM with the maximum possible flexibility regarding permit issuance allowing BLM to accommodate the full range of potential geothermal operations and development scenarios, and (4) reorganizes the regulations to provide specific permit application informational requirements allowing BLM and their customers to interpret regulatory requirements more consistently.

ACCESS TO GEOTHERMAL RESOURCES

Table 6 presents the general land ownership for the selected geothermal sites analyzed in this study. More detailed land ownership information is also shown on the figures associated with the individual areas. Most of the areas encompass a variety of federal, state, and private ownership. Federal land management agencies include the BLM, the U.S. Forest Service (USFS), and the U.S. Bureau of Indian Affairs (Tribal). State management agencies include the Utah School and Institutional Trust Lands Administration (SITLA), Utah Division of Forestry, Fire, and State Lands (FFSL), and Utah Division of Wildlife Resources (DWLR).

The accessibility to resources for the various land management units in Utah is described in the following paragraphs.

Federal Lands

The BLM leases federal land, including USFS land, for geothermal exploration and development. The BLM also monitors and supervises development operations of the leases.

Much of the geothermal activity on public lands takes place in California, which has more than 23 producing leases, followed by Nevada, Utah, and New Mexico. The BLM geothermal program has more than 58 producing leases, produces 24.2 megawatt-hours of energy per year, and accounts for more than $12 million in revenues per year (Farhar and Heimiller, 2003).

During the late 1970s and early 1980s, when interest in geothermal development was very high, the BLM issued more than 130 competitive leases and 280 non-competitive leases involving almost 800,000 acres (323,750 ha) in Utah. These leases were grouped mainly around Roosevelt hot springs, the Cove Fort-Sulphurdale area, Thermo hot springs, Drum Mountains-Sevier Desert, and Newcastle.

All leases except those at Roosevelt, Thermo, Cove Fort, and Newcastle expired by the end of their 10-year primary term -- the period given for lessees to discover, develop and begin production of the resource. During 2002, leases within the Roosevelt Unit, but outside the Participating Area, also expired in accordance with terms of the unit agreement.

In Utah, the BLM established Known Geothermal Resource Area (KGRA) status, based upon competitive interests or geological criteria, in four areas enclosing roughly 60,000 acres (24,300 ha). Table 7 shows the approximate surface-area ownership within the Utah KGRAs (source: James Fouts, BLM, written communication, 2001).

In Utah, the BLM established Known Geothermal Resource Area (KGRA) status, based upon competitive interests or geological criteria, in four areas enclosing roughly 60,000 acres (24,300 ha). Table 7 shows the approximate surface-area ownership within the Utah KGRAs (source: James Fouts, BLM, written communication, 2001).

Although competitive geothermal leases apply only to BLM and USFS lands within the KGRAs, in all cases except Thermo hot springs, the Utah KGRAs enclose a mixture of federal, state, private, and Indian lands. BLM administers all lands within the Thermo KGRA. In addition to BLM-administered and private lands, the Cove Fort-Sulphurdale KGRA also encloses lands controlled by the USFS and the Paiute Tribe.

Table 8 is a summary of federal geothermal leases in Utah according to the BLM's lands and records system (accessed June 2003). Federal geothermal leases in the Roosevelt hot springs and Cove Fort-Sulphurdale geothermal areas involve significant acreage -- 2,323 acres (940 ha) at Roosevelt involving 5 leases, and one lease enclosing 2,594 acres (1,050 ha) of USFS and BLM lands at Cove Fort. Because these lands were within KGRAs, the leases were acquired by competitive bidding. While the competitive bid process generates significant dollars for public lands agencies, potential lessees complain that the sealed bid process inflates the up-front costs of acquiring federal lands and has the potential of allowing an adversarial party to acquire small portions of high potential areas so that they must be included in any geothermal resource development as working interests. From the BLM's perspective, the competitive bidding process assures fair payment for the resource and also discourages speculative holding of leases during the 10-year primary term.

The Utah State Office of the BLM held a geothermal lease sale on December 9, 2003 within all Utah KGRAs. They reportedly leased nearly 2,670 ha (6,600 ac.) within the Roosevelt Hot Springs and the Cove Fort-Sulphurdale KGRAs.

More recently issued two non-competitive federal leases in two of the sites featured as potential electrical generating sites—at Newcastle and at Thermo hot springs (August 1999 and October 2002, respectively). These leases were issued to the interested lessees for a standard rental fee with a primary term of 10-years.

In the case of low- and moderate-temperature (< 120°C, 248°F) geothermal resources for direct use of geothermal fluid, the BLM would reportedly issue a lease on Federal land, requiring royalty payments based upon "equivalent Btu" heat content (enthalpy) of the fluids (Robert Henricks, BLM, verbal communication, June 2003).

State Lands

Water Rights is the lead agency for regulating development of geothermal resources in Utah. A water right, for all practical purposes, is necessary for exploiting geothermal energy even though by statute, geothermal resources are defined as the heat contained in water or steam in excess of 120ºC (248ºF), rather than the water itself. In order to acquire ownership or rights to develop geothermal resources, parties must have water rights containing geothermal resources and control (by fee title or lease) of the surface land overlying geothermal resources.

SITLA manages mineral leasing on state trust lands. FFSL acts as the leasing agency for sovereign lands, lands controlled by the Division of Wildlife Resources, the Utah Division of Parks and Recreation, and the Utah Department of Transportation. These agencies do not define geothermal resources in their administrative rules; rather, geothermal resources are defined in individual leases.

The ownership pattern of state trust lands (the vast majority of Utah state lands) is scattered throughout the state commonly with four sections (normally 2, 16, 32 and 36) per township. These lands are managed for the benefit of public schools and other institutions. The exceptions to this pattern are where private ownership existed before statehood, usually along the major rivers where the most arable land existed. More recently, the federal government and SITLA have negotiated land trades consolidating state ownership into larger blocks. Within the nine geothermal areas considered here, state ownership consists of either small, isolated tracts or is absent.

SITLA uses a separate lease category covering geothermal resources under a special lease form designed for "geothermal products." Obtaining a geothermal lease involves an "over-the-counter" application process. In addition to geothermal steam, the lease defines geothermal products as hot water, steam by-products, steam condensates, minerals, and chemicals. Geothermal products also include electrical and other energy derived, generated, or manufactured from water, and other by-products derived or obtained from the leasehold estate. If lessees develop water resources on trust lands, lessees must make application for appropriation in the name of SITLA. Presently, SITLA administers nine active geothermal leases covering 3,322 acres (1,344 ha) within and around the Roosevelt hot springs KGRA (2,482 ac., 1,004 ha), Cove Fort-Sulphurdale KGRA (400 ac., 162 ha), and Thermo Hot Springs II KGRA (440 ac., 178 ha).

Private Lands

Acquisition of geothermal resources on private lands is much more difficult to track than on federal or state lands. Water Rights records show that water rights acquired for hot springs are used for a variety of direct applications such as space heating of buildings and greenhouses, spas and recreational sites. In most cases, though, geothermal resources at these sites are generally not well explored, are underutilized, and have undergone sporadic development. The reasons for this are unclear and may stem from the relatively small size of individual private parcels, the multitude of owners, and/or the lack of guidance and structure of a regulatory agency. Transfer of water rights is governed by sale of the property containing the source (spring or well), subject to approval by Water Rights.

In some instances, in other states, existing geothermal users have stalled larger geothermal direct-use projects proposed by municipal governments, arguing that wider use of geothermal heat might impinge upon their use. This has led to inflation of project costs, underutilization of the system (low load factor) as potential customers balk at connecting to the system, and a resulting poor public perception of geothermal energy.

PLANNING AND ZONING IN WASATCH FRONT URBAN AREAS

In urban areas, planning guidelines and zoning regulations have an additional impact on development of lands within a given municipal or county jurisdiction. Zoning regulation is an overlay, which seeks to implement planning goals, and applies irrespective of whether land is in private or public ownership. Planning and zoning entities provide regulation and guidance on what developments can take place within their jurisdictional boundaries. Zoning requirements designate areas of industrial or commercial development, seek to preserve neighborhoods and designate open space or other community amenities. While basically restrictive in nature, the purpose of such planning is to create a framework, which balances neighborhood, and commercial or industrial needs. Planning commission decisions often involve compromises, which promote the best interests of the city or county as a whole without infringing on the quality of life of neighborhoods.

Three of the nine sites examined in this study occur along the heavily urbanized Wasatch Front—Hooper hot springs in Davis County, and Utah and Ogden hot springs in Weber County. Zoning regulations in the vicinity of Ogden hot springs are particularly complex. The springs are within Ogden Canyon. Facilities sited to develop this resource could fall within either Ogden City or Weber County jurisdiction. Both county and city certainly have vested interests, which are different but not necessarily opposed to each other. Both entities are committed to open space, building restrictions on steep slopes, and preservation or upgrading of the watershed in Ogden Canyon. Both entities also have an interest in clean sources of electrical power as they face growth over the next few decades.

Ogden City Zoning

Ogden City's Planning Division identifies its environmental resources as follows: "Ogden enjoys the benefits of many natural resources and natural features. The urbanized area contains parks, trails, native vegetation, and some wildlife while the surrounding mountains and river basins offer stunning views, fresh water, refuge for large game animals, and opportunities for hiking, skiing and solitude. At the same time, this natural environment challenges the community to address natural hazards, encroachment on wildlife habitat, air and water pollution and other ways of living and doing business that affect these natural resources and features." The document provides guidelines for siting (and availability of) electrical utilities.

Ogden hot springs are at the heart of these highly valued environmental resources. Ogden City has designated the area adjacent of Ogden hot springs as dedicated to very large single-family lots (minimum of 743 m^2 [8,000 ft^2]), open space and sensitive areas because of steep mountain slopes and watershed issues for Ogden Canyon.

The Ogden Planning Division oversees land use regulations within Ogden City. The Planning Division serves as the advisory staff to the Planning Commission, the Mayor's Administrative Review Meeting, the Ogden Trails Network Committee, the Board of Zoning Adjustment, and the Ogden City Landmarks Commission. Among the functions of the Planning Division which could affect utility siting are:

1. Review development plans to insure they meet the regulations of the City and that the design and layout of the development will be a good neighbor and not detract from the safety and welfare of Ogden residents. Some of those general reviews include site plan review, historic preservation reviews, and approved sign permits.

2. Provide general information to questions about zoning regulations, procedures for getting a development plan approved, possible development options to guide projects through the development process, and how to obtain a permit or a letter of conformance when refinancing.

3. Meet the changing needs of Ogden City, develop zoning ordinance revisions, and review requests for zoning map revisions.

Zoning is a classification system, which divides property into various land uses. An alphanumeric numbering scheme is used to distinguish between intensity of uses within each land use category. The broad categories include residential, commercial, manufacturing, professional, mixed uses, and uses within the Ogden Industrial Park and Ogden Business Depot.

In addition to the zoning categories, which are scattered throughout the community, there are specific zone classifications for particular areas including the Central Business District, Downtown Buffer Overlay, the area surrounding the Central Business District, the area surrounding Rainbow Gardens, and a Sensitive Area Overlay Zone for mountain areas where there may be severe slope, rockfall, or other geological hazards.

Uses are identified in the Zoning Ordinance as "Permitted", "Conditional", or "Not Permitted". Division staff may approve permitted uses, while Conditional Uses require Planning Commission approval. Options for pursuing a use classified as "not permitted" would be to either petition the City for an ordinance amendment, or petition to rezone the property to a zone designation, which would allow the use.

Weber County Zoning

Weber County’s uniform zoning ordinance was adopted to regulate the location, height and bulk of buildings and other structures; the percentage of lot which may be occupied; the size of lots, courts and other open spaces; the density and distribution of population; the location and use of buildings and structures for trade, industry, residence, recreation, public activities, or other purposes; and the uses of land for trade, industry, recreation, or other purposes. The ordinance divides the county into 34 zone classes generally categorized as residential, gravel, agricultural, forestry, shoreline, commercial resorts, commercial, manufacturing, open space, and floodplain.

Sections of the ordinance specifically address electrical generating facilities. The following excerpts from Weber County code apply to public buildings and public utility substations and structures. Numbers refer to specific paragraphs.

26-1. Location: The location and arrangement of Public Buildings and Public Utility Substations and structures will comply with requirements set forth in this Chapter and will be in accordance with construction plans submitted to and approved by the Planning Commission.

26-2. Minimum Lot Area - Public Utility Substations.

26-3. Minimum Yards: Each Public Utility Substation shall maintain the minimum yards required for a dwelling in the same zone except that the rear yard may be reduced to the following: 1.5 m (5 ft) in a residential zone; 3 m (10 ft) in an agricultural zone; 6 m (20 ft) in a forest zone.

26-4. Street Access: Each Public Utility Substation shall be located on a lot with adequate access from a street, alley, right-of-way, or easement.

ENVIRONMENTAL CONFLICTS

NEPA and Special Land Management Designations

The National Environmental Policy Act of 1969 (NEPA) is the basic national charter for protection of the environment. It establishes policy, sets goals, and provides means for carrying out the policy. NEPA is a law of disclosure ensuring that environmental information is available to public officials and citizens before decisions are made and actions are taken with respect to projects on federal lands or using federal money. Prior to any project involving federal resources NEPA requires reviews of specific proposed actions, involvement of the public in the decision process, and consideration of reasonable alternatives. The emphasis is to inform affected parties, be consistent with existing management planning, and minimize impacts to the environment.

Special management prescriptions for federal and state lands may have implications for industrial development including geothermal resources. These prescriptions include designations for wilderness character or wilderness study areas (WSAs) and areas of critical environmental concerns (ACECs) associated with BLM lands. No USFS wilderness lands conflict with these geothermal areas. None of the geothermal areas studied here appear to conflict with BLM WSAs. The Drum Mountains prospect, however, lies directly west of the Swasey Mountain WSA. Current BLM management plans were not reviewed for this effort to determine if ACECs could complicated geothermal development. Newcastle, Thermo, Roosevelt, Cove Fort-Sulphurdale, and the Drum Mountains geothermal study areas all contain some BLM-administered land.

The Endangered Species Act and Sensitive Species

The Endangered Species Act (ESA) of 1973 governs conservation of the ecosystems upon which threatened and endangered (T&E) species depend. All federal agencies are mandated to protect the habitats of T&E species. Moreover, federal agencies must apply their authority to ensure their actions do not jeopardize the continued existence of listed species. The Fish and Wildlife Service within the Department of Interior works with other federal agencies to plan or modify projects so that they will have minimal impact on listed species. The ESA also encourages partnerships with states to develop and maintain conservation programs for resident T&E species.

Among the environmental conflicts that could complicate the development of geothermal power resources in Utah are potential impacts to sensitive plant and animal species found at or near the resource. A review of Federal and State listings identified 25 sensitive animal species and one sensitive plant species within the 7½-minute quadrangles containing the nine geothermal resource sites considered in this study (table 9). Among these were two species that are listed as Threatened, one species that is listed as Endangered, and one species that is a candidate for Federal listing (DWLR, written communication, September 2003). There are also two conservation species that are governed by special, multi-agency conservation agreements. These sensitive species designations can significantly complicate the development of industrial facilities and infrastructure such as power plants and transmission lines through additional planning efforts and mitigation measures, thereby increasing up-front development costs.

ACKNOWLEDGEMENTS

The U.S. Department of Energy, State Energy Program and Geothermal Technologies Program supported this work under a cost-share agreement (grant number: DE-FG48-01R805411) with the Utah Department of Natural Resources. Such support does not constitute an endorsement by the U.S. Department of Energy of the views expressed in this document. The University of Utah, Department of Geology and Geophysics and the Energy and Geoscience Institute provided previously unpublished borehole data used for this study.

REFERENCES

Battocletti, E.C., 2003, Geothermal small business workbook: Washington D.C., Bob Lawrence and Associates, 441 p., prepared for the U.S. Department of Energy under Contract No DE-FG03-01SF22365.

Black, B.D., Hecker, Suzanne, Hylland, M.D., Christensen, G.E., and McDonald, G.N., 2003, Quaternary fault and fold database and map of Utah: Utah Geological Survey Map 193 DM, CD-ROM.

Blackett, R.E., and Ross, H.P., 1992, Recent exploration and development of geothermal energy resources in the Escalante Desert region, southwestern Utah: Utah Geological Association Publication 21, p. 261-279.

Blackett, R.E., and Shubat, M.A., 1992, A case study of the Newcastle geothermal system, Iron County, Utah: Utah Geological Survey Special Study 81, 30 p.

Blackett, R.E., Shubat, M.A., Chapman, D.S., Forster, C.B., Schlinger, C.M., and Bishop, C.E., 1990, The Newcastle geothermal system, Iron County, Utah: Utah Geological Survey Open-File Report 189, 179 p.

Blackett, R.E., and Wakefield, Sharon, 2002, Geothermal resources of Utah: Utah Geological Survey Open-File Report 397, Compact Disk, ISBN 1-55791-677-2.

Blackwell, D.D., Richards, M.A., Wisian, K.W., and Steele, J.L., 1999, System specific geothermal gradient/heat flow database for the western United States: Geothermal Resources Council Transactions, v. 23, p. 461-466.

Bloomquist, R.G., 1992, Geothermal – a regulatory guide to leasing, permitting, and licensing in Idaho, Montana, Oregon, and Washington: Olympia, Washington State Energy Office, 277 p.

Bloomquist, R.G., and Lund, J.W., 1998, Regulatory and Commercial aspects, *in*, Lienau, P.J., and Lunis, B.C., editors, Geothermal direct-use engineering and design guidebook: Oregon Institute of Technology, Geo-Heat Center, p. 421-442.

Bureau of Land Management, 1998, Geothermal leasing and operations; final rule: Federal Register, v. 63, no. 189, p. 52,355-52,391.

California Energy Commission, 2003, Comparative cost of California central station electricity generation technologies: Staff Draft Report No. 100-03-001SD -February 11.

Cluff, L.S., Brogan, G.E., and Glass, C.E., 1970, Wasatch fault (northern portion) – earthquake fault investigation and evaluation: Oakland, California, Woodward Clyde Consultants, various pagination.

Cole, D.R., 1982, Tracing fluid sources in the East Shore area, Utah: Ground Water, v. 20, no. 5, p. 586-593.

---1983, Chemical and isotopic investigation of warm springs associated with normal faults in Utah: Journal of Volcanology and Geothermal Research, v. 16, p. 65-98.

Davis, F.D., 1985, Geology of the northern Wasatch front: Utah Geological and Mineral Survey Map A-53, scale 1:100,000.

DiPippo, Ronald, 1999, Small geothermal power plants: design, performance, and economics: Oregon Institute of Technology – Geo-Heat Center Bulletin, v. 20, no. 2., p. 1-8.

Entingh, D.J., Easwaran, Eyob, and McLarty, Lynn, 1994, Small geothermal electric systems for remote powering: Geothermal Resources Council Transactions, v. 18, p. 39-46.

Farhar, B.C., and Heimiller, D.M, 2003, Opportunities for near-term geothermal development on public lands in the western United States: U.S. Department of Energy/Energy Efficiency and Renewable Energy, and U.S. Department of Interior/Bureau of Land Management report DOE/GO-102003-1707, CD-ROM.

Felmlee, J.K., and Cadigan, R.A., 1978, Determination of uranium in source rocks by using radium in Crystal Springs, Great Salt Lake area, Utah: U.S. Geological Survey Open-File Report 78-102, 35 p.; also, 1977, U.S. Geological Survey Circular 753, p. 48-50.

Fournier, R.O., 1981, Application of water geochemistry to geothermal systems, *in* Rybach, Ladislaus, and Muffler, L.J.P., editors, Geothermal systems – principals and case histories: New York, New York, John Wiley and Sons, p. 109-143.

Gawlik, Keith, and Kutcher, Charles, 2000, Investigation of the opportunity for small-scale geothermal power plants in the western United States: Geothermal Resources Council Transactions, v. 24, p. 109-112.

Giggenbach, W.F., 1988, Geothermal solute equilibria – derivation of Na-K-Mg-Ca geoindicators: Geochimica et Cosmochimica Acta, v.52, p. 2749-2765.

Gilbert, G.K., 1928, Studies of Basin and Range structure: U.S. Geological Survey Professional Paper 153, 92 p.

Goode, H.D., 1978, Thermal waters of Utah: Utah Geological and Mineral Survey Report of Investigation 129, 183 p.

Henrikson, Andrew, and Chapman, D.S., 2002, Terrestrial heat flow in Utah, *in* Blackett, R.E., and Wakefield, Sharon, compilers, Geothermal resources of Utah: Utah Geological Survey Open-File Report 397, Compact Disk, ISBN 1-55791-677-2.

Klauk, R.H., and Gourley, Chad, 1983, Geothermal assessment of a portion of the Escalante Valley, Utah: Utah Geological and Mineral Survey Special Study 63, 57 p.

Mabey, D.R., and Budding, K.E., 1987, High temperature geothermal resources of Utah: Utah Geological and Mineral Survey Bulletin 123, 64 p.

Milligan, J.H., Marsell, R.E., and Bagley, J.M., 1966, Mineralized springs in Utah and their effect on manageable water supplies: Logan, Utah Water Research Laboratory, Utah State University Report WG23-6, 50 p.

Moore, J.N., and Nielson, D.L., 1994, An overview of the geology and geochemistry of the Roosevelt hot springs geothermal system, Utah, *in* Blackett, R.E., and Moore, J.N., editors, Cenozoic geology and geothermal systems of southwestern Utah: Utah Geological Association Publication 23, p. 25-36.

Moore, J.N., Samberg, S.M., and Sibbett, B.S., 1979, Geology of the Cove Fort-Sulphurdale KGRA: Salt Lake City, Earth Science Laboratory/University of Utah Research Institute Report DOE/ET/28392-27, 44 p.

Mundorff, J.C., 1970, Major thermal springs of Utah: Utah Geological and Mineral Survey Water Resources Bulletin 13, 60 p.

Murphy, P.J., and Gwynn, J.W., 1979, Geothermal investigations at selected thermal systems of the northern Wasatch Front, Weber and Box Elder Counties, Utah: Utah Geological and Mineral Survey Report of Investigation 141, 50 p.

Nelson, A.R., and Personius, S.F., 1993, Surficial geologic map of the Weber segment, Wasatch Fault zone, Weber and Davis counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2199, scale 1:50,000.

Oviatt, C.G., 1986, Geologic map of the Honeyville quadrangle, Box Elder and Cache Counties, Utah: Utah Geological and Mineral Survey Open-File Report 75, 28 p. pamphlet, scale 1:24,000.

Pacificorp, 2003, Integrated resource plan – assuring a bright future for our customers: Portland, Pacificorp (Pacific Power, Utah Power), 162 p.

Personius, S.F., 1990, Surficial geologic map of the Brigham City segment and adjacent parts of the Weber and Collinston Segments, Box Elder and Weber Counties, Utah: U.S. Geological Survey, Miscellaneous Investigation Series Map I-1979, scale 1:50,000.

Republic Geothermal Inc., 1977, Temperature-gradient holes – Escalante Valley, Utah: Salt Lake City, University of Utah, Energy and Geoscience Institute unpublished data, not paginated.

Ross, H.P., Blackett, R.E., and Shubat, M.A., 1991, Wood Ranch thermal anomaly: Utah Geological Survey Miscellaneous Publication 91-4, 21 p.

Ross, H.P., Blackett, R.E., Shubat, M.A., and Gloyn, R.W., 1993, Self-potential and fluid chemistry studies of the Meadow-Hatton and Abraham hot springs, Utah: Geothermal Resources Council Transactions, v. 17, p. 167-174.

Ross, H.P., Blackett, R.E., Shubat, M.A., and Mackelprang, C.E., 1990, Delineation of fluid up-flow and outflow plume with electrical resistivity and self-potential data, Newcastle geothermal area, Utah: Geothermal Resources Council Transactions, v. 14, p. 1531-1536.

Ross, H.P., and Moore, J.N., 1985, Geophysical investigations of the Cove Fort-Sulphurdale geothermal system, Utah: Geophysics, v. 50, no. 11, p. 1732-1745.

Ross, H.P., Nielson, D.L., and Moore, J.N., 1982, Roosevelt hot springs geothermal system, Utah - case study: American Association of Petroleum Geologists Bulletin, v. 66, no. 7, p. 879-902.

Rowley, P.D., 1978, Geologic map of the Thermo 15-minute quadrangle, Beaver and Iron Counties, Utah, U.S. Geological Survey Map GQ-1493, scale 1:62,500.

Rowley, P.D., 1998, Cenozoic transverse zones and igneous belts in the Great Basin, western United States – their tectonic and economic implications: Geological Society of America Special Paper 323, p. 195-228.

Rush, E.F., 1983, Reconnaissance of the hydrothermal resources of Utah: U.S. Geological Survey Professional Paper 1044-H, 44 p.

Sass, J.H., Priest, S.S., Blanton, A.J., Sackett, P.C., Welch, S.L., and Walters, M.A., 1999, Geothermal industry temperature profiles from the Great Basin: U.S. Geological Survey Open-File Report 99-425, on-line version 1.0. [http://wrgis.wr.usgs.gov/open-file/of99-425/webmaps/home.html, July 2003].

U.S. Department of Commerce, 2003, Regional economic information system (REIS), DOC Economics and Statistics Administration, Bureau of Economic Analysis.

U.S. Department of Energy, 2003, DOE Energy Information Administration form 906 Database.

Utah Geological and Mineral Survey, compilers, 1980, Geothermal resources of Utah, 1980: Map prepared by the National Oceanic and Atmospheric Administration for the U.S. Department of Energy, scale 1:500,000.

Ward, S.H., Parry, W.T., Nash, W.P., Cook, K.L., Smith, R.B., Chapman, D.S., Brown, F.H., Whelan, J.A., and Bowman, J.R., 1978, A summary of the geology, geochemistry and geophysics of the Roosevelt hot springs thermal area, Utah: Geophysics, v. 43, p. 1515-1542.

Wilson, W.R., and Chapman, D.S., 1980, Three topical reports: I. Thermal studies at Roosevelt hot springs, Utah; II. Heat flow above an arbitrarily dipping plane of heat sources; III. A datum correction for heat flow measurements made on an arbitrary surface: Salt Lake City, Earth Science Laboratory/University of Utah Research Institute Report, no. DOE/ID/12079-19, 144 p.

Wright, P.M., and Culver, Gene, 1991, Nature of geothermal resources, *in* Lienau, P.J., and Lunis, B.C., editors, Geothermal direct-use engineering and design guidebook: Klamath Falls, Oregon, Geo-Heat Center, Oregon Institute of Technology, prepared under U.S. Department of Energy Contract no. DE-FG07-90ID 13040, ISBN 1-880228-00-9, p. 23-54.

Return

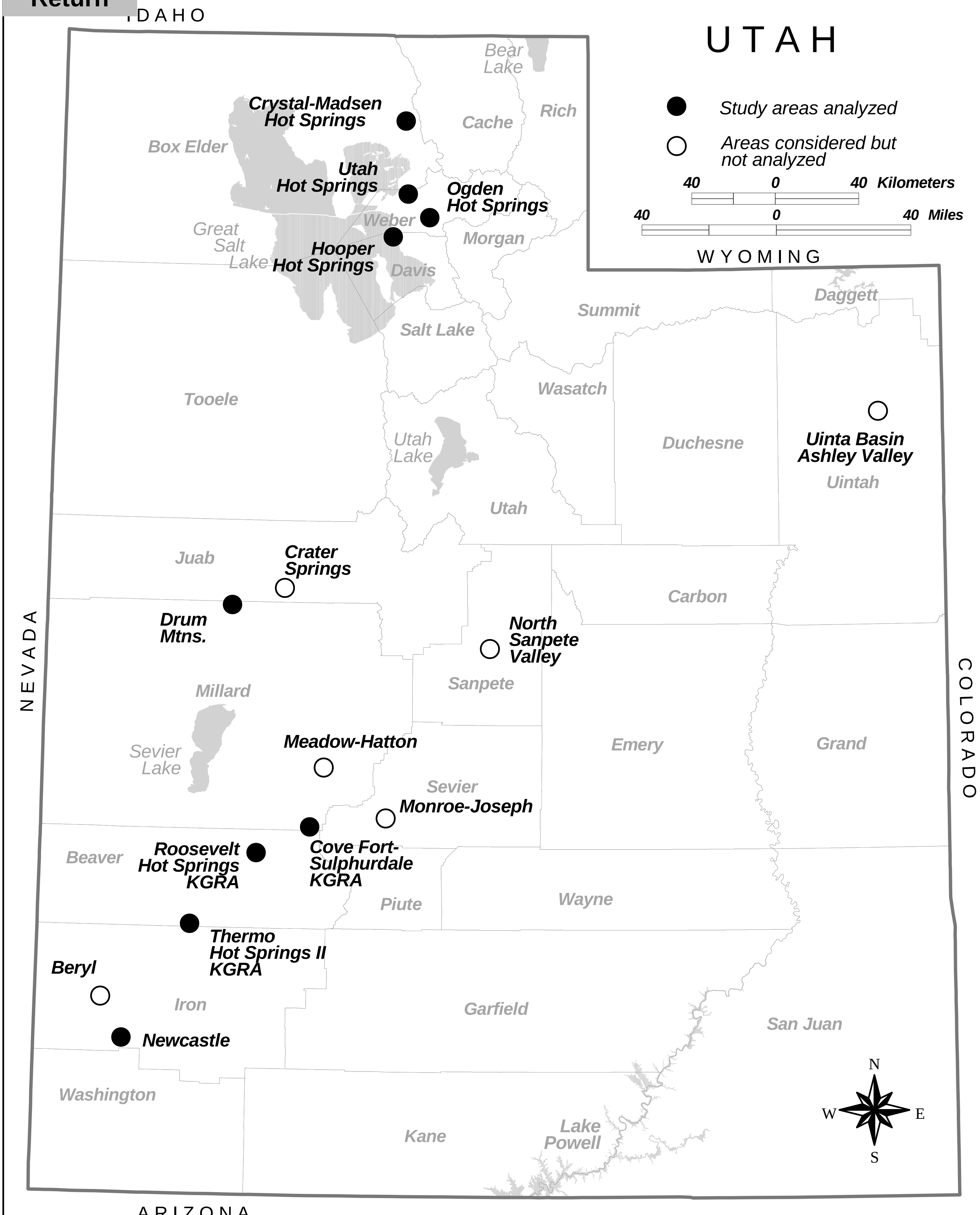

Figure 1. Location of geothermal study areas

Return

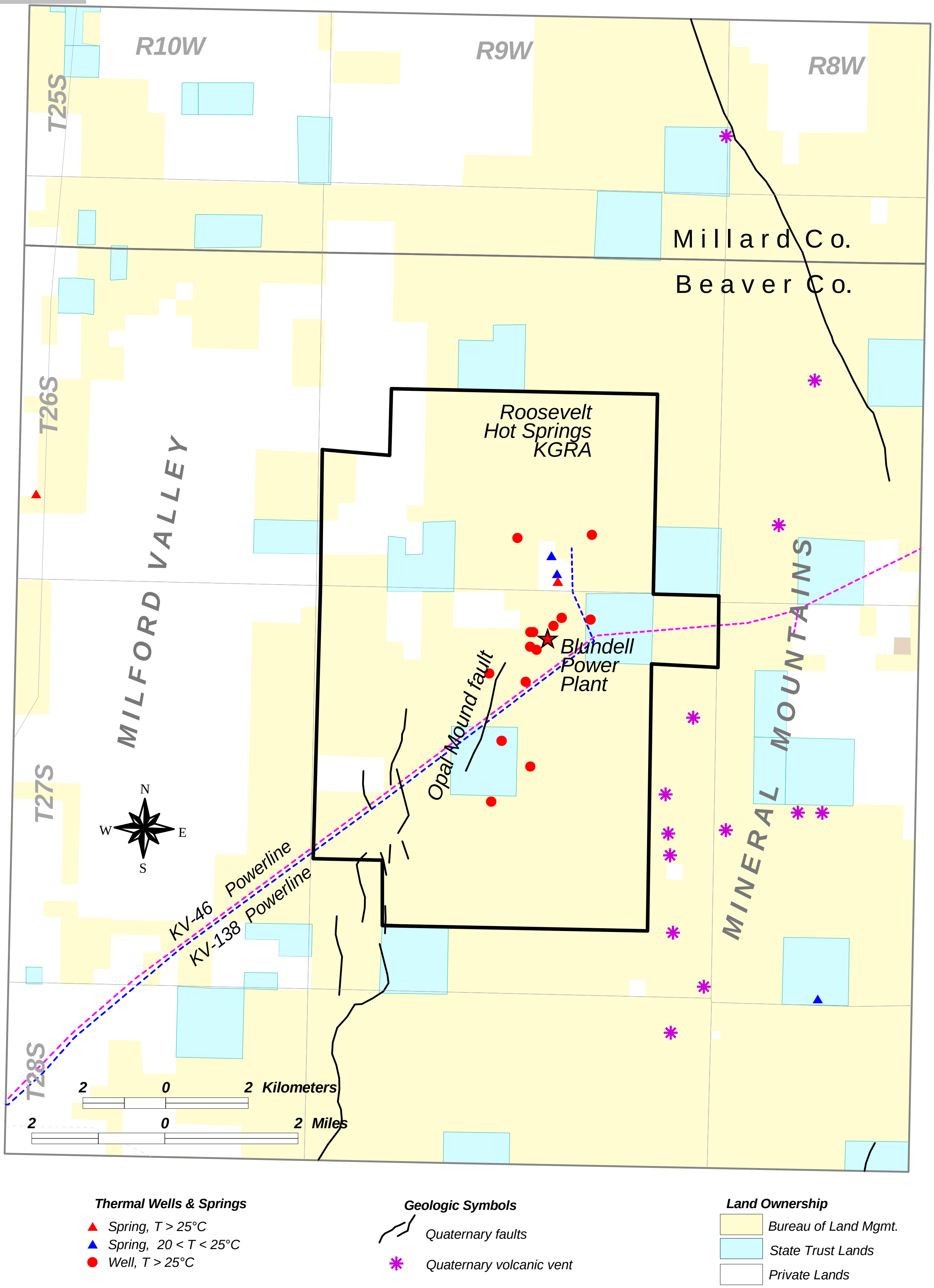

Figure 2. Roosevelt Hot Springs geothermal area showing land ownership patterns, roads, powerlines, general geologic features, and thermal wells and springs. The outline of the Roosevelt KGRA and location of the Blundell power plant are noted.

Return

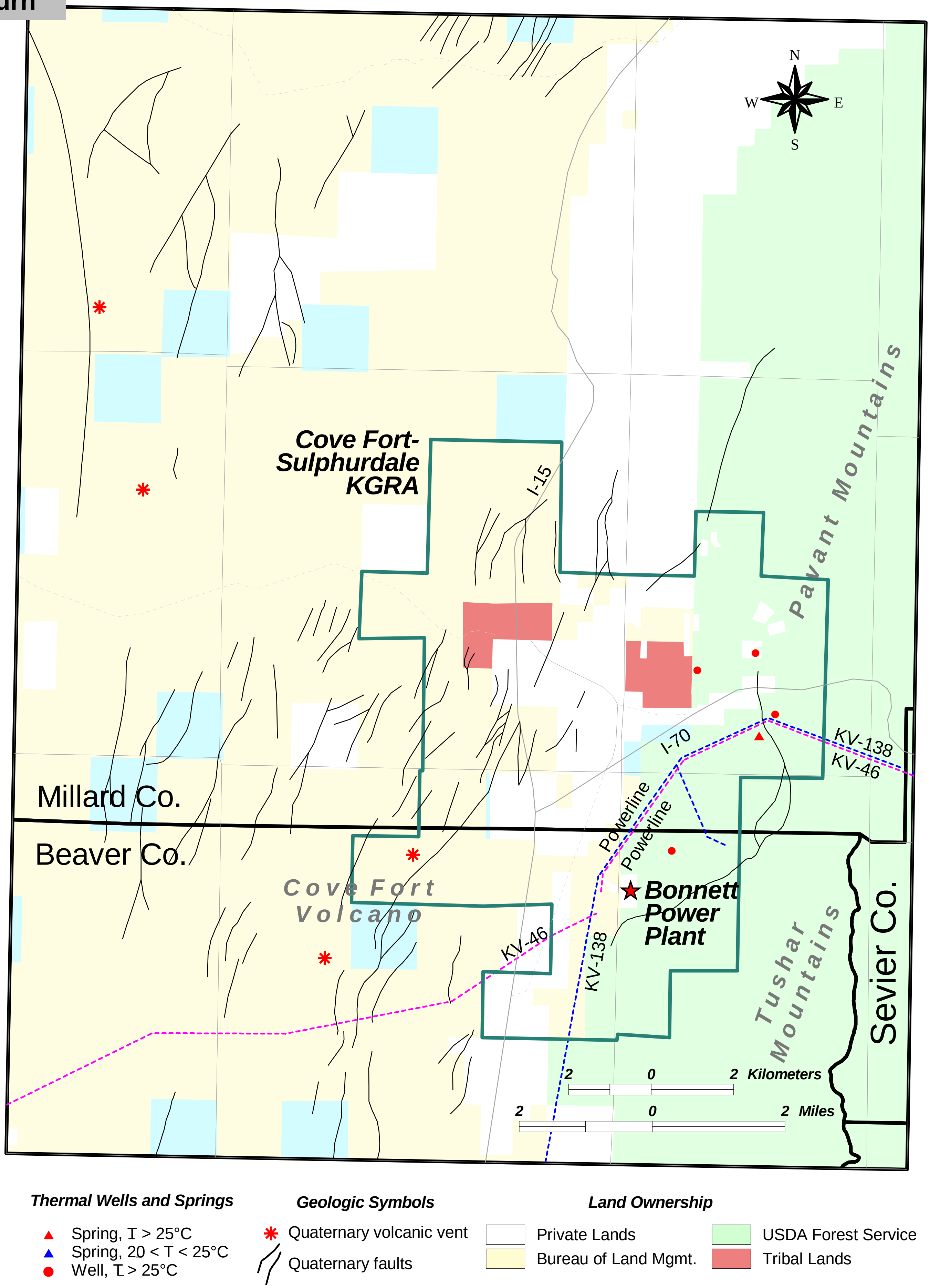

Figure 3. Cove Fort-Sulfurdale Known Geothermal Resource Area (KGRA) and vicinity showing Quaternary features, land ownership, thermal wells, power lines, and roads.

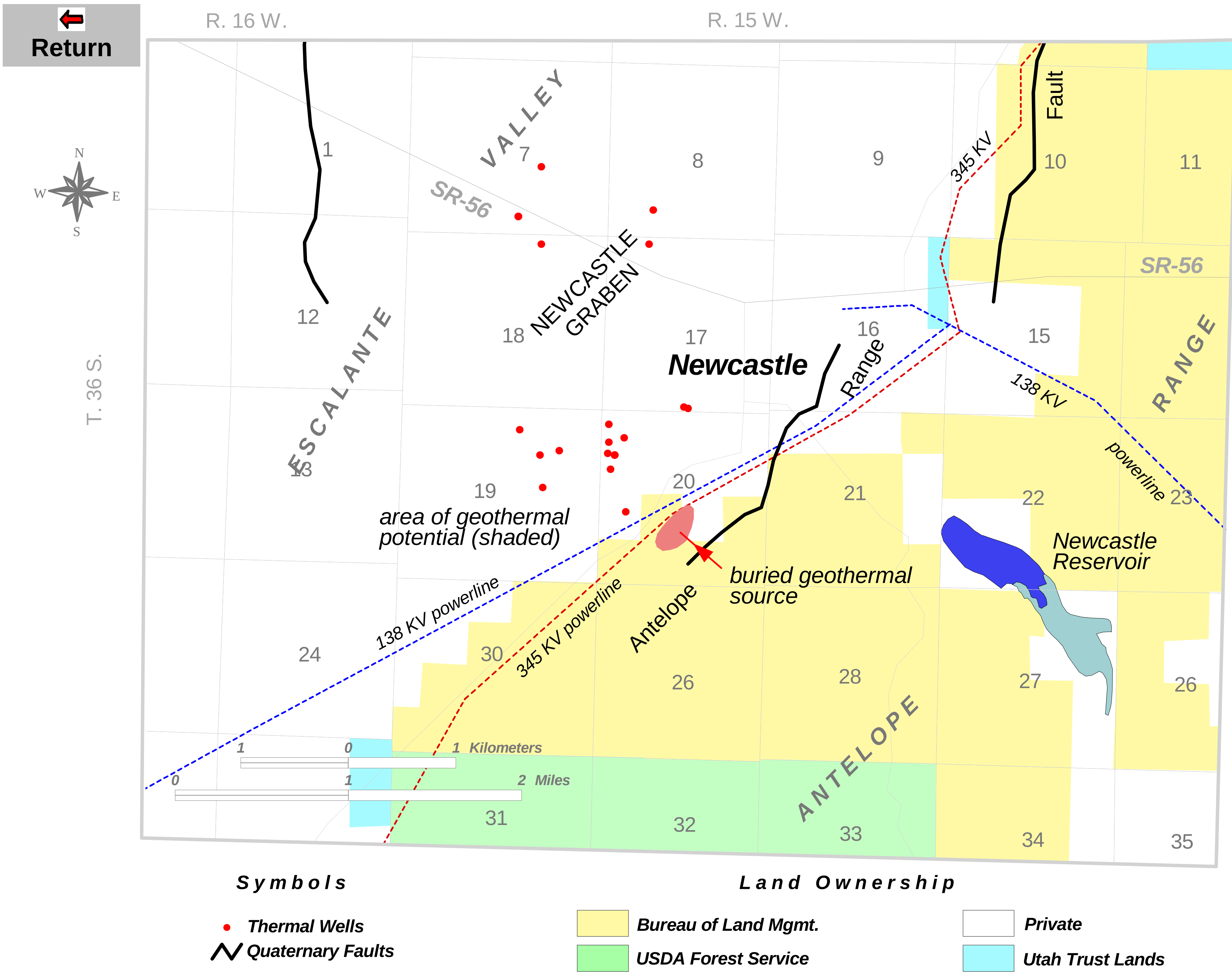

Figure 4. The Newcastle geothermal area showing thermal wells, Quaternary faults, and land ownership.

Return

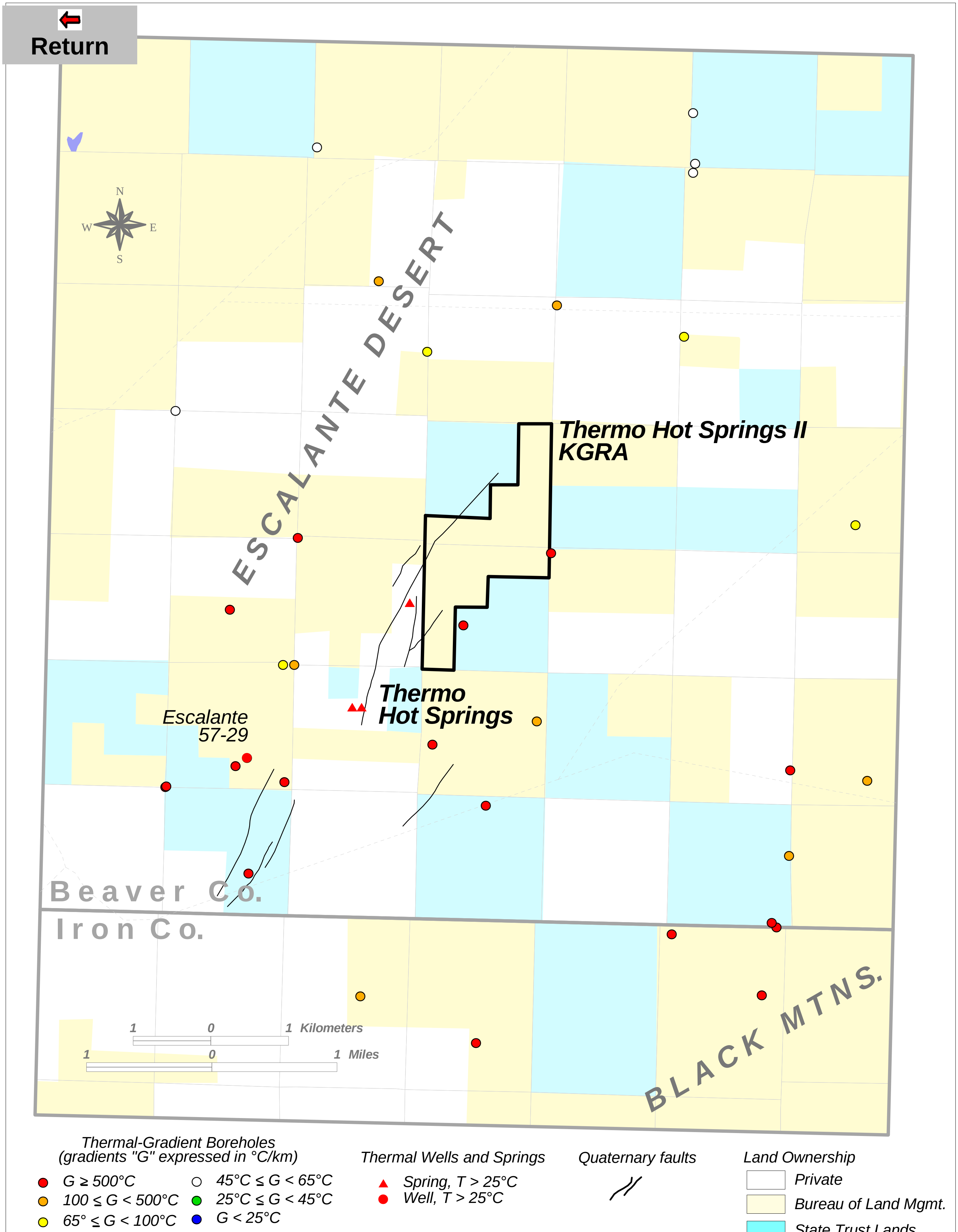

Figure 5. Thermo Hot Springs and surrounding area showing thermal-gradient boreholes, thermal wells and springs, and Quaternary faults.

Return

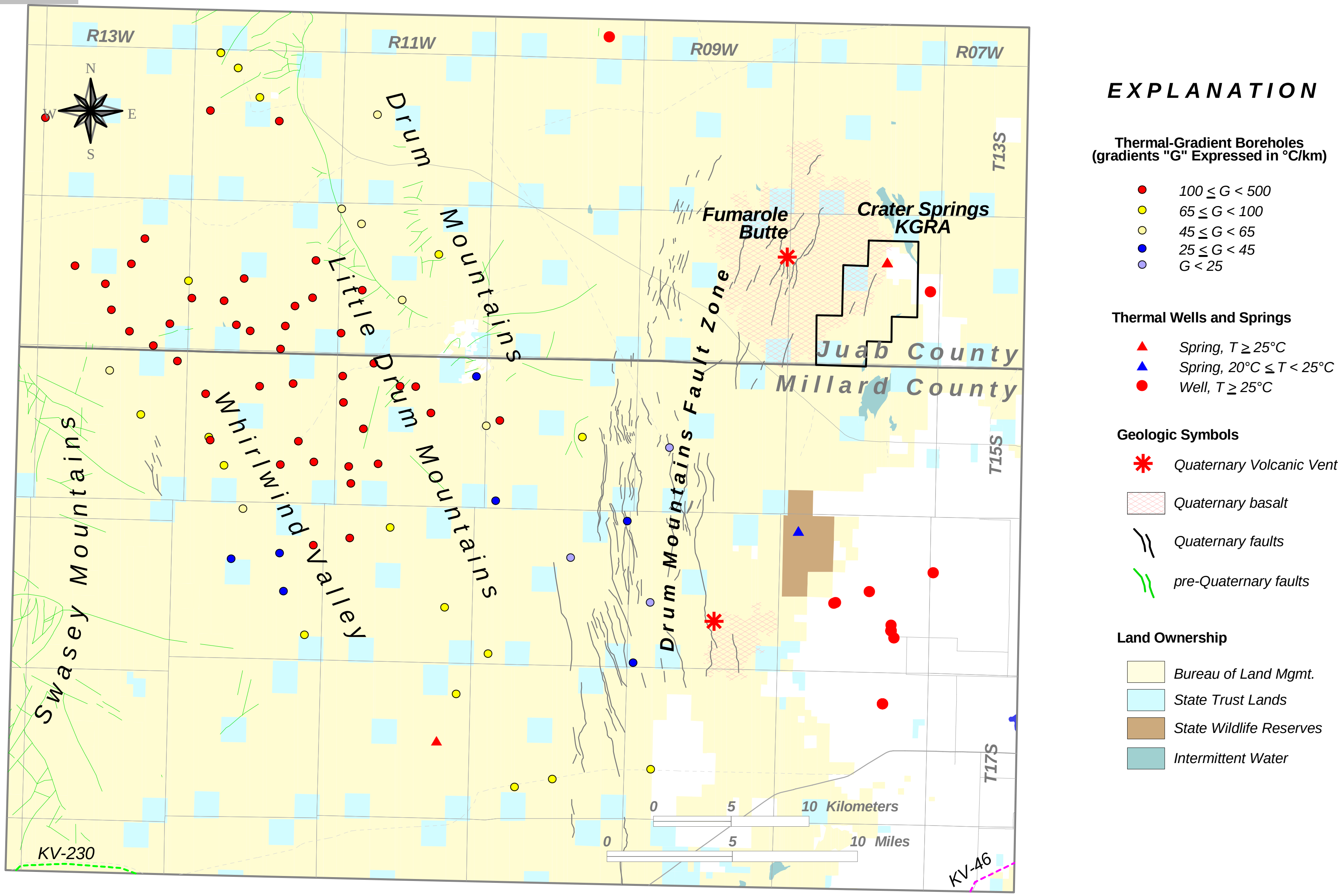

Figure 6. General geology of the Drum Mountains geothermal prospect showing locations of thermal-gradient boreholes, and thermal wells and springs. The Crater Springs and Fumarole Butte geothermal area are shown for reference. The outline along the west side of Crater Bench shows the area included in the Crater Springs Known Geothermal Resource Area (KGRA).

Return

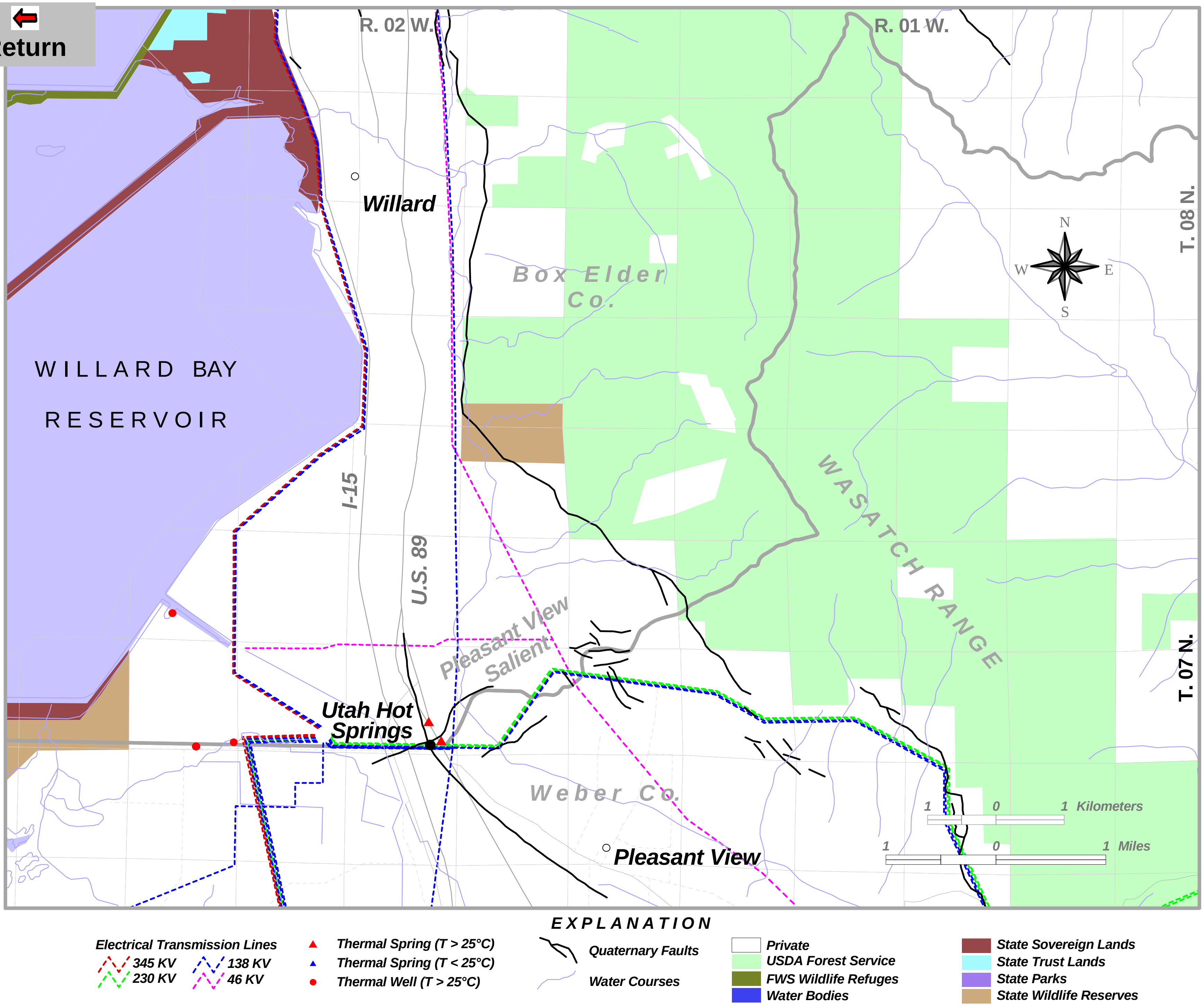

Figure 7. Utah Hot Springs and vicinity showing land ownership, thermal wells and springs, and Quaternary faults.

Return

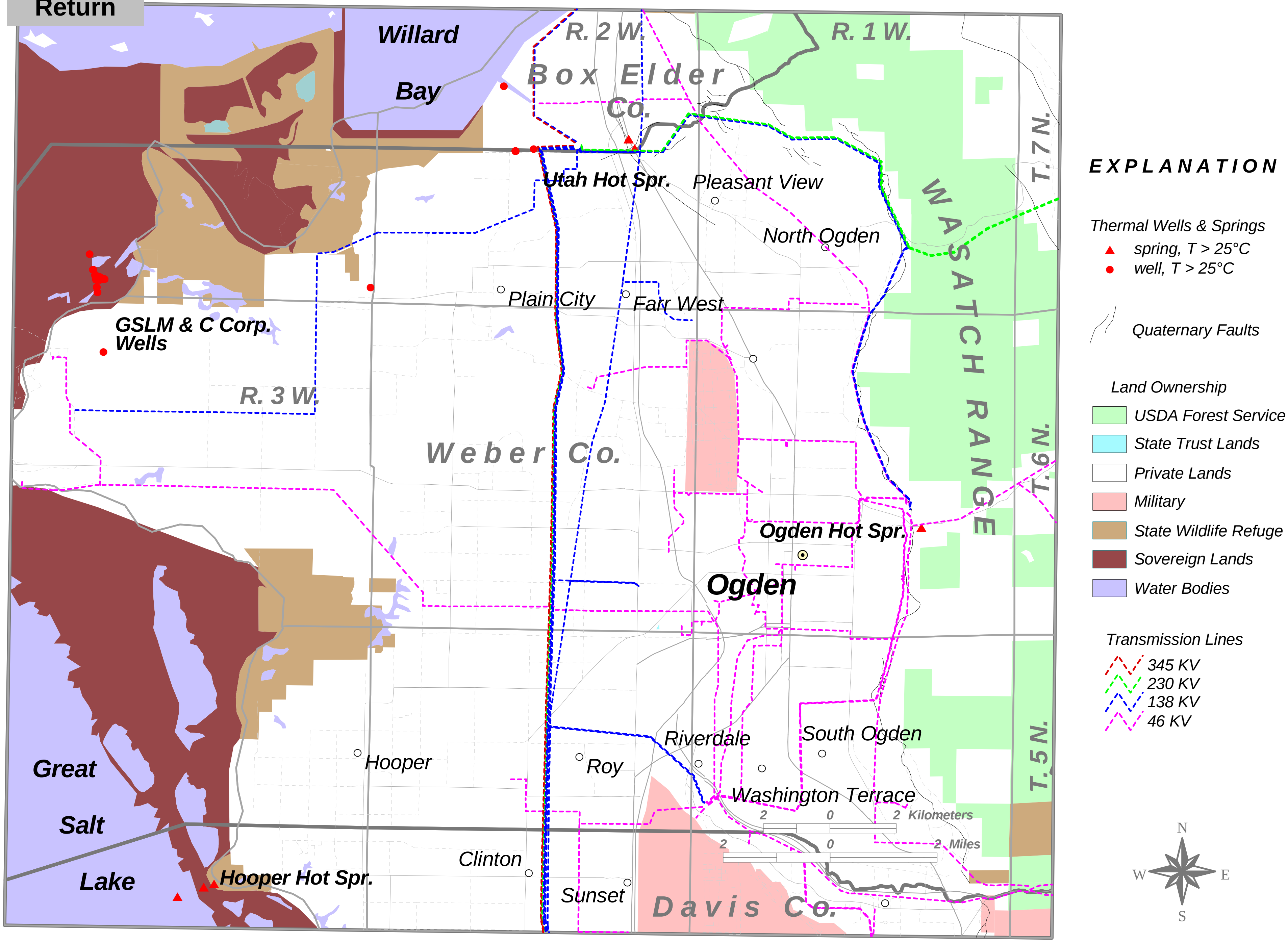

Figure 8. Ogden, Utah, and Hooper hot springs and surrounding areas showing thermal wells & springs, Quaternary faults, powerlines, roads, water courses, and land ownership.

Return

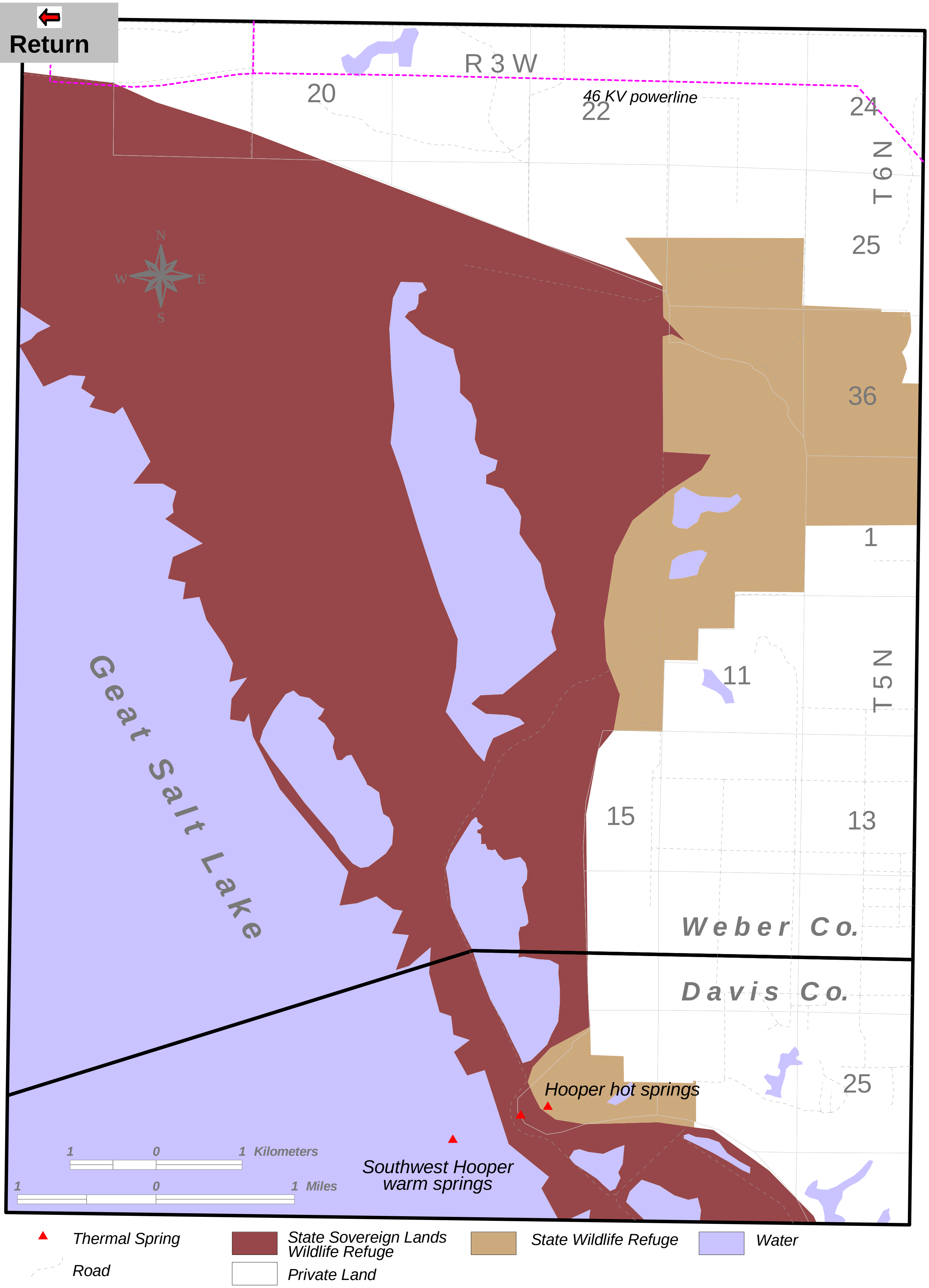

Figure 9. Hooper Hot Springs area showing land ownership, thermal springs, powerlines, and roads.

Return

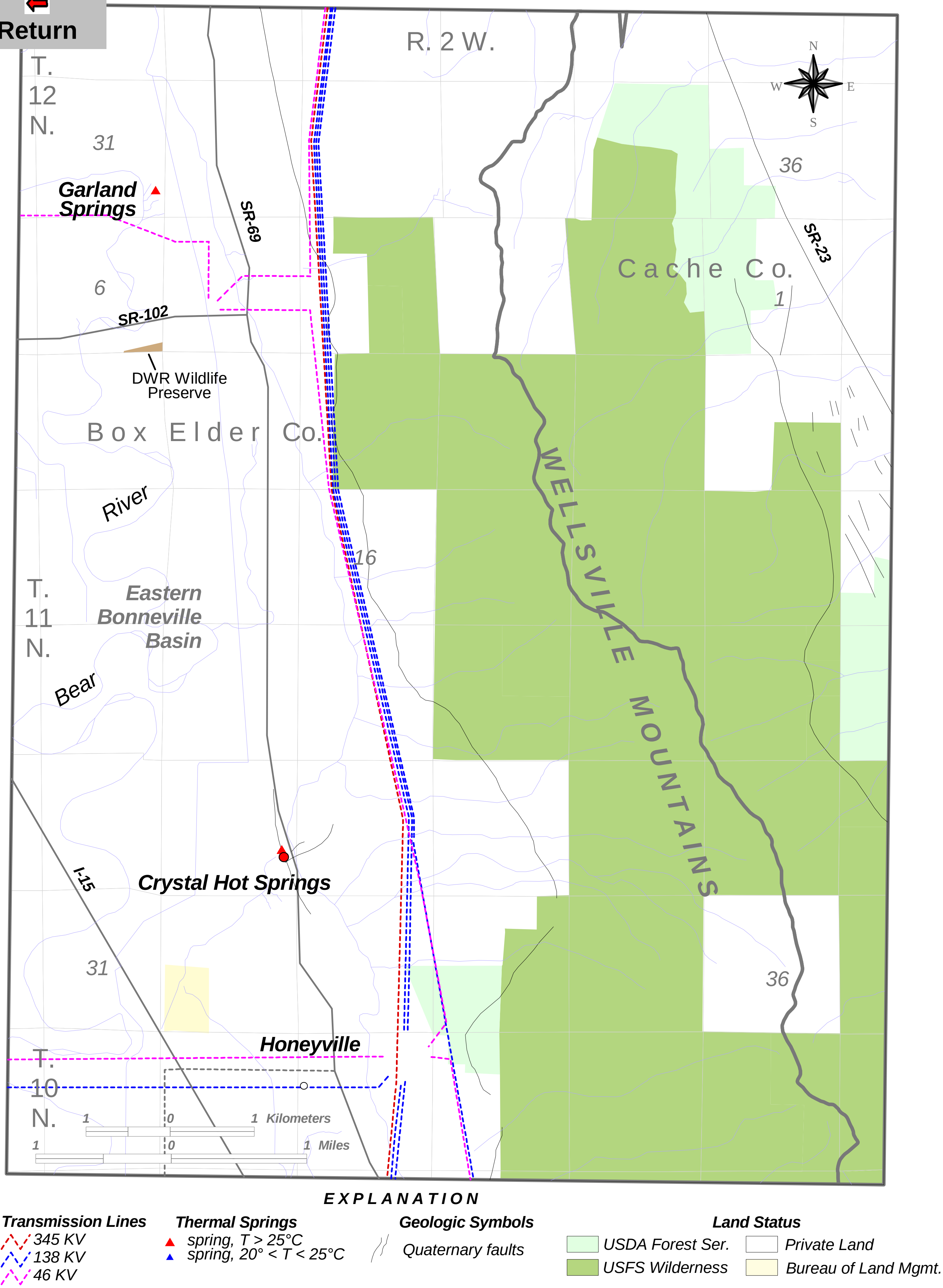

Figure 10. Crystal-Madsen hot springs and vicinity, showing land ownership, transmission lines, thermal springs, and Quaternary faults.

Return

Table 1. General parameters for selected geothermal areas in Utah.

Geothermal Area	Location	Lat_North	Long_West	County	Meas T[1]	Res T[2]	Res Depth[3]	TDS[4]
	Twn, Rng, Sec	(Degrees)	(Degrees)		(°C)	(°C)	(m)	(mg/L)
Geothermal Areas Analyzed								
Newcastle	T.36S., R.15W., sec. 20	37.6591	113.5651	Iron	118	130	150-270	1000-1100
Thermo	T.30S., R12W., sec 28	38.1731	113.2036	Beaver	174	160-217	2200	1300-3300
Roosevelt	T.26S., R.09W., sec. 34	38.5019	112.8503	Beaver	270	270	1000-2000	7000-7800
Cove Fort	T.26S., R06W., sec. 07	38.5685	112.5668	Beaver-Millard	150	150	180-900	9400
Ogden HS	T.06N, R.01W., sec. 23	41.2356	111.9233	Weber	57	190	1800?	8800
Utah HS	T.07N., R.02W., sec.14	41.3375	112.0278	Box Elder-Weber	59	192	1800?	22000
Hooper HS	T.05N., R.03W., sec. 27	41.1370	112.1753	Davis	57	135	1500?	8600
Crystal-Madsen	T.11N., R.02W., sec. 29	41.6600	112.0864	Box Elder	54	153	1800?	43600
Drum Mtns	T.14-16S., R.11-13W.	39.4900	113.1533	Juab-Millard	NA	200?	800?	NA
Geothermal Areas Considered, Not Analyzed								
Beryl	T.34S., R.16W., sec. 18	37.8390	113.6870	Iron	149	~150	2134	~4000
Meadow-Hatton	T.22S., R.06W., sec. 35	38.8500	112.4900	Millard	29-66	~110	NA	4450
Monroe-Joseph	T.25S., R.03W., sec. 10	38.6330	112.1070	Sevier	70-76	94-110	NA	2650
N. Sanpete Valley	T.07S., R.03W., sec. 03	39.3628	111.5653	Sanpete	38	~200?	NA	8260
Crater Springs	T.14S., R.08W., sec. 10	39.6125	112.7281	Juab	75-85	87-116	NA	3600-4000
Uinta Basin	T.05S., R.22E., sec. 23	40.3650	109.4160	Uintah	40-56	NA	1300	2000

NA = Not Available

1. Meas T = Measured Temperature in degrees Celsius

2. Res T = Estimated Resource Temperature in degrees Celsius

3. Res Depth = Estimated Resource Depth in Meters

4. TDS = total dissolved solids

Return

Table 2. Levelized cost comparison of natural gas power versus selected renewable technologies (California Energy Commission, 2003).

Technology	***Fuel***	***Operative Mode***	***Economic Lifetime (years)***	***Gross Capacity (MW)***	***Direct Cost Levelized (cents/kWh)***
Combined Cycle	Natural Gas	Baseload	20	500	4.58
Simple Cycle	Natural Gas	Peaking	20	100	14.06
Wind	None	Variable	30	100	5.44
Hydropower	Water	Load-Following	30	100	7.20
Geothermal Flash	Water	Baseload	30	50	4.71
Geothermal Binary	Water	Baseload	30	35	7.64

Return

Table 3. Cost comparison of alternative technologies for additional power generating capacity at PacifiCorp's Blundell geothermal plant (PacifiCorp, 2003).

Technology	***Fuel***	***Real Levelized Cost*** *(CY 2002 cents/kWh)*	
		Low	High
Combined Cycle	Natural Gas	3.83	4.68
Simple Cycle	Natural Gas	8.93	14.07
Wind	None	3.38	5.74
Geothermal Flash w/ Bottoming Cycle	Water	3.49	
Pulverized Coal	Coal	2.75	3.68

Return

Table 4. Electric Power Generation from Blundell Geothermal Power Plant, Roosevelt Hot Springs KGRA, 1992-2003.

Year	Megawatt-Hours
1992	186,369
1993	148,148
1994	194,804
1995	139,742
1996	191,912
1997	168,518
1998	160,057
1999	155,530
2000	151,843
2001	152,742
2002	184,447
2003	198,465

Return

Table 5. Electric power generation from the Cove Fort Geothermal Power Plant, Cove Fort-Sulphurdale KGRA, 1992-2002.

Year	Megawatt-Hours
1992	47,024
1993	38,727
1994	37,827
1995	28,422
1996	31,399
1997	34,657
1998	34,500
1999	30,396
2000	34,618
2001	33,247
2002	29,681

Return

Table 6. Summary of land ownership in the study areas.

Site	***Ownership***
Cove Fort-Sulphurdale	USFS, Private, SITLA, BLM, Tribal
Crystal-Madsen Hot Springs	Private
Hooper Hot Springs	FFSL/DWLR, Private
Newcastle	Private, BLM
Ogden Hot Springs	Private, USFS
Roosevelt Hot Springs	Private, SITLA, BLM
Thermo Hot Springs	Private, BLM, SITLA
Utah Hot Springs	Private
Drum Mountains	BLM, SITLA

USFS = U.S. Forest Service
BLM = U.S. Bureau of Land Management
SITLA = Utah School & Institutional Trust Lands Administration
FFSL = Utah Division of Forestry, Fire, & State Lands
DWLR = Utah Division of Wildlife Resources

Return

Table 7. Surface-area ownership in Utah KGRAs.

KGRA Name	Total Acres	BLM	State	Private	USFS	Tribal
Crater Springs	8,320	6,120	1,280	920	-	-
Roosevelt Hot Springs	25,600	10,632	200	5,161	8,450	1,157
Cove Fort-Sulphurdale	24,960	20,680	1,800	2,480	-	-
Thermo Hot Springs II	640	640	-	-	-	-
Total Acres	59,520	38,072	3,280	8,561	8,450	1,157

Return

Table 8. Federal geothermal leases in Utah (written communication, James Fouts, U.S. BLM Utah State Office, September 2000)[1].

Serial Number	***Area***	***Proprietor***	***Twp/Rng (SL)***	***Acres***
Non-competitive				
71373	Thermo	Lewis Katz	30S/12W	1,760.79
78044	Newcastle	New Castle Irr. Co.	36S/15W	228.04
Subtotal (acres)				*1,988.83*
Competitive				
14990	Roosevelt	R.L. Wright	27S/09W	40.00
27386	Roosevelt	Intermountain Geo	26-27S/09W	963.45
27388	Roosevelt	Intermountain Geo	27S/09W	200.00
27389	Roosevelt	Intermountain Geo	27S/09W	680.00
27392	Roosevelt	Intermountain Geo	27S/09W	440.00
29557	Cove Fort	UMPA/City of Provo	26S/06-07W	2,594.37
Subtotal (acres)				*4,877.82*
Total				***6,866.65***

[1] The Utah State Office of the BLM held a geothermal lease sale on December 9, 2003 within all Utah KGRAs. They reportedly leased nearly 2,670 ha (6,600 ac.) within the Roosevelt Hot Springs and the Cove Fort-Sulphurdale KGRAs.

Return

Table 9. Geothermal areas showing identified threatened or endangered species or their potential habitat.

Geothermal Area	***T & E Species (Common Name)***	***Number of T & E Species***
Cove Fort-Sulphurdale	Greater Sage-Grouse, Burrowing Owl, Ferruginous Hawk	3
Newcastle	Burrowing Owl, Ferruginous Hawk, Long-billed Curlew	3
Thermo Hot Springs	Burrowing Owl, Ferruginous Hawk, Swainson's Hawk, Greater Sage-Grouse	4
Crystal-Madsen Hot Springs	Bluehead Sucker, Bonneville Cutthroat Trout, Long-billed Curlew, Wolverine	4
Roosevelt Hot Springs	Burrowing Owl, Ferruginous Hawk, Greater Sage-Grouse, Wolverine, Least Chub, Brazilian Free-tailed Bat	6
Utah Hot Springs	American White Pelican, Blue Grosbeak, Brazilian Free-tailed Bat, Lewis's Woodpecker, Pacific Treefrog, Bald Eagle, Burrowing Owl, Long-billed Curlew, Osprey, Short-eared Owl	10
Ogden Hot Springs	Bluehead Sucker, Common Yellowthroat, June Sucker, Pacific Treefrog, Ute Ladies' Tresses, Yellow-billed Cuckoo, American White Pelican, Blue Grosbeak, Brazilian Free-tailed Bat, Lewis's Woodpecker	10
Hooper Hot Springs	American White Pelican, Bald Eagle, Ferruginous Hawk, Long-billed Curlew, Mountain Plover, Peregrine Falcon, Short-eared Owl, Bobolink, Common Yellowthroat, Grasshopper Sparrow, Townsend's Big-eared Bat	11
Drum Mountains	Townsend’s Big-eared Bat	1

APPENDIX A: CHEMICAL GEOTHERMOMETRY

Geothermometers, or geoindicators, are computations applied to natural waters from springs or wells based on empirically derived formulas using dissolved chemical species. Geothermometers in geothermal exploration are used to estimate temperature and composition of the original reservoir fluid prior to cooling by conduction and mixing with shallow ground water at the sample collection point (well or spring). Geothermometers indicate a hotter geothermal fluid reservoir somewhere in the system, usually at greater depth.

Some constituents in natural fluids are unstable and change significantly with time following sample collection. Others are relatively stable, or can be fixed using proper sampling methods. Assumptions include:

- Temperature-dependent reactions involving rock and water fix the amounts of dissolved "indicator" constituents in water.
- There is an adequate supply of all reactants.
- There is equilibrium in the reservoir or aquifer with respect to the "indicator" reaction.
- No re-equilibration of the "indicator" constituents occurs after the water leaves the reservoir.
- Either no mixing of different waters occurs during movement to the surface or evaluation of the results of such mixing is possible.

Chemical reactions used in major element geothermometry include:

silica dissolution

Quartz	150 - 230ºC
Chalcedony	below 150ºC

feldspar dissolution/cation exchange

Na – K – Ca	150 - 280ºC
Na – K – Ca – Mg	70 - 250ºC
K – Mg	--

Equations for SiO_2 solubility include (concentrations expressed in mg/kg ~ mg/L):

Quartz (steam loss) $T^{o}C = [1522/(5.75 - \log SiO_2)] - 273.15$

Quartz (conductive) $T^{o}C = [1309/(5.19 - \log SiO_2)] - 273.15$

Chalcedony $T^{o}C = [1032/(4.69 - \log SiO_2)] - 273.15$

Equations for alkaline earth exchange include (concentrations expressed in mg/kg ~ mg/L):

Sodium-Potassium-Calcium

Na-K-Ca; $T^{o}C = [1647/(\log (Na/K) + ß(\log (vCa/Na) + 2.06) + 2.47] - 273.15$
(Where ß = 4/3 for T < 100, or ß = 1/3 for T > 100) (Fournier, 1981)

Na-K-Ca, Mg correction (in ºC to be subtracted from the Na-K-Ca calculated temp)

Where
R = [Mg/(Mg + Ca + K)] x 100 (with concentrations expressed in equivalents).
and
T = Na-K-Ca calculated temperature in kelvin.

for,

5 < R < 50 $? t_{Mg} = 10.66 - 4.7415R + 325.87(\log R)^2 - 1.032 \times 10^5 (\log R)^2 /T$
$- \quad 1.968 \times 10^7 (\log R)^2 /T^2 + 1.605 \times 10^7 (\log R)^3 /T^2$,

R < 5 $? t_{Mg} = - 1.03 + 59.971 x \log R + 145.05 (\log R)^2 /T - 1.67 x 10^7$
$- \quad 1.67 \times 10^7 \log R/T^2$,

Potassium-Magnesium

K–Mg; $T^{o}C = [4410/(13.95 - \log (K^2/Mg))] - 273.15$ (Giggenbach, 1988)

Return

APPENDIX B: Results of Geothermometers

MAPNO	SOURCE	AREA	TYPE	*Concentrations*					*Geothermometers*						Meas. T.
				SiO2	NA	K	CA	MG	Qtz-Max	Qtz-Cond.	Chalc	Na-K-Ca	Na-K-Ca-Mg	K-MG	
			units	mg/L	mg/L	mg/L	mg/L	mg/L	°C	°C	°C	°C	°C	°C	°C
BE-001	Utah State 42-7 Well	CFS	W	180.0	3460.0	225.0	26.4	12.0	162	173	151	211	136	**154**	**178**
BE-005	Roosevelt Hot Spr.	RHS	S	400.0	2100.0	470.0	19.0	3.3	210	233	221	292	283	**210**	**85**
BE-011	Thermal Power 14-2	RHS	W	383.0	2200.0	410.0	6.9	0.1	207	229	217	292	202	**298**	**268**
BE-012	Phillips 54-3	RHS	W	263.0	2320.0	461.0	8.0	2.0	184	199	181	297	296	**221**	**260**
BE-013	Phillips 3-1	RHS	W	590.0	1950.0	400.0	7.0	0.1	238	268	265	297	208	**296**	*****
BE-018	Phillips 9-1	RHS	W	178.0	1780.0	440.0	69.1	1.0	162	172	150	278	276	**236**	**225**
BE-021	Utah State 72-16	RHS	W	244.0	2000.0	400.0	12.2	0.3	179	194	175	288	260	**263**	**243**
BE-022	Utah State 52-21	RHS	W	65.0	1900.0	216.0	107.0	4.0	113	114	86	219	209	**173**	**204**
BE-068	Escalante 57-29	THS	W	440.0	961.0	75.0	36.3	0.7	217	241	231	193	***	**166**	**160**
BO-008	Utah Hot Spr.	UHS	S	35.0	6580.0	935.0	1020.0	39.0	89	86	55	236	213	**186**	**58**
BO-029	Crystal Hot Spr. (Madsen)	CHS	S	22.0	15800.0	720.0	840.0	130.0	72	67	35	186	112	**153**	**54**
DA-012	Hooper Hot Spr.	HHS	S	24.0	2463.0	204.0	459.0	72.0	75	70	39	191	102	**121**	**57**
DA-013	SW Hooper Warm Spr.	HHS	S	48.0	8290.0	803.0	536.0	458.0	101	100	70	223	29	**135**	**32**
IR-024	Hildebrande	NCA	W	79.2	273.3	15.2	64.6	0.8	122	125	97	99	***	**111**	**77**
IR-026	Troy Hygro	NCA	W	69.4	290.2	17.0	78.7	0.7	116	118	89	99	***	**116**	**63**
IR-027	Christensen Bros.	NCA	W	110.0	260.0	14.0	52.0	1.3	137	143	116	148	***	**101**	**100**
IR-027	Christensen Bros.	NCA	W	140.0	240.0	14.0	36.0	0.6	149	157	133	154	***	**112**	**97**
SA-003	J. Paulsen	SSV	W	15.0	3600.0	77.0	1.0	0.1	60	53	21	179	162	**207**	**38**
WE-011	Ogden Hot Spr.	OHS	S	47.0	2730.0	360.0	360.0	4.9	100	99	69	223	***	**190**	**57**
WE-022	Utah Hot Spr.	UHS	S	28.0	6588.0	821.0	974.0	23.0	89	86	55	236	213	**192**	**59**

RHS = Roosevelt KGRA; CFS = Cove Fort-Sulfurdale KGRA; SSV = Sanpete-Sevier Valley; THS = Thermo HS KGRA; NCA = Newcastle

HHS = Hooper Hot Springs; OHS = Ogden Hot Springs; UHS = Utah Hot Springs

Type field refers to source of fluid: W = well; S = spring

Return

APPENDIX C

Geothermal Resource Legislation and Regulation In Selected Western States (adapted from Bloomquist, 1992; Bloomquist and Lund, 1998; and Battocletti, 2003)

FEDERAL

DEFINITION OF GEOTHERMAL: Statute and No.: Geothermal Steam Act of 1970 (Public Law 91 - 581) "Geothermal steam and associated resources" means (i) all products of geothermal processes, embracing indigenous steam, hot water, and hot brines, (ii) steam and other gases, hot water, and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formation; (iii) heat or other associated energy found in geothermal formation; and (iv) by-products derived from them.

GEOTHERMAL IS CHARACTERIZED AS: Mineral

OWNERSHIP: Statute and No.: U.S. Court of Appeals for the Ninth Circuit, Ottobonite vs the United States of America, 549F .2d 1271 (9th Circ.) The federal government claims ownership of all geothermal resources underlying federal lands or where mineral rights have been maintained.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: Geothermal Steam Act of 1970 (Public Law 91-581) Bureau of Land Management, State Office. Indian Lands 25 CFR Parts 131.171.172,173. For information concerning the leasing of Indian Lands, contact the Bureau of Indian Affairs or the governing body of the Indian Nation.

LEASING: Competitive leases are available on Known Geothermal Resource Areas (KGRA) lands. Non-Competitive leases are available on all other lands. Exploration permits are also available on all lands including those under lease. For leasing state, county, or municipal lands, contact the appropriate officials in the jurisdiction of interest.

LEASE TERMS: Bureau of Land Management, State Office

Primary: 10 years, 5-year extension available if drilling or have power purchase agreement.*

Renewable: For as long as producing in commercial quantities, 40 year maximum,

Rentals: $2/acre KGRA lands, $l/acre non-KGRA lands but increasing in year 6-10 and $12/acre in years 10-15.

Royalties: (% of gross sales): 10 to 15% plus up to 5% of by-products.

DILIGENCE REQUIREMENTS: Bureau of Land Management, State Office

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Groundwater regulation is the responsibility of the surface management agency or, in most instances, the state agency responsible for groundwater regulation.

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: Geothermal Steam Act of 1970 (Public Law 91 - 581). Bureau of Land Management, State Office

INJECTION REQUIREMENTS: Statute and No.: Geothermal Steam Act of 1970 (Public Law 91-581). Bureau of Land Management. State Office

ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: National Environmental Policy Act 42 U.S.C. 4321 ct. seg., and Geothermal Steam Act of 1970. 43 C.F.R., Part 3200 and 30 C.F.R., Part 270

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Environmental Protection Agency; Bureau of Land Management, State Office

ADDITIONAL INFORMATION: For the regulation of geothermal leasing, exploration, and development contact the appropriate state office of the Bureau of Land Management or see 30 U.S.C. 1001 and the following one, 43 C.F.R., Part 3200, and 30 C.F.R., Part 270.

* Legislation passed and signed into law in 1988 (PI 100.443) provides for three 5-year extension of the primary lease term if special circumstances exist. PI 100.443 also extended protection for units of the National Park System.

ARIZONA

DEFINITION OF GEOTHERMAL: Statute and No.: Arizona Revised Statutes (ARS) 27-651

a. "Geothermal resource" means all products of geothermal processes embracing indigenous steam, hot water, and hot brines;

b. Steam and other gases, hot water, and hot brines resulting from water, other fluids, or gas artificially introduced into geothermal formations;

c. Heat or other associated energy found in geothermal formations including any artificial stimulation or induction thereof; and

d. Any mineral or minerals, exclusive of fossil fuels and helium gas, which may be present in solution or in association with geothermal steam, water, or brines.

GEOTHERMAL IS CHARACTERIZED FOR LEASING AS: Steam, hot water, heat, or mineral.

OWNERSHIP: The geothermal resource is included in the ownership of the land.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: ARS 27-668. State Lands Department, For Public Lands: Bureau of Land Management

LEASING: ARS 27-670 Leasing is on a competitive basis.

LEASE TERMS: ARS 27-671 State Land Department

Primary;	10 years
Renewable:	As long as production is maintained.
Rentals:	$ 1.00/acre/year
Royalties:	(% of sales): Not less than 12.5% of gross value at the wellhead.

DILIGENCE REQUIREMENTS: None

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: See ARS 27-667. Department of Water Resources

AGENCY RESPONSIBLE FOR DRILLING/REGULATING: Statute and No.: ARS 27-656. Arizona Geological Survey

INJECTION REQUIREMENTS: Arizona Administrative Code Rule Title 12 Chapter 7-175

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: ARS 27-652

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Environmental Quality

ADDITIONAL INFORMATION REGARDING PERMITTING, REGULATING, OR MONITORING:

Arizona Geological Survey
(Lead Agency)
416 W. Congress #100
Tucson, AZ 85701
(520) 770-3500

State Land Department
1616 W. Adams, Rm. 329
Phoenix, AZ 85007
(602) 542-4631

Dept. of Environmental Quality
3033 N. Central
Phoenix, AZ 85012
(602) 207-2300

Department of Water Resources
500 N. 3rd
Phoenix, AZ 85004
(602) 417-2400

CALIFORNIA

DEFINITION OF GEOTHERMAL: Statute and No.: Public Resources Code (PRC), Section 6903. For purposes of this chapter, "geothermal resources" shall mean the natural heat of the earth, the energy in whatever form below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such as natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, or other hydrocarbon substances.

"Low-temperature geothermal well" means a well drilled for the purpose of providing geothermal resources as defined in Section 6903 from which fluids can be produced which have value by virtue of the heat contained therein and have a temperature that is not more than the boiling point of water at the altitude of the occurrence.

GEOTHERMAL IS CHARACTERIZED AS: Mineral

OWNERSHIP: Statute and No.: PRC. Paragraph 6904. Also see Pariani vs California (CA Court of Appeals, 1981). The state claims ownership whenever it owns the mineral estate, otherwise the resource is the property of the owner of the mineral estate.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: PRC, Paragraph 6904, 6911, and 6916. California State Lands Commission

LEASING: Leasing in a Geothermal Resource Areas (GRA) is by competitive bid. Exploration permits are available in non-GRA areas.

LEASE TERMS: State Lands Commission

Primary: 10 years and so long as geothermal resources are being produced or utilized or are capable of being produced or utilized in commercial quantities but not to exceed 99 years.

Renewable: Yes

Rentals: Not less than $ 1/acre on up

Royalties: (% of sales): Minimum of 10% of gross revenue and not higher than 16-2/3%.

DILIGENCE REQUIREMENTS: California State Lands Commission

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATING: Division of Oil, Gas and Geothermal Resources

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: PRC, Paragraph 6911. Division of Oil, Gas and Geothermal Resources

INJECTION REQUIREMENTS: Statute and No.: PRC, Paragraph 6921, Chapter 4, commencing with Section 3700 of Division 3. Division of Oil, Gas and GeothermaL Resources

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: Statute and No.: PRC, Section 3715.5. Division of Oil, Gas and Geothermal Resources

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Division of Oil, Gas and Geothermal Resources

ADDITIONAL INFORMATION:

California State Lands Comm.
Mineral Resources Mgmt. Division
200 Oceangate, 12th Floor
Long Beach, CA 90802
(562) 590-5201

Div. Oil, Gas and Geothermal Res.
801 K Street, MS 20-20
Sacramento, CA 95814-3530
(916) 323-1788

California Energy Commission
1516 9th Street
Sacramento. CA 95814
(916) 654-287

COLORADO

DEFINITION OF GEOTHERMAL: Statute and No.: Colorado Geothermal Resources Act, Colorado Revised Statutes CRS 37-90.5-103

"Geothermal resource" means the natural heat of the earth and includes:

a. The energy that may be extracted from the natural heat;

b. The material medium used to extract the energy from a geothermal resource; and

c. Geothermal by-products.

"Geothermal fluid" means naturally occurring groundwater, brines, vapor, and steam associated with a geothermal resource.

"Geothermal by-products" means dissolved or entrained minerals and gases that may be obtained from the material medium, excluding hydrocarbon substances and carbon dioxide.

GEOTHERMAL IS CHARACTERIZED AS: Water

OWNERSHIP: Statute and No.: Colorado Revised Statutes 37.90.5-104. Where a geothermal resource is found in association with geothermal fluid which is tributary groundwater, such geothermal resource is declared to be a public resource to which usufructuary rights only may be established according to the procedures of this article. No correlative property right to such a geothermal resource in place is recognized as an incidence of ownership of an estate in land. The property rights to a hot dry rock resource is an incident of the ownership of the overlying surfaces unless severed, reserved, or transferred with the subsurface estate expressly. Nothing in this section shall be deemed to derogate valid, existing property rights to geothermal resource which has vested prior to July 1, 1983. However, such property rights shall not be deemed vested absent the award of a decree for an application filed prior to the effective date of this article pursuant to existing water law or the entering into a geothermal lease prior to the effective date of this article or unless utilizing facilities are actually in existence prior to July 1, 1983. A facility for utilization of geothermal resources shall be considered to be in existence if it is in actual operation or is undergoing significant construction activities prior to operation. Nothing in this section shall be deemed to derogate the rights of a landowner to non-tributary groundwater.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: "Special Rules and Regulation Relating to Geothermal Resource Leases," (Form 248-1)1972, Lease Form (Form 248-2)1972. State Board of Land Commissioners

LEASING: Leases may be awarded by the State Board of Land Commissioners for lands under its jurisdiction through negotiation or by competitive bidding.

LEASE TERMS: State Board of Land Commissioners

Primary: Set in the lease.

Renewable: As long as production continues; if no production. State Board of Land Commissioner decides.

Rentals: Set in the lease.

Royalties: (% of sales): Set in the lease.

DILIGENCE REQUIREMENTS: Water Quality Control Commission and the State Board of Land Commissioners - To continue injection and/or discharge and maintain lease

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Department of Natural Resources, Division of Water Resources

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: Colorado Revised Statutes 37-90-138, 37-90.5-106,37-91. Department of Natural Resources, Division of Water Resources

INJECTION REQUIREMENTS: Statute and No.: Colorado Geothermal Resources Act 37-90.5-106. Department of Natural Resources, Oil & Gas Conservation Commission, and/or Division of Water Resources

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: Title 37, Colorado Revised Statutes, Article 90.5

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: U S. Environmental Protection Agency

ADDITIONAL INFORMATION:

Dept. of Natural Resources
Oil & Gas Conservation Comm.
1580 Logan Street
Denver. CO 80203
(303) 894-2100

Dept. of Natural Resources
Division of Water Resources
818 Centennial Building
1313 Sherman Street
Denver, CO 80203
(303) 866-3581
Info Desk: 866-3587

Water Quality Control Comm.
Department of Health
4210 E. 11th Avenue
Denver, CO 80220
(303) 692-3500

IDAHO

DEFINITION OF GEOTHERMAL: Statute and No.: Geothermal Resource Act, Idaho Code, Paragraph 42-4002. "The natural heat energy of the earth, the energy, in whatever form, which may be found in any position and at any depth below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from the material medium of any geothermal resource. Ground water having a temperature of two hundred twelve (212) degrees Fahrenheit or more in the bottom of a well shall be classified as a geothermal resource. Geothermal resources are found and hereby declared to be *sui generis*, being neither a mineral resource nor a water resource, but they are also found and hereby declared to be closely related to and possibly affecting and affected by water and mineral resources in many instances" (1C § 42-002).

Section 42-230 Idaho Code

(a) "ground water" is all water under the surface of the ground whatever may be the geological structure in which it is standing or moving.

(1) All ground water having a temperature of greater than eighty-five (85) degrees Fahrenheit and less than two hundred twelve (212) degrees Fahrenheit in the bottom of a well shall be classified and administered as a low temperature geothermal resource pursuant to section 42-233, Idaho Code.

(2) All ground water having a temperature of two hundred twelve (212) degrees Fahrenheit or more in the bottom of a well shall be classified as a geothermal resource pursuant to section 42-4002, Idaho Code, and shall be administered as a geothermal resource pursuant to chapter 40, title 42, Idaho Code.

Section 42-233 Idaho Code

Low temperature geothermal resource. The right to the use of low temperature geothermal resources of the state shall be acquired by appropriation. The appropriation may be perfected by means of the application, permit and license procedure as provided for in chapter 4.

GEOTHERMAL IS CHARACTERIZED AS: *Sui generis*

OWNERSHIP: Statute and No.: Idaho Code, Chapter 16, Section 47-1602. State claims ownership of all geothermal resources underlying state and school lands.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: Idaho Code, Chapter 16, Section 47-1603. Idaho State Board of Land Commissioners

LEASING: Leasing is by competitive bid in areas designated by Director of the Department of State Lands or where competitive interest. Other areas are available for a lease upon submittal of application to the Department of State Lands.

LEASE TERMS: Idaho State Department of Lands

Primary: 10 years.

Renewable: So long as commercial production or drilling continues to minimum of 1,000 ft, maximum 40 years with preferential right to renew.

Rental: $1 /acre first 5 years, $2/acre second 5 years, $3/acre thereafter.

Royalties: (% of sales): 10%

DILIGENCE REQUIREMENTS: N/A

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Idaho Department of Water Resources

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: Idaho Code, Chapter 40, Sec. 42-238 and Sec. 42-4001 through 42-4015. See Drilling/or Geothermal Resources Rules and Regulations and Minimum Well Construction Standards, and/or contact the Idaho Department of Water Resources.

INJECTION REQUIREMENTS: Statute and No.: Idaho Code, Title 42, Chapter 39 and Chapter 40, Section 42. See A Guide to the Idaho Well Program and Rules and Regulations, Drilling for Geothermal Resources, and/or contact the Idaho Department of Water Resources.

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: Statute and No.: Idaho Code, Chapter 40, Section 42-4003 through 42-4009

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Idaho Department of Health & Welfare, Environmental Division, and/or Idaho Department of Water Resources

ADDITIONAL INFORMATION: Drilling for Geothermal Resources Rules and Regulations. Minimum Well Construction Standards, and Low-Temperature Geothermal Resources, June 1988. A Guide to the Idaho Injection Well Program, April 1986; Rules and Regulations, Construction and Use of Injection Wells, June 1993; Rules and Regulations, Water Well Driller's Licenses, March 1985 Geothermal Energy Development: A Guide So the Federal and State Regulating Process in Idaho, Montana, Oregon, and Washington. 1991, Geothermal Energy Development, A Guide to the Federal and State Regulating Process in Idaho, Montana, Oregon, and Washington, 1991.

Idaho State Dept. of Lands
Statehouse
Boise, ID S3720
(208) 334-0200

Idaho Dept. of Water Res.
Statehouse
Boise, ID 83720
(208) 327-7900

Idaho Dept. of Health & Welfare
Environmental Division
Statehouse
Boise, ID 83720
(208) 334-5000

MONTANA

DEFINITION OF GEOTHERMAL: Statute and No.: Leasing Statute 77-4-102(1) Montana Code Annotated (M.C.A.). "Geothermal resource" means the natural heat energy of the earth, including the energy, in whatever form, which may be found in any position and at any depth below the surface of the earth, either present in, resulting from, created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from the material medium of any geothermal resource.

GEOTHERMAL IS CHARACTERIZED AS: *Sui generis* but governed by law as to groundwater.

OWNERSHIP: Statute and No.: Leasing Statute 7-4-102(1) M.C.A. On state lands geothermal resources are owned by the state as part of their mineral reservation. However, state water laws also apply to all geothermal development involving production and diversion of geothermal fluids.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: Administrative Rules of Montana (ARM) 26-26(2)-S60120, State Board of Land Commissioners

LEASING: All leasing is by competitive bid. However, if only one bid is received, the applicant may negotiate a lease with the Department of Natural Resources and Conservation

LEASE TERMS: State Board of Land Commissioners

Primary:	10 years.
Renewable:	As long as resources are produced in paying quantity.
Rentals:	Minimum of $ 1/acre; $2/acre after discovery.
Royalties:	(% of sales): 10% of gross revenue from the sale of heat energy, steam, brine, or associated gas on the fair market value of such heat energy or steam.

DILIGENCE REQUIREMENTS: Department of Environmental Quality

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Department of Natural Resources & Conservation, Water Resources Division

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: 37-43-101 et seq., ARM40.3.106(6)-S10620 Department of Natural Resources and Conservation

INJECTION REQUIREMENTS: Department of Environmental Quality

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION:

a. Air Pollution Discharge Permit 75-2-101 et seq. M.C.A. Regulation at l6-2.14(l)-S1400.;

b. Water Pollution Discharge Permit/Pre-treatment standards for waste water discharged into municipal sewer system; 40 C.F.R. Parts 128,403;

c. Permit requirements for discharge into state water: 75-5-101 et. seq. M.C.A. Regulation at ARM 16-2.14(10)-S14460;

d. Underground Injection Control/Standard for geothermal injection well permits: 40 C.F.R. Parts 122, 123,124,146; 44 Fed. Reg. 34267 et seq. and 44 Fed. Reg. 23738; and

e. Environmental Impact Statements, Montana Environmental Policy Act: 75-1-101 et. seq. M.C.A.

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Natural Resources & Conservation, Water Resources; Environmental Quality and/or Fish, Wildlife, and Parks

ADDITIONAL INFORMATION: Bloomquist, R.G., 1991, A regulatory guide to leasing, permitting, and licensing in Idaho, Montana, Oregon, and Washington: Olympia, Washington State Energy Office, report number DOE/BP-00425-2, 275 p.

Dept. of Natural Resources & Conservation Water Management Bureau 48 N. Last Chance Gulch PO Box 201601 Helena, MT 59620 Ph: (406) 444-6637	Dept. of Natural Resources & Conservation Water Operations Bureau 48 N. Last Chance Gulch PO Box 201601 Helena, MT 59620 Ph: (406) 444-6610	Dept. of Environmental Quality Permitting & Compliance Div. 1520 E. Sixth Street Helena, MT 59620 Ph: (406) 444-4323 Fax: (406) 444-5275	State-Owned Lands Dept. of Natural Resources & Conservation Trustland Mgmt. Div. 1625 11th Avenue Helena, MT 59620 Ph: (406) 444-2074

NEVADA

DEFINITION OF GEOTHERMAL: Statute and No.: Nevada Revised Statute (NRS) 534A.010 Geothermal resources are defined as the natural heat of the earth and the energy associated with that natural heat, but excluding hydrocarbons and helium. In addition, geothermal resources are divided into classes for purposes of regulation as follows:

Domestic Class: This type of geothermal resource is developed for dwellings with common ownership on a single parcel of land, and uses not more than an annual average of 1800 gallons per day. A geothermal resource developed for a community's usage that does not produce geothermal heat for sale or for the generation of power is also considered as a domestic well.

Commercial Class: A commercial well is primarily used to provide geothermal resources on a commercial basis for purposes other than generation of power.

Industrial Class: This type of geothermal resource is used primarily to generate power.

GEOTHERMAL IS CHARACTERIZED AS: Mineral if use is only for heat content. For low temperature uses and where there is consumptive use, the resource would be characterized as both water and mineral and would fall under the jurisdiction of the State Engineer, Division of Water Resources (water) and the State Division of Minerals (heat).

OWNERSHIP: Statute and No.: NRS 534A.050 Geothermal resources in Nevada belong to the owner of the surface estate, unless they have been reserved by or conveyed to another person,

AGENCY RESPONSIBLE FOR LEASING: Contact Office of State Lands. For federal lands, contact the Bureau of Land Management.

LEASING: Leases are negotiated.

LEASE TERMS: Office of State Lands

Primary:	N/A
Renewable:	N/A
Rentals:	N/A
Royalties:	(% of sales): N/A

DILIGENCE REQUIREMENTS: Nevada Administrative Code (NAC) 534A.210

AGENCY RESPONSIBLE FOR CROUNDWATER REGULATING: Department of Conservation and Natural Resources, Division of Environmental Protection

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: NRS 534A. Department of Minerals

INJECTION REQUIREMENTS: Statute and No.: NAC 534A.410 and Chapter 445 Nevada Administrative Code, Section 2596 inclusive. State Department of Conservation and Natural Resources, Division of Environmental Protection and Division of Minerals

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION. DEVELOPMENT, AND INJECTION: NRS 534A, Department of Minerals

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: State Department of Conservation and Natural Resources, Division of Environmental Protection, and Division of Minerals.

ADDITIONAL INFORMATION:

State Lands Division	Department of Conservation	Division of Minerals
333 West Nye Lane	123 West Nye Lane	400 West King Street, #106
Carson City, NV 89710	Carson City, NV 89710	Carson City, NV 89703
(702) 687-4363	(702) 687-4670, ext. 3150	(702) 687-5050
Pamela Wilcox	Russ Land	Fax: (702) 687-395
		John Snow
		Ndom@govmail.state.nv.us
		Http://www.state.nv.us/b&i/minerals

NEW MEXICO

DEFINITION OF GEOTHERMAL: Statute and No.: New Mexico Statutes Annotated (NMSA) 1978 71-5-3 and NMSA 1978 72-2-17. "Geothermal resource" means the natural heat of the earth, or the energy, in whatever form, below the surface of the earth present in, resulting from, creating by or which may be extracted from, this natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas and other hydrocarbon substances. "Geothermal fluid" means naturally occurring steam or hot water which is at a temperature of at least 95°F in the natural state of free-flowing springs or pumped from wells.

GEOTHERMAL IS CHARACTERIZED AS: Mineral

OWNERSHIP: Statute and No.; NMSA 1978, 19-13-3 and NMSA 1978, 71-5-2. The state claims ownership of geothermal resources whenever it holds the mineral rights.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: NMSA 1978,19-13-5. State Land Office

LEASING: Leasing is competitive in geothermal resource fields and non-competitive in all other areas.

LEASE TERMS: NMSA 1978, 19-13-7 and 19-13-11. State Land Office

Primary: 5 years.

Renewable: 5 years and for so long as resources are produced.

Rentals: $1/acre for first 5 years or when in production. $5/acre second 5 years and no production.

Royalties: (% of sales): 10% of gross revenues minus transportation costs or royalty of 8% of the net revenue received from the operation of an energy producing plant.

DILIGENCE REQUIREMENTS: N/A

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Office of the State Engineer

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: NMSA 1978, 71-5-6,71-6-8,72-12-3,72-12-26. Oil Conservation Division and/or Office of the State Engineer

INJECTION REQUIREMENTS: Statute and No.: NMSA 1978,71-5-6. Oil Conservation Division, Office of the State Engineer; and New Mexico Environment Department

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: NMSA 1978, 71-5-6 and 74-6-1 through 12. -Note: All NMSA numbers are being revised.

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: New Mexico Environment Department

ADDITIONAL INFORMATION: Southwest Technology Development Institute, NMSU, Las Cruces, NM (505) 646-1846.

Leasing/Land Entry/Archeology
New Mexico State Land Office
Oil, Gas and Mineral Division
310 Old Santa Fe Trail
PO Box 1148
Santa Fe, NM 87504-1148
Sam Taylor
(505) 827-5750

Drilling, Injection, Production
Oil Conservation Division (OCD)
New Mexico, Mineral, and
Natural Resources Dept.
2040 South Pacheco
PO Box 6429
Santa Fe, NM 87505-5472
Roy Johnson
(505) 827-8198
Rjohnson@emnrdsf.state.nm.us

Water Rights, Drilling, Prod., Inject.
New Mexico State Engineer Office
Water Rights Division
Bataan Memorial Building
PO Box 25102
Santa Fe, NM 87504-5102
(505) 827-6120
(800) 928-3766

Environmental, Discharge, Injection
New Mexico Environment Dept.
Water and Waste Management Div.
Ground Water Bureau
Harold S. Runnels Building
1190 St. Francis Drive
Santa Fe, NM 87505-4182
(505) 827-2855
(800) 879-3421

Geothermal Resources, Development and Uses
Southwest Technology
Development Institute
New Mexico State University
Box 30001, Dept. 3 SOL
Las Cruces, NM 88003-0001
James C. Witcher
(505) 646-3949
jwitcher@nmsu.edu

Geologic Reports and Maps
New Mexico Bur. of Mines & Mineral Resources
New Mexico Inst. of Mining & Tech.
801 Leroy Place
Socorro, NM 87801-4796
(505) 835-5410

OREGON

DEFINITION OF GEOTHERMAL: Statute and No.: Oregon Revised Statute (ORS) 522.005(11); ORS 577.090 Subsection (II): "Geothermal resources" means the natural heat of the earth, the energy in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from the natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, exclusive of helium or of oil, hydrocarbon gas or other hydrocarbon substances, but including, specifically:

a. All products of geothermal process, embracing indigenous steam, hot water, and hot brines;
b. Steam and other gases, hot water and hot brines resulting from water, gas, or other fluids artificially introduced into geothermal formation;
c. Heat or other associated energy found in geothermal formations; and
d. Any by-product derived from them.

Subsection (12): "Geothermal well" includes any excavation made for producing geothermal resources and any geothermal reinjection well as defined in subsection (10) of this subsection.

Subsection (13): "Geothermal reinjection well" means any well or converted well constructed to dispose of geothermal fluids derived from geothermal resources into an underground reservoir.

GEOTHERMAL IS CHARACTERIZED AS: Water if the temperature is (less than 250°F; and under the jurisdiction of the Department of Water Resources. If it is above 250°F, it is considered mineral and under the jurisdiction of the Department of Geology and Mineral Resources. Also, if exploration for geothermal resources of any temperature at depth greater than 2,000 feet, it is under the jurisdiction of the Department of Geology and Mineral Resources.

OWNERSHIP: Statute and No.: ORS 522,035; ORS 537.090. Owner of the surface estate, unless otherwise reserved or conveyed.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: ORS 273.551; Oregon Administrative Rules, Chapter 141 75-010 through 141-75-575. Division of State Lands

LEASING: Leases are available on a non-competitive as well as competitive basis.

LEASE TERMS: Division of State Lands

Primary: 10 years.
Renewable: 5 years if discovery has been made or is imminent. Leases are renewable every 10 years. No lease shall exceed 50 years except the lessee shall have a right of first refusal if the Division decides to continue leasing.
Rentals: $1 /acre (1st, 2nd, and 3rd year); $3/acre (4th year); $5/acre all subsequent years.
Royalties: (% of sales): 10% of production value of resource produced.

DILIGENCE REQUIREMENTS: Division of State Lands

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: ORS 537, Department of Water Resources (<250°F) and/or ORS 522, Department of Geology & Mineral Industries (>250°F)

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Same as above

INJECTION REQUIREMENTS: Same as above, plus Oregon Administrative Rules, Chapter 690, Division 65-055-Water Resources Department/Low Temperature Geothermal Effluent Disposal.

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: Statute and No.: ORS 522 and Oregon Administrative Rules, Chapter 141-75-265. Department of Geology and Mineral Industries; Department of Water Resources and/or Department of Environmental Quality

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Environmental Quality

UTAH

DEFINITION OF GEOTHERMAL: Statute and No.: Geothermal Resource Conservation Act, Section 73-22-3, Utah Code Annotated (UCA) 1953. "Geothermal resources" means:

a. The natural heat of the earth at temperatures greater than 120°C; and
b. The energy, in whatever form, including pressure, present in, resulting from, created by, or which may be extracted from the natural heat, directly or through a material medium. Geothermal resource does not include geothermal fluids.

"Geothermal fluid" means water and steam at temperatures greater than 120°C naturally present in a geothermal system.

GEOTHERMAL IS CHARACTERIZED AS: Water

OWNERSHIP: Statute and No.: Geothermal Resource Conservation Act, UCA, Section 73-21-4. Ownership of a geothermal resource derives from an interest in land and not from an appropriated right to geothermal fluids. This chapter shall apply to all lands in the state of Utah, including federal and Indian lands to the extent allowed by law. In effect, the right to geothermal resource is based on ownership of the mineral rights or surface rights, which are usually obtained by direct ownership or by leasing. Because of the potential relationship between geothermal fluids and groundwater resource, however, an approved application to appropriate geothermal fluids is required prior to the production of geothermal fluids from a well (UCA, Section 73-21-8). The appropriations process for geothermal fluids is similar to that of water appropriations, and includes provisions for advertisement of the application and the filing of protests, Utah Division of Water Rights

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: UCA, Section 65-1-18. Utah School and Institutional Trust Lands Administration (SITLA). Hydrothermal resources at low and moderate temperatures (<120°C) are regulated by the Department of Natural Resources, Division of Water Rights under Utah Water Law.

LEASING: Competitive leasing involves lands that have newly become available for lease because of new purchase, relinquished leases, or any other reason and are leased under the simultaneous filing procedures. Applications for non-competitive leases are filed with the SITLA Board of Trustees.

LEASE TERMS:

Primary: 10 years.
Renewable: For as long as land is in production.
Rentals: $1 /acre per year.
Royalties: (% of sales): 10% of gross proceeds received from sale of those products, or 10% of the fair market value when the products are utilized but not directly sold.

DILIGENCE REQUIREMENTS: Currently a drilling requirement by the end of the first 5 years. SITLA is considering dropping the 5-year drilling requirement.

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Utah Division of Water Rights

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: UCA, Section 73-21 -5. Utah Division of Water Rights

INJECTION REQUIREMENTS: Statute and No.: UCA, Section 73-21-5. Utah Division of Water Rights and/or Division of Water Quality; injection may be required in order to maintain water levels in heavily used aquifers.

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: Statute and No,: UCA, Section 73-21-2 and UCA 26-11, Section 1-20

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Environmental Quality, Division of Water Quality

ADDITIONAL INFORMATION: Wagstaff, L.W., and Green, Stanley, 1982, Utah geothermal handbook: a user's guide of agencies, regulations, permits and aids for geothermal development: Idaho Falls, U.S. Department of Energy report DOE/ID/12016-2, 84 p.

Dept. of Natural Resources
Division of Water Rights
PO Box 146300
Salt Lake City, UT 84116-6300
(801) 538-7240
http://www.waterrights.utah.gov/

Dept. of Environmental Quality
Division of Water Quality
PO Box 144870
Salt Lake City, UT 84114-4870
(801) 538-6146
(801) 538-6016 (fax)
http://waterquality.utah.gov/

Utah School and Institutional Trust
Lands Administration
675 E. 500 S, Suite 500
Salt Lake City, UT 84102
(801)538-5100
(801) 355-0922 (fax)
http://wwwtl.state.ut.us/

Department of Natural Resources
Utah Geological Survey
1594 W. North Temple, Suite 3110
Box 146100
Salt Lake City, UT 84114-6100
(801) 537-3300
(801) 537-3400 (fax)
http://geology.utah.gov/

Department of Natural Resources
Utah Geological Survey
Southern Regional Office
Southern Utah University
Electronic Learning Center, Rm 116
(435) 865-8139
(435) 865-8180
http://geology.utah.gov/

WASHINGTON

DEFINITION OF GEOTHERMAL: Statute and No.: Geothermal Resources Act. Revised Code Washington (RCW), Chapter 79.76(3). "Geothermal resource" means only that natural heat energy of the earth from which it is <u>technologically practical to produce electricity commercially</u> and the medium by which such heat energy is extracted from the earth, including liquids or gases, as well as any mineral contained in any natural or injected fluids, brines, and associated gas, but excluding oil, hydrocarbon gas, and other hydrocarbon substances. All direct-use geothermal resources are considered to be groundwater and regulated accordingly. (Emphasis added)

GEOTHERMAL IS CHARACTERIZED AS: *Sui generis*. Direct use resources are characterized as groundwater.

OWNERSHIP: Statute and No.: Geothermal Resource Act, RCW, Chapter 79.76. Geothermal resources are the property of the surface owner. Water Rights: Chapters 18.104,43.27A, 90,14,90.16,90.22,90,44 and 90.54 RCW; Chapters 173-100, 173-136,173-50, 173-154, 173-166, 173-500, and 173-590 WAC.

AGENCY RESPONSIBLE FOR LEASING: Statute and No.: Geothermal Resources Act, RCW, Chapter 79.76. Department of Natural Resources, Division of Lands

LEASING: All leases are negotiated.

LEASE TERMS: All terms are negotiated.

DILIGENCE REQUIREMENTS: All terms are negotiated.

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: Department of Ecology. Groundwater Management Areas: Chapter 90.44 RCW; Chapter 173-100 WAC.

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Department of Ecology, RCW 18.104, Chapter 173-160 WAC. Chapter 173-162 WAC.

INJECTION REQUIREMENTS: Statute and No.: Geothermal Resources Act, RCW, Chapter 79.76, Department of Natural Resources, Division of Geology & Earth Resources. Department of Ecology, Chapter 90.48 RCW, Chapter 173-218 WAC - Underground Injection control program.

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: State Environmental Policy Act 1971 and Geothermal Resources Act, RCW, Chapter 79.76

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Ecology, RCW 43.21A.040

ADDITIONAL INFORMATION:

Bloomquist, R.G., 1986, Geothermal energy development in Washington State, a guide to the federal, state and local regulatory process: Olympia, Washington State Energy Office, ISBN 8944935, 66 p.

Bloomquist, R.G., 1991, Geothermal - a regulatory guide to leasing, permitting, and licensing in Idaho, Montana, Oregon, and Washington: Olympia, Washington State Energy Office, report number DOE/BP-00425-2, 275 p.

Department of Natural Resources
Division of Lands
1111 Washington Street SE
PO Box 47001
Olympia. WA 98504-7001
(360) 902-1000

Department of Ecology
300 Desmond Drive
PO Box 47600
Lacey, WA 98504-7600
(360) 407-6000

Department of Natural Resources
Division of Geology & Earth Resources
1111 Washington Street NE
PO Box 47001
Olympia, WA 98504-7001
(360) 902-1450

Washington State University Energy Program
925 Plum Street, Bldg. 4
Olympia, WA 98504-3165
(360) 956-2016

WYOMING

DEFINITION OF GEOTHERMAL: Statute and No.: Wyoming Statutes (WS) Chapter XI Rules and Regulations Governing the Issuance of Geothermal Permits and Leases. "Geothermal resources" shall mean the natural heat in the subsurface of the earth, its energy, in whatever form, resulting from, or created by, or which may be extracted from, such natural heat and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases, and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas, other hydrocarbon substances or miscellaneous minerals.

GEOTHERMAL IS CHARACTERIZED AS: Water

OWNERSHIP: Statute and No.: Nature of Water Rights and Beneficial Use, Article 1, §41-3-101 Wyoming Statutes (WS). Geothermal is a public resource available for appropriation.

AGENCY RESPONSIBLE FOR LEASING: Article 1. § 41-3-101: Rules and Regulations Governing the Issuance of Geothermal Resource Permits and Leases, Wyoming State Lands Office

LEASING: Leasing in Known Geothermal Resource Areas (KGRA) is by competitive bid. Other lands are available through a non-competitive permit which may be converted to a lease within 50 days should the area be classified as a KGRA.

LEASE TERMS: Wyoming State Lands Office

Primary: 10 years.

Renewable: As long as geothermal resources are being produced or utilized, or are capable of being produced or utilized in commercial quantities.

Rentals: $2/year.

Royalties: (% of sales): 10% of gross revenue as determined by a reasonable value received from the sale of steam, brine, from which no minerals have been extracted, and associated gases at the point of delivery to purchaser thereof. In such a case where the resource is used by the lessee and not sold, the gross revenue therefrom to be determined as those said geothermal resources had been sold to a third person and then primarily market price in the same market area and under the same market conditions.

DILIGENCE REQUIREMENTS: Drilling must commence within two (2) years. State Board of Land Commissioners

AGENCY RESPONSIBLE FOR GROUNDWATER REGULATIONS: State Engineer - a permit must be obtained from the State Engineer's Office prior to drilling any water well (Wyoming Statue 41-3-930)

AGENCY RESPONSIBLE FOR REGULATING DRILLING: Statute and No.: Rules and Regulations Governing the Issuance of Geothermal Resource Permits and Leases. State Board of Land Commissioners and State Engineer

INJECTION REQUIREMENTS: Surface disposal may be approved by the Wyoming Game and Fish Department, State Engineer or Department of Environmental Quality.

STATE ENVIRONMENTAL STATUTE PERTAINING TO EXPLORATION, DEVELOPMENT, AND INJECTION: State Engineer or Department of Environmental Quality, Section 12, Board of Land Commissioners Permit to Prospect for Geothermal Resources

AGENCY RESPONSIBLE FOR ENVIRONMENTAL PROTECTION: Department of Environmental Quality

ADDITIONAL INFORMATION:

Wyoming State Lands Office
and/or State Board of Land
Commissioners
3rd Floor West
Herschler Building
Cheyenne, WY 82002
(307) 777-6638

Dept. of Environmental Quality
4th Floor West
Herschler Building
Cheyenne, WY 82002
(307) 777-7781

University of Wyoming
Department of Geology
and Geophysics
16th & Gibbon Street
PO Box 3006
Laramie, WY 82071
(307) 766-3389

State Engineer's Office
4th Floor East
Herschler Building
Cheyenne, WY 82002
(307) 777-6159

Return

Appendix D: Overall comparison matrix of geothermal sites studied.

Site	Long: (W)	Lat: (N)	T, R, S SLB&M	County:	Meas Temp (°C):	Res Temp (°C):	Depth (m):	Resource Type:	TDS (mg/L)	Dist to KV-46 or Greater (mi)	Line Label	Dist to Road (mi)	Road Label	Land Ownership	T & E Species	No. T & E Species	Ground Water Basin(s) and Status[1]	2000 Population[2]	2000 Income[3]
Roosevelt Hot Springs	112.8503	38.5019	T26S, R9W, sec 34	Beaver	270	270	1000 - 2000	high-temp liquid	7,000-7,800	0.2	KV-138	7.7	hwy 257	Private, State, BLM	Burrowing Owl, Ferruginous Hawk, Greater Sage-Grouse, Wolverine, Least Chub, Brazilian Free-tailed Bat	6	Basin 71 = Closed, Restricted; Basin 77 = Closed	6024	21,339
Cove Fort-Sulphurdale	112.5668	38.5685	T26S, R6W, sec 07	Beaver	150	150	180 - 900	dry steam in shallow reservoir, high-temp liquid in deep reservoir	9,400	0.7	KV-46	4.6	I-70	USDA Forest Service, Private, State, BLM, Tribal	Greater Sage-Grouse, Burrowing Owl, Ferruginous Hawk	3	Basin 71 = Closed, Restricted; Basin 67 = Closed; Basin 63 = Closed	6024	21,339
Thermo Hot Springs	113.2036	38.1731	T30S, R12W, sec 28	Beaver	160	160-217	2200	high-temp liquid	1,300-3,300	12.3	KV-46	13.3	hwy 130	Private, BLM, State	Burrowing Owl, Ferruginous Hawk, Swainson's Hawk, Greater Sage-Grouse	4	Basin 71 = Closed	6024	21,339
Newcastle	113.5651	37.6591	T36S, R15W, S20	Iron	118	130	150 - 270	moderate-temp liquid	1000-1100	0.5	KV-138	1.0	hwy 56	Private, BLM	Burrowing Owl, Ferruginous Hawk, Long-billed Curlew	3	Basin 71 = Closed	33960	16,104
Hooper Hot Springs	112.1753	41.1370	T5N, R3W, S27	Davis	57	135	1500?	low- to mod-temp liquid	8600	6.2	KV-46	3.5	unknown	SOV/Wildlife Management Area, Private	American White Pelican, Bald Eagle, Ferruginous Hawk, Long-billed Curlew, Mountain Plover, Peregrine Falcon, Short-eared Owl, Bobolink, Common Yellowthroat, Grasshopper Sparrow, Townsend's Big-eared Bat	11	Basin 31 = Restricted; Basin 35 = Restricted	240,259	24,100
Utah Hot Springs	112.0278	41.3375	T7N, R2W, S14	Weber	59	192	1800?	high-temp liquid (?)	22000	0.0	KV-230	0.1	hwy 89	Private	American White Pelican, Blue Grosbeak, Brazilian Free-tailed Bat, Lewis's Woodpecker, Pacific Treefrog, Bald Eagle, Burrowing Owl, Long-billed Curlew, Osprey, Short-eared Owl	10	Basin 29 = Open; Basin 35 = Restricted	197,264	22,757

[1] Ground water basin number and status as classified by the Utah Division of Water Rights.
[2] United States 2000 Census county population estimates.
[3] United States 2000 Census county average per-capita income.

Appendix D: Overall comparison matrix of geothermal sites studied (continued).

Site	Long:	Lat:	T, R, S	County:	Meas Temp (°C):	Res Temp (°C):	Depth (m):	Resource Type:	TDS (mg/L)	Dist to KV-46 or Greater (mi)	Line Label	Dist to Road (mi)	Road Label	Land Ownership	T & E Species	No. T & E Species	Ground Water Basin(s) and Status[1]	2000 Population[2]	2000 Income[3]
Ogden Hot Springs	111.9233	41.2356	T6N, R1W, S23	Weber	57	190	1800?	high-temp liquid (?)	8800	0.1	KV-46	0.1	hwy 39	Private, USDA Forest Service	Bluehead Sucker, Common Yellowthroat, June Sucker, Pacific Treefrog, Ute Ladies' Tresses, Yellow-billed Cuckoo, American White Pelican, Blue Grosbeak, Brazilian Free-tailed Bat, Lewis's Woodpecker	10	Basin 35 = Restricted, Closed; Basin 31 = Restricted, Closed	197,264	22,757
Crystal-Madsen Hot Springs	112.0864	41.6600	T11N, R2W, S29	Box Elder	54	153	1800?	mod- to high-temp liquid	43600	0.9	KV-345	0.1	hwy 69	Private	Bluehead Sucker, Bonneville Cutthroat Trout, Long-billed Curlew, Wolverine	4	Basin 29 = Open; Basin 25 = Open	42,872	22,321
Drum Mountains	113.1533	39.4900	T14-15S, R12-13W	Juab and Millard	?	200?	800?	?	?	22.3	KV-230	10.0	unknown	State, BLM	Townsend's Big-Eared Bat	1	Basin 18 = Open; Basin 16 = Open; Basin 68 = Closed, Open; Basin 67 = Restricted; Basin 69 = Open;	Juab: 8,285; Millard: 12,416	Juab: 15,206; Millard: 16,880

[1] Ground water basin number and status as classified by the Utah Division of Water Rights.
[2] United States 2000 Census county population estimates.
[3] United States 2000 Census county average per-capita income.

Return

Appendix E: County Economic Profiles, 1969-1984 (Part 1)

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
State of Utah Total	All	Personal income (thousands of dollars)	3248701	3614045	4026202	4514470	5056616	5685997	6354904	7301818	8330509	9605627	11026413	12464137	14078428	15281825	16480744	18223095
State of Utah Total	All	Nonfarm personal income	3171217	3531224	3942720	4417395	4918669	5582092	6281886	7221918	8261281	9528073	10934630	12400366	14038301	15237117	16444753	18162534
State of Utah Total	All	Farm income	77484	82821	83482	97075	137947	103905	73018	79900	69228	77554	91783	63771	40127	44708	35991	60561
State of Utah Total	All	Net earnings 1/	2603649	2851564	3149962	3527845	3945870	4408397	4867179	5614235	6426276	7394348	8360537	9225811	10236826	10847298	11504562	12807248
State of Utah Total	All	Transfer payments	244494	297221	353692	402578	469040	532767	659432	721675	789717	876118	993070	1174053	1367801	1575799	1712261	1734846
State of Utah Total	All	Income maintenance 2/	23946	32158	38597	45340	47096	49316	59397	66984	69451	73496	78889	107635	118796	125236	141781	140026
State of Utah Total	All	Unemployment insurance benefit payments	12774	17107	23841	27600	24159	31583	65390	58154	48121	40075	47418	73765	83872	151512	151100	78783
State of Utah Total	All	Retirement and other	207774	247956	291254	329638	397785	451868	534645	596537	672145	762547	866763	992653	1165133	1299051	1419380	1516037
State of Utah Total	All	Dividends, interest, and rent	400558	465260	522548	584047	641706	744833	828293	965908	1114516	1335161	1672806	2064273	2473801	2858728	3263921	3681001
State of Utah Total	All	Population (number of persons) 3/	1047000	1065672	1100733	1134601	1168784	1198793	1233935	1272365	1316421	1364235	1416094	1472595	1515472	1558314	1594943	1622342
State of Utah Total	All	Per capita personal income	3103	3391	3658	3979	4326	4743	5150	5739	6328	7041	7786	8464	9290	9807	10333	11233
State of Utah Total	All	Per capita net earnings	2487	2676	2862	3109	3376	3677	3944	4412	4882	5420	5904	6265	6755	6961	7213	7894
State of Utah Total	All	Per capita transfer payments	234	279	321	355	401	444	534	567	600	642	701	797	903	1011	1074	1069
State of Utah Total	All	Per capita income maintenance	23	30	35	40	40	41	48	53	53	54	56	73	78	80	89	86
State of Utah Total	All	Per capita unemployment insurance benefits	12	16	22	24	21	26	53	46	37	29	33	50	55	97	95	49
State of Utah Total	All	Per capita retirement and other	198	233	265	291	340	377	433	469	511	559	612	674	769	834	890	934
State of Utah Total	All	Per capita dividends, interest, and rent	383	437	475	515	549	621	671	759	847	979	1181	1402	1632	1835	2046	2269
State of Utah Total	All	Earnings by place of work ($000)	2689024	2944667	3254963	3649328	4102809	4589353	5062150	5833799	6674556	7680630	8705375	9600046	10702046	11358149	12064105	13443522
State of Utah Total	All	Wage and salary disbursements	2197216	2417436	2647808	2947696	3296545	3695919	4042778	4580311	5212653	6037064	6874319	7649819	8644254	9190546	9673365	10717817
State of Utah Total	All	Other labor income	137393	162691	203253	235983	267343	331110	417068	514756	636745	742804	864035	1007797	1160874	1282734	1379222	1483307
State of Utah Total	All	Proprietors' income	354415	364540	403902	465649	538921	562324	602304	738732	825158	900762	967021	942430	896918	884869	1011518	1242398
State of Utah Total	All	Nonfarm proprietors' income	296816	301125	339192	385646	421908	482093	554187	686646	785331	863346	918738	924416	902077	891804	1023995	1228930
State of Utah Total	All	Farm proprietors' income	57599	63415	64710	80003	117013	80231	48117	52086	39827	37416	48283	18014	-5159	-6935	-12477	13468
State of Utah Total	All	Total full-time and part-time employment	443666	454613	466945	494083	522552	544692	552712	580314	612701	651347	678982	688713	699156	709116	721291	764375
State of Utah Total	All	Wage and salary jobs	382639	392894	404533	428335	452582	470229	474773	495605	523245	559278	581762	584431	592740	596724	603694	641912
State of Utah Total	All	Number of proprietors	61027	61719	62412	65748	69970	74463	77939	84709	89456	92069	97220	104282	106416	112392	117597	122463
State of Utah Total	All	Number of nonfarm proprietors 5/	46651	47837	48921	52701	57307	61824	65231	71892	76447	78954	83829	90616	92486	98274	102516	107487
State of Utah Total	All	Number of farm proprietors	14376	13882	13491	13047	12663	12639	12708	12817	13009	13115	13391	13666	13930	14118	15081	14976
State of Utah Total	All	Average earnings per job (dollars)	6061	6477	6971	7386	7851	8426	9159	10053	10894	11792	12821	13939	15307	16017	16726	17588
State of Utah Total	All	Average wage and salary disbursements	5742	6153	6545	6882	7284	7860	8515	9242	9962	10794	11816	13089	14584	15402	16024	16697
State of Utah Total	All	Average nonfarm proprietors' income	6362	6295	6933	7318	7362	7798	8496	9551	10273	10935	10960	10201	9754	9075	9989	11433
Beaver	Roosevelt, Cove Fort, Thermo	Personal income (thousands of dollars)	9929	10884	12172	13756	15316	16871	17446	20254	22812	25062	27120	29752	33160	36385	40600	45681
Beaver	Roosevelt, Cove Fort, Thermo	Nonfarm personal income	8738	9617	10982	12332	13537	15164	16544	19052	21632	23745	26040	29419	32263	34403	39261	43783
Beaver	Roosevelt, Cove Fort, Thermo	Farm income	1191	1267	1190	1424	1779	1707	902	1202	1180	1317	1080	333	897	1982	1339	1898
Beaver	Roosevelt, Cove Fort, Thermo	Net earnings 1/	7408	7972	8835	10012	11013	11788	11293	13386	15178	16571	17396	18325	19811	20985	23224	26296
Beaver	Roosevelt, Cove Fort, Thermo	Transfer payments	1305	1531	1795	2039	2347	2670	3452	3814	4142	4546	4985	5662	6607	7538	8201	8434
Beaver	Roosevelt, Cove Fort, Thermo	Income maintenance 2/	52	72	65	100	85	107	147	209	220	261	249	359	398	421	479	484
Beaver	Roosevelt, Cove Fort, Thermo	Unemployment insurance benefit payments	65	66	79	88	67	87	341	214	179	148	177	194	206	348	346	219
Beaver	Roosevelt, Cove Fort, Thermo	Retirement and other	1188	1393	1651	1851	2195	2476	2964	3391	3743	4137	4559	5109	6003	6769	7376	7731
Beaver	Roosevelt, Cove Fort, Thermo	Dividends, interest, and rent	1216	1381	1542	1705	1956	2413	2701	3054	3492	3945	4739	5765	6742	7862	9175	10951
Beaver	Roosevelt, Cove Fort, Thermo	Population (number of persons) 3/	3900	3798	3830	3864	3993	3976	4064	4074	4064	4194	4240	4408	4518	4678	4771	4969
Beaver	Roosevelt, Cove Fort, Thermo	Per capita personal income	2546	2866	3178	3560	3836	4243	4293	4972	5613	5976	6396	6750	7340	7778	8510	9193
Beaver	Roosevelt, Cove Fort, Thermo	Per capita net earnings	1899	2099	2307	2591	2758	2965	2779	3286	3735	3951	4103	4157	4385	4486	4868	5292
Beaver	Roosevelt, Cove Fort, Thermo	Per capita transfer payments	335	403	469	528	588	672	849	936	1019	1084	1176	1284	1462	1611	1719	1697
Beaver	Roosevelt, Cove Fort, Thermo	Per capita income maintenance	13	19	17	26	21	27	36	51	54	62	59	81	88	90	100	97
Beaver	Roosevelt, Cove Fort, Thermo	Per capita unemployment insurance benefits	17	17	21	23	17	22	84	53	44	35	42	44	46	74	73	44

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Beaver	Roosevelt, Cove Fort, Thermo	Per capita retirement and other	305	367	431	479	550	623	729	832	921	986	1075	1159	1329	1447	1546	1556
Beaver	Roosevelt, Cove Fort, Thermo	Per capita dividends, interest, and rent	312	364	403	441	490	607	665	750	859	941	1118	1308	1492	1681	1923	2204
Beaver	Roosevelt, Cove Fort, Thermo	Earnings by place of work ($000)	7765	8364	9291	10558	11614	12430	11762	13868	15682	17125	18021	19113	20379	21797	24706	28318
Beaver	Roosevelt, Cove Fort, Thermo	Wage and salary disbursements	5278	5780	6565	7370	8020	8651	8381	9520	10832	11982	13025	14617	15521	15939	18760	20661
Beaver	Roosevelt, Cove Fort, Thermo	Other labor income	254	310	386	454	517	641	671	823	1045	1243	1359	1573	1641	1731	2252	2586
Beaver	Roosevelt, Cove Fort, Thermo	Proprietors' income	2233	2274	2340	2734	3077	3138	2710	3525	3805	3900	3637	2923	3217	4127	3694	5071
Beaver	Roosevelt, Cove Fort, Thermo	Nonfarm proprietors' income	1307	1284	1431	1578	1643	1834	2252	2836	3174	3366	3452	3580	3323	3346	3542	4384
Beaver	Roosevelt, Cove Fort, Thermo	Farm proprietors' income	926	990	909	1156	1434	1304	458	689	631	534	185	-657	-106	781	152	687
Beaver	Roosevelt, Cove Fort, Thermo	Total full-time and part-time employment	1781	1711	1779	1799	1800	1866	1808	1880	1939	1947	1874	1876	1906	1888	1984	2080
Beaver	Roosevelt, Cove Fort, Thermo	Wage and salary jobs	1238	1189	1259	1306	1317	1343	1284	1347	1383	1369	1268	1243	1277	1241	1309	1430
Beaver	Roosevelt, Cove Fort, Thermo	Number of proprietors	543	522	520	493	483	523	524	533	556	578	606	633	629	647	675	650
Beaver	Roosevelt, Cove Fort, Thermo	Number of nonfarm proprietors 5/	293	285	294	278	278	324	322	328	346	368	393	417	409	423	435	409
Beaver	Roosevelt, Cove Fort, Thermo	Number of farm proprietors	250	237	226	215	205	199	202	205	210	210	213	216	220	224	240	241
Beaver	Roosevelt, Cove Fort, Thermo	Average earnings per job (dollars)	4360	4888	5223	5869	6452	6661	6506	7377	8088	8796	9616	10188	10692	11545	12453	13614
Beaver	Roosevelt, Cove Fort, Thermo	Average wage and salary disbursements	4263	4861	5214	5643	6090	6442	6527	7068	7832	8752	10272	11759	12154	12844	14332	14448
Beaver	Roosevelt, Cove Fort, Thermo	Average nonfarm proprietors' income	4461	4505	4867	5676	5910	5660	6994	8646	9173	9147	8784	8585	8125	7910	8143	10719
Box Elder	Crystal-Madsen HS	Personal income (thousands of dollars)	88089	95061	102450	114118	125738	139763	146135	163561	179756	205156	236679	271516	307918	333428	366268	403079
Box Elder	Crystal-Madsen HS	Nonfarm personal income	78202	83578	91949	103285	109459	121927	136743	155640	175723	199259	230737	268135	308303	333042	366520	401367
Box Elder	Crystal-Madsen HS	Farm income	9887	11483	10501	10833	16279	17836	9392	7921	4033	5897	5942	3381	-385	386	-252	1712
Box Elder	Crystal-Madsen HS	Net earnings 1/	72760	76977	81471	90742	99969	110760	112744	126137	137745	157293	180508	201733	224607	239165	262426	289197
Box Elder	Crystal-Madsen HS	Transfer payments	5576	6826	8400	9445	10847	11960	14224	15704	17208	18915	20826	24804	29199	32733	34540	35774
Box Elder	Crystal-Madsen HS	Income maintenance 2/	361	514	782	1062	1068	907	1029	1306	1215	1288	1124	1767	2097	2403	2515	2541
Box Elder	Crystal-Madsen HS	Unemployment insurance benefit payments	324	493	703	593	761	893	1441	1479	1244	950	1111	1344	1479	2377	1603	848
Box Elder	Crystal-Madsen HS	Retirement and other	4891	5819	6915	7790	9018	10160	11754	12919	14749	16677	18591	21693	25623	27953	30422	32385
Box Elder	Crystal-Madsen HS	Dividends, interest, and rent	9753	11258	12579	13931	14922	17043	19167	21720	24803	28948	35345	44979	54112	61530	69302	78108
Box Elder	Crystal-Madsen HS	Population (number of persons) 3/	27600	28185	28535	29133	29228	29181	29623	30247	30844	31547	32441	33455	34313	34805	35223	35829
Box Elder	Crystal-Madsen HS	Per capita personal income	3192	3373	3590	3917	4302	4790	4933	5408	5828	6503	7296	8116	8974	9580	10399	11250
Box Elder	Crystal-Madsen HS	Per capita net earnings	2636	2731	2855	3115	3420	3796	3806	4170	4466	4986	5564	6030	6546	6872	7450	8072
Box Elder	Crystal-Madsen HS	Per capita transfer payments	202	242	294	324	371	410	480	519	558	600	642	741	851	940	981	998
Box Elder	Crystal-Madsen HS	Per capita income maintenance	13	18	27	36	37	31	35	43	39	41	35	53	61	69	71	71
Box Elder	Crystal-Madsen HS	Per capita unemployment insurance benefits	12	17	25	20	26	31	49	49	40	30	34	40	43	68	46	24
Box Elder	Crystal-Madsen HS	Per capita retirement and other	177	206	242	267	309	348	397	427	478	529	573	648	747	803	864	904
Box Elder	Crystal-Madsen HS	Per capita dividends, interest, and rent	353	399	441	478	511	584	647	718	804	918	1090	1344	1577	1768	1968	2180
Box Elder	Crystal-Madsen HS	Earnings by place of work ($000)	64574	69273	73625	85984	96279	107948	111354	125550	139193	161116	189260	212690	245880	268024	303532	341830
Box Elder	Crystal-Madsen HS	Wage and salary disbursements	47205	49876	53457	63516	67338	74995	83368	94791	107684	125516	150498	172591	204199	221643	250112	282493
Box Elder	Crystal-Madsen HS	Other labor income	3319	3753	4495	5760	6190	7676	9626	11649	14879	16885	19659	23682	29375	34074	38477	39407
Box Elder	Crystal-Madsen HS	Proprietors' income	14050	15644	15673	16708	22751	25277	18360	19110	16630	18715	19103	16417	12306	12307	14943	19930
Box Elder	Crystal-Madsen HS	Nonfarm proprietors' income	6323	6305	7258	7787	8816	10109	11731	14245	15801	17167	17658	17551	16977	16592	19525	22366
Box Elder	Crystal-Madsen HS	Farm proprietors' income	7727	9339	8415	8921	13935	15168	6629	4865	829	1548	1445	-1134	-4671	-4285	-4582	-2436
Box Elder	Crystal-Madsen HS	Total full-time and part-time employment	11072	11213	11017	11899	12134	12293	12500	12827	13370	14148	15064	15530	15935	15643	16259	17150
Box Elder	Crystal-Madsen HS	Wage and salary jobs	8285	8425	8417	9288	9580	9611	9801	10124	10684	11498	12297	12626	13066	12757	13267	14074
Box Elder	Crystal-Madsen HS	Number of proprietors	2787	2788	2600	2611	2554	2682	2699	2703	2686	2650	2767	2904	2869	2886	2992	3076
Box Elder	Crystal-Madsen HS	Number of nonfarm proprietors 5/	1329	1368	1205	1248	1219	1332	1422	1480	1499	1496	1626	1776	1730	1787	1819	1908
Box Elder	Crystal-Madsen HS	Number of farm proprietors	1458	1420	1395	1363	1335	1350	1277	1223	1187	1154	1141	1128	1139	1099	1173	1168
Box Elder	Crystal-Madsen HS	Average earnings per job (dollars)	5832	6178	6683	7226	7935	8781	8908	9788	10411	11388	12564	13695	15430	17134	18669	19932
Box Elder	Crystal-Madsen HS	Average wage and salary disbursements	5698	5920	6351	6839	7029	7803	8506	9363	10079	10916	12239	13669	15628	17374	18852	20072
Box Elder	Crystal-Madsen HS	Average nonfarm proprietors' income	4758	4609	6023	6240	7232	7589	8250	9625	10541	11475	10860	9882	9813	9285	10734	11722
Davis	Hooper HS	Personal income (thousands of dollars)	289316	317694	366188	402818	446382	511016	575002	666920	764347	889464	1027212	1177454	1344319	1486355	1624788	1819599

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Davis	Hooper HS	Nonfarm personal income	286064	314479	362751	398506	441443	507407	572081	663243	761144	885551	1021227	1171317	1340187	1481994	1620556	1815395
Davis	Hooper HS	Farm income	3252	3215	3437	4312	4939	3609	2921	3677	3203	3913	5985	6137	4132	4361	4232	4204
Davis	Hooper HS	Net earnings 1/	245980	266019	305973	336018	370433	422889	471915	548579	629841	732709	832977	934022	1049711	1141472	1236369	1387461
Davis	Hooper HS	Transfer payments	14324	17201	20438	23149	27536	31474	39576	43862	49434	54160	64304	77190	91507	106509	114545	118630
Davis	Hooper HS	Income maintenance 2/	1086	1462	1617	1771	1974	2004	2334	2899	3152	2733	4036	5508	5930	6546	7427	7549
Davis	Hooper HS	Unemployment insurance benefit payments	962	1105	1452	1620	1711	2160	4424	3663	3416	3053	3708	5999	7220	9827	8891	4780
Davis	Hooper HS	Retirement and other	12276	14634	17369	19758	23851	27310	32818	37300	42866	48374	56560	65683	78357	90136	98227	106301
Davis	Hooper HS	Dividends, interest, and rent	29012	34474	39777	43651	48413	56653	63511	74479	85072	102595	129931	166242	203101	238374	273874	313508
Davis	Hooper HS	Population (number of persons) 3/	97000	99760	103665	105296	110035	112078	117173	120786	126880	133807	140324	147884	152924	158043	162239	165723
Davis	Hooper HS	Per capita personal income	2983	3185	3532	3826	4057	4559	4907	5522	6024	6647	7320	7962	8791	9405	10015	10980
Davis	Hooper HS	Per capita net earnings	2536	2667	2952	3191	3367	3773	4028	4542	4964	5476	5936	6316	6864	7223	7621	8372
Davis	Hooper HS	Per capita transfer payments	148	172	197	220	250	281	338	363	390	405	458	522	598	674	706	716
Davis	Hooper HS	Per capita income maintenance	11	15	16	17	18	18	20	24	25	20	29	37	39	41	46	46
Davis	Hooper HS	Per capita unemployment insurance benefits	10	11	14	15	16	19	38	30	27	23	26	41	47	62	55	29
Davis	Hooper HS	Per capita retirement and other	127	147	168	188	217	244	280	309	338	362	403	444	512	570	605	641
Davis	Hooper HS	Per capita dividends, interest, and rent	299	346	384	415	440	505	542	617	670	767	926	1124	1328	1508	1688	1892
Davis	Hooper HS	Earnings by place of work ($000)	296844	327971	395745	407227	435885	501528	554725	628546	708863	797573	886226	967311	1094266	1176837	1243184	1387182
Davis	Hooper HS	Wage and salary disbursements	257938	284309	335432	340070	362994	411137	442988	490149	541619	615802	679009	734024	833549	894840	934451	1026348
Davis	Hooper HS	Other labor income	19604	23489	36975	38861	41638	55995	72029	86572	108567	118854	138979	161359	189541	208059	222683	254122
Davis	Hooper HS	Proprietors' income	19302	20173	23338	28296	31253	34396	39708	51825	58677	62917	68238	71928	71176	73938	86050	106712
Davis	Hooper HS	Nonfarm proprietors' income	17117	18025	20953	24949	27469	32126	38097	49541	56883	60869	64323	68018	69286	72181	84330	105043
Davis	Hooper HS	Farm proprietors' income	2185	2148	2385	3347	3784	2270	1611	2284	1794	2048	3915	3910	1890	1757	1720	1669
Davis	Hooper HS	Total full-time and part-time employment	40762	41222	42601	44673	46079	47740	48746	50947	53916	56972	59584	59978	61778	62848	63953	68004
Davis	Hooper HS	Wage and salary jobs	36837	37239	38452	40189	41152	42285	42851	44339	46871	49659	51709	51370	52888	53497	54196	57479
Davis	Hooper HS	Number of proprietors	3925	3983	4149	4484	4927	5455	5895	6608	7045	7313	7875	8608	8890	9351	9757	10525
Davis	Hooper HS	Number of nonfarm proprietors 5/	3331	3411	3596	3950	4410	4936	5356	6050	6468	6719	7262	7976	8243	8684	9047	9822
Davis	Hooper HS	Number of farm proprietors	594	572	553	534	517	519	539	558	577	594	613	632	647	667	710	703
Davis	Hooper HS	Average earnings per job (dollars)	7282	7956	9290	9116	9460	10505	11380	12337	13148	13999	14874	16128	17713	18725	19439	20399
Davis	Hooper HS	Average wage and salary disbursements	7002	7635	8723	8462	8821	9723	10338	11055	11556	12401	13131	14289	15761	16727	17242	17856
Davis	Hooper HS	Average nonfarm proprietors' income	5139	5284	5827	6316	6229	6509	7113	8189	8795	9059	8857	8528	8405	8312	9321	10695
Iron	Newcastle	Personal income (thousands of dollars)	33299	34682	40061	44976	49989	55327	61433	71515	83237	94197	107497	119436	126260	137268	151499	168799
Iron	Newcastle	Nonfarm personal income	30234	32258	37626	41928	45844	51902	59526	68964	80265	92410	104626	117136	125040	136032	150839	166291
Iron	Newcastle	Farm income	3065	2424	2435	3048	4145	3425	1907	2551	2972	1787	2871	2300	1220	1236	660	2508
Iron	Newcastle	Net earnings 1/	26576	26687	30881	34491	37988	41224	44731	52331	61654	69114	76698	81019	83508	87357	95570	109086
Iron	Newcastle	Transfer payments	2526	3041	3614	4183	4855	5643	7292	8304	9139	10294	11944	15186	16971	18959	20381	20799
Iron	Newcastle	Income maintenance 2/	149	191	205	202	193	232	294	383	414	484	532	810	1043	1315	1665	1769
Iron	Newcastle	Unemployment insurance benefit payments	124	145	157	286	256	257	633	729	556	416	479	1281	1069	1568	1316	839
Iron	Newcastle	Retirement and other	2253	2705	3252	3695	4406	5154	6365	7192	8169	9394	10933	13095	14859	16076	17400	18191
Iron	Newcastle	Dividends, interest, and rent	4197	4954	5566	6302	7146	8460	9410	10880	12444	14789	18855	23231	25781	30952	35548	38914
Iron	Newcastle	Population (number of persons) 3/	11900	12314	12846	13236	13718	14110	14722	15172	15546	16244	16840	17429	17714	18294	18704	19273
Iron	Newcastle	Per capita personal income	2798	2816	3119	3398	3644	3921	4173	4714	5354	5799	6383	6853	7128	7503	8100	8758
Iron	Newcastle	Per capita net earnings	2233	2167	2404	2606	2769	2922	3038	3449	3966	4255	4555	4649	4714	4775	5110	5660
Iron	Newcastle	Per capita transfer payments	212	247	281	316	354	400	495	547	588	634	709	871	958	1036	1090	1079
Iron	Newcastle	Per capita income maintenance	13	16	16	15	14	16	20	25	27	30	32	46	59	72	89	92
Iron	Newcastle	Per capita unemployment insurance benefits	10	12	12	22	19	18	43	48	36	26	28	73	60	86	70	44
Iron	Newcastle	Per capita retirement and other	189	220	253	279	321	365	432	474	525	578	649	751	839	879	930	944
Iron	Newcastle	Per capita dividends, interest, and rent	353	402	433	476	521	600	639	717	800	910	1120	1333	1455	1692	1901	2019
Iron	Newcastle	Earnings by place of work ($000)	27548	27565	32050	35799	39530	43096	46843	54728	64635	72937	81103	85102	88972	92965	101602	115305

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Iron	Newcastle	Wage and salary disbursements	19082	19889	23191	25245	27474	30646	34177	38682	44942	53510	60225	63936	69185	72903	79228	87130
Iron	Newcastle	Other labor income	1054	1221	1520	1775	2051	2498	3191	3998	5314	6436	7506	8228	8611	9323	10547	11368
Iron	Newcastle	Proprietors' income	7412	6455	7339	8779	10005	9952	9475	12048	14379	12991	13372	12938	11176	10739	11827	16807
Iron	Newcastle	Nonfarm proprietors' income	5022	4702	5560	6333	6598	7366	8458	10496	12470	12661	12066	12271	11569	11313	12915	16049
Iron	Newcastle	Farm proprietors' income	2390	1753	1779	2446	3407	2586	1017	1552	1909	330	1306	667	-393	-574	-1088	758
Iron	Newcastle	Total full-time and part-time employment	5170	5202	5571	5762	5939	6168	6449	6624	6854	7171	7434	7376	7456	7635	8022	8341
Iron	Newcastle	Wage and salary jobs	4039	4078	4440	4620	4781	4930	5144	5252	5474	5798	6022	5910	5973	6104	6423	6712
Iron	Newcastle	Number of proprietors	1131	1124	1131	1142	1158	1238	1305	1372	1380	1373	1412	1466	1483	1531	1599	1629
Iron	Newcastle	Number of nonfarm proprietors 5/	692	710	737	769	805	885	951	1016	1020	1009	1040	1087	1094	1137	1181	1216
Iron	Newcastle	Number of farm proprietors	439	414	394	373	353	353	354	356	360	364	372	379	389	394	418	413
Iron	Newcastle	Average earnings per job (dollars)	5328	5299	5753	6213	6656	6987	7264	8262	9430	10171	10910	11538	11933	12176	12665	13824
Iron	Newcastle	Average wage and salary disbursements	4724	4877	5223	5464	5746	6216	6644	7365	8210	9229	10001	10818	11583	11943	12335	12981
Iron	Newcastle	Average nonfarm proprietors' income	7257	6623	7544	8235	8196	8323	8894	10331	12225	12548	11602	11289	10575	9950	10936	13198
Juab	Drum Mountains	Personal income (thousands of dollars)	11254	12034	12906	14489	16461	18290	19517	22182	25914	28183	33945	38421	45539	43738	46390	52321
Juab	Drum Mountains	Nonfarm personal income	10181	10853	11919	13286	15040	17036	18679	20940	24201	27696	33501	37905	45031	43346	45994	51106
Juab	Drum Mountains	Farm income	1073	1181	987	1203	1421	1254	838	1242	1713	487	444	516	508	392	396	1215
Juab	Drum Mountains	Net earnings 1/	8809	9145	9586	10804	12143	13307	13722	15589	18340	19318	23343	25650	31182	25700	26582	31183
Juab	Drum Mountains	Transfer payments	1324	1624	1947	2187	2579	2916	3462	3705	4088	4644	5244	6342	6756	8505	9301	9080
Juab	Drum Mountains	Income maintenance 2/	131	157	183	165	165	231	249	286	283	295	281	428	385	433	539	540
Juab	Drum Mountains	Unemployment insurance benefit payments	71	130	197	196	161	191	253	213	236	231	238	485	307	1457	1456	757
Juab	Drum Mountains	Retirement and other	1122	1337	1567	1826	2253	2494	2960	3206	3569	4118	4725	5429	6064	6615	7306	7783
Juab	Drum Mountains	Dividends, interest, and rent	1121	1265	1373	1498	1739	2067	2333	2888	3486	4221	5358	6429	7601	9533	10507	12058
Juab	Drum Mountains	Population (number of persons) 3/	4500	4577	4645	4776	4922	4884	4972	5010	5144	5317	5442	5547	5607	5711	5863	6027
Juab	Drum Mountains	Per capita personal income	2501	2629	2778	3034	3344	3745	3925	4428	5038	5301	6238	6926	8122	7659	7912	8681
Juab	Drum Mountains	Per capita net earnings	1958	1998	2064	2262	2467	2725	2760	3112	3565	3633	4289	4624	5561	4500	4534	5174
Juab	Drum Mountains	Per capita transfer payments	294	355	419	458	524	597	696	740	795	873	964	1143	1205	1489	1586	1507
Juab	Drum Mountains	Per capita income maintenance	29	34	39	35	34	47	50	57	55	55	52	77	69	76	92	90
Juab	Drum Mountains	Per capita unemployment insurance benefits	16	28	42	41	33	39	51	43	46	43	44	87	55	255	248	126
Juab	Drum Mountains	Per capita retirement and other	249	292	337	382	458	511	595	640	694	774	868	979	1082	1158	1246	1291
Juab	Drum Mountains	Per capita dividends, interest, and rent	249	276	296	314	353	423	469	576	678	794	985	1159	1356	1669	1792	2001
Juab	Drum Mountains	Earnings by place of work ($000)	11382	11633	11947	12853	14157	15263	15186	16282	18456	18888	23849	26707	33985	24320	24021	26113
Juab	Drum Mountains	Wage and salary disbursements	8203	8297	8502	8735	9792	10784	10876	11207	12342	13596	17722	20570	27674	18698	17815	18986
Juab	Drum Mountains	Other labor income	552	570	643	664	773	920	999	1121	1302	1452	1935	2212	2777	2141	2174	2295
Juab	Drum Mountains	Proprietors' income	2627	2766	2802	3454	3592	3559	3311	3954	4812	3840	4192	3925	3534	3481	4032	4832
Juab	Drum Mountains	Nonfarm proprietors' income	1737	1758	1975	2390	2333	2473	2685	2980	3408	3791	4253	3972	3610	3783	4306	4291
Juab	Drum Mountains	Farm proprietors' income	890	1008	827	1064	1259	1086	626	974	1404	(L)	-61	(L)	-76	-302	-274	541
Juab	Drum Mountains	Total full-time and part-time employment	2215	2136	2092	2087	2144	2251	2200	2199	2312	2313	2350	2416	2579	2219	2166	2190
Juab	Drum Mountains	Wage and salary jobs	1723	1663	1639	1628	1682	1771	1707	1676	1775	1763	1797	1858	1987	1636	1569	1601
Juab	Drum Mountains	Number of proprietors	492	473	453	459	462	480	493	523	537	550	553	558	592	583	597	589
Juab	Drum Mountains	Number of nonfarm proprietors 5/	257	242	226	235	241	250	258	282	290	302	309	318	348	350	350	346
Juab	Drum Mountains	Number of farm proprietors	235	231	227	224	221	230	235	241	247	248	244	240	244	233	247	243
Juab	Drum Mountains	Average earnings per job (dollars)	5139	5446	5711	6159	6603	6781	6903	7404	7983	8166	10149	11054	13178	10960	11090	11924
Juab	Drum Mountains	Average wage and salary disbursements	4761	4989	5187	5365	5822	6089	6371	6687	6953	7712	9862	11071	13928	11429	11354	11859
Juab	Drum Mountains	Average nonfarm proprietors' income	6759	7264	8739	10170	9680	9892	10407	10567	11752	12553	13764	12491	10374	10809	12303	12402
Millard	Drum Mountains	Personal income (thousands of dollars)	18919	19952	22706	25752	29596	31683	31629	34793	36330	42273	48183	53151	59998	69695	95576	135586
Millard	Drum Mountains	Nonfarm personal income	15554	15458	17830	19200	20274	23538	26903	29234	31936	36011	41736	49046	57913	66809	92877	129923
Millard	Drum Mountains	Farm income	3365	4494	4876	6552	9322	8145	4726	5559	4394	6262	6447	4105	2085	2886	2699	5663
Millard	Drum Mountains	Net earnings 1/	14598	14986	17037	19302	22243	22983	21657	23390	23497	27472	30590	31575	34637	40024	61774	96436

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Millard	Drum Mountains	Transfer payments	2034	2325	2684	3109	3602	4209	4863	5381	5708	6476	7165	8337	9424	11048	11910	12551
Millard	Drum Mountains	Income maintenance 2/	80	101	106	162	165	238	225	322	323	399	390	574	658	699	817	829
Millard	Drum Mountains	Unemployment insurance benefit payments	84	102	114	128	124	154	265	235	166	160	142	302	253	755	830	575
Millard	Drum Mountains	Retirement and other	1870	2122	2464	2819	3313	3817	4373	4824	5219	5917	6633	7461	8513	9594	10263	11147
Millard	Drum Mountains	Dividends, interest, and rent	2287	2641	2985	3341	3751	4491	5109	6022	7125	8325	10428	13239	15937	18623	21892	26599
Millard	Drum Mountains	Population (number of persons) 3/	7000	7026	7258	7555	7611	7625	7985	8230	8377	8450	8874	9080	9498	10166	11052	12554
Millard	Drum Mountains	Per capita personal income	2703	2840	3128	3409	3889	4155	3961	4228	4337	5003	5430	5854	6317	6856	8648	10800
Millard	Drum Mountains	Per capita net earnings	2085	2133	2347	2555	2922	3014	2712	2842	2805	3251	3447	3477	3647	3937	5589	7682
Millard	Drum Mountains	Per capita transfer payments	291	331	370	412	473	552	609	654	681	766	807	918	992	1087	1078	1000
Millard	Drum Mountains	Per capita income maintenance	11	14	15	21	22	31	28	39	39	47	44	63	69	69	74	66
Millard	Drum Mountains	Per capita unemployment insurance benefits	12	15	16	17	16	20	33	29	20	19	16	33	27	74	75	46
Millard	Drum Mountains	Per capita retirement and other	267	302	339	373	435	501	548	586	623	700	747	822	896	944	929	888
Millard	Drum Mountains	Per capita dividends, interest, and rent	327	376	411	442	493	589	640	732	851	985	1175	1458	1678	1832	1981	2119
Millard	Drum Mountains	Earnings by place of work ($000)	14751	15035	17262	19601	22587	23540	22511	24151	24307	28644	32307	33942	37303	43936	73995	120739
Millard	Drum Mountains	Wage and salary disbursements	8980	7937	9410	9650	9751	11314	13436	13915	15091	18017	20350	23445	27972	33249	59654	97475
Millard	Drum Mountains	Other labor income	440	462	587	647	723	958	1206	1350	1547	1871	2312	2887	3593	4063	6828	10695
Millard	Drum Mountains	Proprietors' income	5331	6636	7265	9304	12113	11268	7869	8886	7669	8756	9645	7610	5738	6624	7513	12569
Millard	Drum Mountains	Nonfarm proprietors' income	2769	2978	3242	3571	3852	4367	4883	5625	5987	6550	7085	7087	6743	6821	7672	9657
Millard	Drum Mountains	Farm proprietors' income	2562	3658	4023	5733	8261	6901	2986	3261	1682	2206	2560	523	-1005	-197	-159	2912
Millard	Drum Mountains	Total full-time and part-time employment	3555	3383	3529	3495	3358	3436	3620	3615	3662	3730	3680	3787	4021	4148	5226	6701
Millard	Drum Mountains	Wage and salary jobs	2176	2037	2203	2173	2121	2163	2374	2410	2415	2462	2424	2540	2734	2821	3869	5300
Millard	Drum Mountains	Number of proprietors	1379	1346	1326	1322	1237	1273	1246	1205	1247	1268	1256	1247	1287	1327	1357	1401
Millard	Drum Mountains	Number of nonfarm proprietors 5/	559	540	529	538	463	483	498	488	551	595	593	594	630	698	691	744
Millard	Drum Mountains	Number of farm proprietors	820	806	797	784	774	790	748	717	696	673	663	653	657	629	666	657
Millard	Drum Mountains	Average earnings per job (dollars)	4149	4444	4891	5608	6726	6851	6219	6681	6638	7679	8779	8963	9277	10592	14159	18018
Millard	Drum Mountains	Average wage and salary disbursements	4127	3896	4271	4441	4597	5231	5660	5774	6249	7318	8395	9230	10231	11786	15418	18392
Millard	Drum Mountains	Average nonfarm proprietors' income	4953	5515	6129	6638	8320	9041	9805	11527	10866	11008	11948	11931	10703	9772	11103	12980
Weber	Utah HS, Ogden HS	Personal income (thousands of dollars)	419352	467766	523430	553008	594785	652918	719274	807296	887383	1004774	1134418	1267559	1411706	1533666	1659758	1818560
Weber	Utah HS, Ogden HS	Nonfarm personal income	415393	463622	518909	547098	587020	649321	716612	804047	884981	1001747	1131494	1265815	1411237	1532621	1659132	1817059
Weber	Utah HS, Ogden HS	Farm income	3959	4144	4521	5910	7765	3597	2662	3249	2402	3027	2924	1744	469	1045	626	1501
Weber	Utah HS, Ogden HS	Net earnings 1/	337310	370496	411762	429218	455881	494840	539373	605016	661586	745286	827243	901828	982169	1042713	1109733	1225976
Weber	Utah HS, Ogden HS	Transfer payments	31995	39335	46669	52050	61424	69682	83215	90650	98514	109859	123094	143599	166152	187829	204876	205548
Weber	Utah HS, Ogden HS	Income maintenance 2/	3527	4807	5717	6474	7155	7689	7570	8377	8706	10171	11118	15102	16393	17304	20254	19302
Weber	Utah HS, Ogden HS	Unemployment insurance benefit payments	2087	2897	3790	3771	3989	4978	9531	9222	8300	6769	7626	9773	11265	16556	16551	9092
Weber	Utah HS, Ogden HS	Retirement and other	26381	31631	37162	41805	50280	57015	66114	73051	81508	92919	104350	118724	138494	153969	168071	177154
Weber	Utah HS, Ogden HS	Dividends, interest, and rent	50047	57935	64999	71740	77480	88396	96686	111630	127283	149629	184081	222132	263385	303124	345149	387036
Weber	Utah HS, Ogden HS	Population (number of persons) 3/	125500	126703	129153	132700	132016	134174	135455	137696	139002	140822	143225	145405	148229	150858	153305	154831
Weber	Utah HS, Ogden HS	Per capita personal income	3341	3692	4053	4167	4505	4866	5310	5863	6384	7135	7921	8717	9524	10166	10827	11745
Weber	Utah HS, Ogden HS	Per capita net earnings	2688	2924	3188	3234	3453	3688	3982	4394	4760	5292	5776	6202	6626	6912	7239	7918
Weber	Utah HS, Ogden HS	Per capita transfer payments	255	310	361	392	465	519	614	658	709	780	859	988	1121	1245	1336	1328
Weber	Utah HS, Ogden HS	Per capita income maintenance	28	38	44	49	54	57	56	61	63	72	78	104	111	115	132	125
Weber	Utah HS, Ogden HS	Per capita unemployment insurance benefits	17	23	29	28	30	37	70	67	60	48	53	67	76	110	108	59
Weber	Utah HS, Ogden HS	Per capita retirement and other	210	250	288	315	381	425	488	531	586	660	729	817	934	1021	1096	1144
Weber	Utah HS, Ogden HS	Per capita dividends, interest, and rent	399	457	503	541	587	659	714	811	916	1063	1285	1528	1777	2009	2251	2500
Weber	Utah HS, Ogden HS	Earnings by place of work ($000)	271961	293466	316323	340192	365994	391725	435437	499078	549126	627905	711071	782352	852924	904096	964478	1081069
Weber	Utah HS, Ogden HS	Wage and salary disbursements	226852	246517	261193	277940	298989	319377	348980	392348	426531	491584	560477	620898	683369	725609	764987	858130
Weber	Utah HS, Ogden HS	Other labor income	13156	15554	19895	21666	23183	28066	36157	44912	54620	62370	72472	85228	97936	107213	116158	126952
Weber	Utah HS, Ogden HS	Proprietors' income	31953	31395	35235	40586	43822	44282	50300	61818	67975	73951	78122	76226	71619	71274	83333	95987

County/Area Name	Geothermal Site(s)	Line Title	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
Weber	Utah HS, Ogden HS	Nonfarm proprietors' income	28957	28208	31655	35537	37114	41912	48782	59728	66701	72362	76829	76270	72972	72399	84754	96482
Weber	Utah HS, Ogden HS	Farm proprietors' income	2996	3187	3580	5049	6708	2370	1518	2090	1274	1589	1293	(L)	-1353	-1125	-1421	-495
Weber	Utah HS, Ogden HS	Total full-time and part-time employment	47439	47599	47535	49009	49992	50720	51246	53308	54445	57359	59822	60822	61122	61452	62320	66424
Weber	Utah HS, Ogden HS	Wage and salary jobs	41879	41873	41674	42851	43298	43756	44077	45484	46350	49186	51495	52131	52471	52291	52919	56654
Weber	Utah HS, Ogden HS	Number of proprietors	5560	5726	5861	6158	6694	6964	7169	7824	8095	8173	8327	8691	8651	9161	9401	9770
Weber	Utah HS, Ogden HS	Number of nonfarm proprietors 5/	4903	5082	5226	5536	6081	6350	6497	7101	7324	7360	7481	7811	7746	8218	8397	8778
Weber	Utah HS, Ogden HS	Number of farm proprietors	657	644	635	622	613	614	672	723	771	813	846	880	905	943	1004	992
Weber	Utah HS, Ogden HS	Average earnings per job (dollars)	5733	6165	6655	6941	7321	7723	8497	9362	10086	10947	11886	12863	13954	14712	15476	16275
Weber	Utah HS, Ogden HS	Average wage and salary disbursements	5417	5887	6268	6486	6905	7299	7918	8626	9202	9994	10884	11910	13024	13876	14456	15147
Weber	Utah HS, Ogden HS	Average nonfarm proprietors' income	5906	5551	6057	6419	6103	6600	7508	8411	9107	9832	10270	9764	9421	8810	10093	10991

Source: Regional Economic Information System (REIS), U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis

Appendix E: County Economic Profiles, 1985-2000 (Part 2)

County/Area Name	Geothermal Site(s)	Line Title	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
State of Utah Total	All	Personal income (thousands of dollars)	19462380	20367186	21208237	22224834	23842737	25938559	27749681	29788209	31950465	34578711	37278220	40354052	43695891	46771866	49148488	52532150
State of Utah Total	All	Nonfarm personal income	19400797	20275972	21085261	22017100	23641088	25692701	27525972	29526244	31641474	34366221	37116278	40192059	43511260	46536619	48906190	52318277
State of Utah Total	All	Farm income	61583	91214	122976	207734	201649	245858	223709	261965	308991	212490	161942	161993	184631	235247	242298	213873
State of Utah Total	All	Net earnings 1/	13647979	14186701	14799019	15686779	16723250	18305764	19625711	21301865	22951182	24869336	26778451	28999948	31422210	33802393	35965210	38442052
State of Utah Total	All	Transfer payments	1864706	2038776	2210780	2300466	2515027	2811912	3145696	3507806	3819046	3907690	4206303	4445237	4695143	4857465	5053197	5329154
State of Utah Total	All	Income maintenance 2/	146606	161093	172031	189101	212210	232577	268861	317561	335255	346800	372156	377285	395795	393364	396748	407578
State of Utah Total	All	Unemployment insurance benefit payments	90880	107549	104433	72506	62984	65138	83532	125815	115311	80726	70379	78072	81895	94618	103769	119195
State of Utah Total	All	Retirement and other	1627220	1770134	1934316	2038859	2239833	2514197	2793303	3064430	3368480	3480164	3763768	3989880	4217453	4369483	4552680	4802381
State of Utah Total	All	Dividends, interest, and rent	3949695	4141709	4198438	4237589	4604460	4820883	4978274	4978538	5180237	5801685	6293466	6908867	7578538	8112008	8130081	8760944
State of Utah Total	All	Population (number of persons) 3/	1642910	1662833	1678120	1689372	1705865	1731223	1779780	1836799	1898404	1960446	2014177	2067976	2119784	2165960	2203482	2241555
State of Utah Total	All	Per capita personal income	11846	12248	12638	13156	13977	14983	15592	16217	16830	17638	18508	19514	20613	21594	22305	23436
State of Utah Total	All	Per capita net earnings	8307	8532	8819	9286	9803	10574	11027	11597	12090	12686	13295	14023	14823	15606	16322	17150
State of Utah Total	All	Per capita transfer payments	1135	1226	1317	1362	1474	1624	1767	1910	2012	1993	2088	2150	2215	2243	2293	2377
State of Utah Total	All	Per capita income maintenance	89	97	103	112	124	134	151	173	177	177	185	182	187	182	180	182
State of Utah Total	All	Per capita unemployment insurance benefits	55	65	62	43	37	38	47	68	61	41	35	38	39	44	47	53
State of Utah Total	All	Per capita retirement and other	990	1065	1153	1207	1313	1452	1569	1668	1774	1775	1869	1929	1990	2017	2066	2142
State of Utah Total	All	Per capita dividends, interest, and rent	2404	2491	2502	2508	2699	2785	2797	2710	2729	2959	3125	3341	3575	3745	3690	3908
State of Utah Total	All	Earnings by place of work ($000)	14363975	14956180	15615284	16601314	17722796	19394299	20822512	22589636	24338474	26394365	28445169	30776565	33341511	35818914	38115200	40714426
State of Utah Total	All	Wage and salary disbursements	11442061	11855636	12344083	13168597	14083691	15277156	16392118	17706893	18846698	20504109	22469839	24498371	26653006	28613569	30463491	32670915
State of Utah Total	All	Other labor income	1584194	1648868	1747979	1823135	2000625	2236417	2509524	2779614	3022283	3230501	3280752	3382190	3320431	3523262	3661973	3852293
State of Utah Total	All	Proprietors' income	1337720	1451676	1523222	1609582	1638480	1880726	1920870	2103129	2469493	2659755	2694578	2896004	3368074	3682083	3989736	4191218
State of Utah Total	All	Nonfarm proprietors' income	1322398	1402555	1440904	1448728	1487765	1694980	1755930	1900573	2228349	2532437	2622062	2820982	3279036	3545348	3844398	4088276
State of Utah Total	All	Farm proprietors' income	15322	49121	82318	160854	150715	185746	164940	202556	241144	127318	72516	75022	89038	136735	145338	102942
State of Utah Total	All	Total full-time and part-time employment	792763	805392	835108	870184	903052	944622	967063	985619	1033804	1111548	1160232	1228442	1281882	1321435	1358714	1394198
State of Utah Total	All	Wage and salary jobs	667222	677082	686385	711736	743563	778448	798411	822026	861598	910656	960116	1010602	1052591	1083329	1111003	1138088
State of Utah Total	All	Number of proprietors	125541	128310	148723	158448	159489	166174	168652	163593	172206	200892	200116	217840	229291	238106	247711	256110
State of Utah Total	All	Number of nonfarm proprietors 5/	110609	113697	134483	144652	145847	152403	154835	149820	157209	186089	184868	202817	214246	222821	232006	240410
State of Utah Total	All	Number of farm proprietors	14932	14613	14240	13796	13642	13771	13817	13773	14997	14803	15248	15023	15045	15285	15705	15700
State of Utah Total	All	Average earnings per job (dollars)	18119	18570	18699	19078	19625	20531	21532	22919	23543	23746	24517	25053	26010	27106	28052	29203
State of Utah Total	All	Average wage and salary disbursements	17149	17510	17984	18502	18941	19625	20531	21541	21874	22516	23403	24241	25321	26413	27420	28707
State of Utah Total	All	Average nonfarm proprietors' income	11956	12336	10714	10015	10201	11122	11341	12686	14174	13609	14183	13909	15305	15911	16570	17005
Beaver	Roosevelt, Cove Fort, Thermo	Personal income (thousands of dollars)	50148	47596	49485	52882	55903	59556	63048	65353	72310	70839	74316	84288	92686	100830	110193	128549
Beaver	Roosevelt, Cove Fort, Thermo	Nonfarm personal income	49694	46449	45216	46544	50359	52958	58044	60044	65823	66222	70144	75696	80471	84573	87176	91463
Beaver	Roosevelt, Cove Fort, Thermo	Farm income	454	1147	4269	6338	5544	6598	5004	5309	6487	4617	4172	8592	12215	16257	23017	37086
Beaver	Roosevelt, Cove Fort, Thermo	Net earnings 1/	28396	25511	27397	30714	31722	34600	36886	37194	40045	41212	42241	50618	56813	63476	71888	87656
Beaver	Roosevelt, Cove Fort, Thermo	Transfer payments	8909	9206	9876	10422	11644	12629	13452	15998	16586	16782	18190	18956	19760	19726	20369	21612
Beaver	Roosevelt, Cove Fort, Thermo	Income maintenance 2/	423	544	558	633	728	873	751	1054	971	1124	1133	1323	1454	1333	1353	1435
Beaver	Roosevelt, Cove Fort, Thermo	Unemployment insurance benefit payments	448	256	247	182	150	148	183	279	284	181	183	270	283	272	229	283
Beaver	Roosevelt, Cove Fort, Thermo	Retirement and other	8038	8406	9071	9607	10766	11608	12518	14665	15331	15477	16874	17363	18023	18121	18787	19894
Beaver	Roosevelt, Cove Fort, Thermo	Dividends, interest, and rent	12843	12879	12212	11746	12537	12327	12710	12161	15679	12845	13885	14714	16113	17628	17936	19281
Beaver	Roosevelt, Cove Fort, Thermo	Population (number of persons) 3/	5087	4968	4876	4739	4726	4769	4798	4929	5001	5159	5394	5687	5851	5883	5978	6024
Beaver	Roosevelt, Cove Fort, Thermo	Per capita personal income	9858	9581	10149	11159	11829	12488	13140	13259	14459	13731	13778	14821	15841	17139	18433	21339
Beaver	Roosevelt, Cove Fort, Thermo	Per capita net earnings	5582	5135	5619	6481	6712	7255	7688	7546	8007	7988	7831	8901	9710	10790	12025	14551
Beaver	Roosevelt, Cove Fort, Thermo	Per capita transfer payments	1751	1853	2025	2199	2464	2648	2804	3246	3317	3253	3372	3333	3377	3353	3407	3588
Beaver	Roosevelt, Cove Fort, Thermo	Per capita income maintenance	83	110	114	134	154	183	157	214	194	218	210	233	249	227	226	238
Beaver	Roosevelt, Cove Fort, Thermo	Per capita unemployment insurance benefits	88	52	51	38	32	31	38	57	57	35	34	47	48	46	38	47
Beaver	Roosevelt, Cove Fort, Thermo	Per capita retirement and other	1580	1692	1860	2027	2278	2434	2609	2975	3066	3000	3128	3053	3080	3080	3143	3302
Beaver	Roosevelt, Cove Fort, Thermo	Per capita dividends, interest, and rent	2525	2592	2505	2479	2653	2585	2649	2467	3135	2490	2574	2587	2754	2996	3000	3201
Beaver	Roosevelt, Cove Fort, Thermo	Earnings by place of work ($000)	31539	27926	29753	33638	35841	38585	41616	41639	44551	46190	48230	57658	63739	70410	78803	94475
Beaver	Roosevelt, Cove Fort, Thermo	Wage and salary disbursements	24140	20057	19087	20659	23591	24288	27820	27374	28655	31854	35566	40196	43334	46322	47181	48939
Beaver	Roosevelt, Cove Fort, Thermo	Other labor income	3168	2956	3052	2984	3406	3737	4386	4497	4703	5094	5278	5801	6134	6666	6687	6977
Beaver	Roosevelt, Cove Fort, Thermo	Proprietors' income	4231	4913	7614	9995	8844	10560	9410	9768	11193	9242	7386	11661	14271	17422	24935	38559
Beaver	Roosevelt, Cove Fort, Thermo	Nonfarm proprietors' income	5021	4954	4546	4941	4599	5406	5740	5750	6833	8060	7596	8038	8274	7576	8222	8706

County/Area Name	Geothermal Site(s)	Line Title	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Beaver	Roosevelt, Cove Fort, Thermo	Farm proprietors' income	-790	(L)	3068	5054	4245	5154	3670	4018	4360	1182	-210	3623	5997	9846	16713	29853
Beaver	Roosevelt, Cove Fort, Thermo	Total full-time and part-time employment	2169	1936	1949	2028	2040	2123	2208	2213	2301	2591	2690	2968	3146	3140	3202	3279
Beaver	Roosevelt, Cove Fort, Thermo	Wage and salary jobs	1554	1361	1379	1421	1446	1480	1575	1577	1684	1822	1934	2140	2300	2247	2276	2328
Beaver	Roosevelt, Cove Fort, Thermo	Number of proprietors	615	575	570	607	594	643	633	636	617	769	756	828	846	893	926	951
Beaver	Roosevelt, Cove Fort, Thermo	Number of nonfarm proprietors 5/	373	335	336	379	367	413	401	405	372	532	517	595	617	660	687	712
Beaver	Roosevelt, Cove Fort, Thermo	Number of farm proprietors	242	240	234	228	227	230	232	231	245	237	239	233	229	233	239	239
Beaver	Roosevelt, Cove Fort, Thermo	Average earnings per job (dollars)	14541	14425	15266	16587	17569	18175	18848	18816	19362	17827	17929	19427	20260	22424	24611	28812
Beaver	Roosevelt, Cove Fort, Thermo	Average wage and salary disbursements	15534	14737	13841	14538	16315	16411	17663	17358	17016	17483	18390	18783	18841	20615	20730	21022
Beaver	Roosevelt, Cove Fort, Thermo	Average nonfarm proprietors' income	13461	14788	13530	13037	12531	13090	14314	14198	18368	15150	14692	13509	13410	11479	11968	12228
Box Elder	Crystal-Madsen HS	Personal income (thousands of dollars)	432649	461149	500624	515130	539625	556631	575118	616676	645666	670993	715955	779332	823607	855999	894346	956967
Box Elder	Crystal-Madsen HS	Nonfarm personal income	431459	454815	482020	490748	517768	529765	549476	583325	606480	643989	690652	753013	794659	828740	864123	934753
Box Elder	Crystal-Madsen HS	Farm income	1190	6334	18604	24382	21857	26866	25642	33351	39186	27004	25303	26319	28948	27259	30223	22214
Box Elder	Crystal-Madsen HS	Net earnings 1/	310926	330642	368186	383386	398005	410351	423680	460259	480243	497675	527986	571765	605804	628348	658786	701304
Box Elder	Crystal-Madsen HS	Transfer payments	38622	41873	44758	46156	49477	55266	59854	67148	74922	75923	82749	89870	95533	97458	102141	107852
Box Elder	Crystal-Madsen HS	Income maintenance 2/	2580	2847	2862	3081	3448	3597	3977	4755	5335	5486	5845	5875	6270	6453	6634	7027
Box Elder	Crystal-Madsen HS	Unemployment insurance benefit payments	1334	1094	1108	922	831	1017	1053	1931	2118	1439	1247	1320	1335	1617	1613	1934
Box Elder	Crystal-Madsen HS	Retirement and other	34708	37932	40788	42153	45198	50652	54824	60462	67469	68998	75657	82675	87928	89388	93894	98891
Box Elder	Crystal-Madsen HS	Dividends, interest, and rent	83101	88634	87680	85588	92143	91014	91584	89269	90501	97395	105220	117697	122270	130193	133419	147811
Box Elder	Crystal-Madsen HS	Population (number of persons) 3/	35948	36259	36562	36875	36542	36568	36864	37317	37882	38541	39077	39802	40751	41571	42378	42872
Box Elder	Crystal-Madsen HS	Per capita personal income	12035	12718	13692	13970	14767	15222	15601	16525	17044	17410	18322	19580	20211	20591	21104	22321
Box Elder	Crystal-Madsen HS	Per capita net earnings	8649	9119	10070	10397	10892	11222	11493	12334	12677	12913	13511	14365	14866	15115	15545	16358
Box Elder	Crystal-Madsen HS	Per capita transfer payments	1074	1155	1224	1252	1354	1511	1624	1799	1978	1970	2118	2258	2344	2344	2410	2516
Box Elder	Crystal-Madsen HS	Per capita income maintenance	72	79	78	84	94	98	108	127	141	142	150	148	154	155	157	164
Box Elder	Crystal-Madsen HS	Per capita unemployment insurance benefits	37	30	30	25	23	28	29	52	56	37	32	33	33	39	38	45
Box Elder	Crystal-Madsen HS	Per capita retirement and other	966	1046	1116	1143	1237	1385	1487	1620	1781	1790	1936	2077	2158	2150	2216	2307
Box Elder	Crystal-Madsen HS	Per capita dividends, interest, and rent	2312	2444	2398	2321	2522	2489	2484	2392	2389	2527	2693	2957	3000	3132	3148	3448
Box Elder	Crystal-Madsen HS	Earnings by place of work ($000)	378980	414655	480950	514435	531164	548881	562507	607965	623622	641112	666135	699107	729856	768043	740577	765200
Box Elder	Crystal-Madsen HS	Wage and salary disbursements	318326	344794	391680	417804	432200	439306	447577	474005	474386	496863	513197	540051	576130	614951	588107	615367
Box Elder	Crystal-Madsen HS	Other labor income	41555	45578	54547	56877	61829	65527	71929	80379	84509	85170	84231	77429	74250	81964	74483	77310
Box Elder	Crystal-Madsen HS	Proprietors' income	19099	24283	34723	39754	37135	44048	43001	53581	64727	59079	68707	81627	79476	71128	77987	72523
Box Elder	Crystal-Madsen HS	Nonfarm proprietors' income	21924	21541	19520	19409	19768	22588	22734	25752	32055	40503	52498	64387	60740	54391	58123	62136
Box Elder	Crystal-Madsen HS	Farm proprietors' income	-2825	2742	15203	20345	17367	21460	20267	27829	32672	18576	16209	17240	18736	16737	19864	10387
Box Elder	Crystal-Madsen HS	Total full-time and part-time employment	17937	18218	19635	20741	21000	20853	20940	20799	21003	22305	22693	23596	24751	25424	24915	24689
Box Elder	Crystal-Madsen HS	Wage and salary jobs	14818	15070	16185	17046	17285	17059	17092	17091	17188	17902	18165	18783	19714	20155	19480	19122
Box Elder	Crystal-Madsen HS	Number of proprietors	3119	3148	3450	3695	3715	3794	3848	3708	3815	4403	4528	4813	5037	5269	5435	5567
Box Elder	Crystal-Madsen HS	Number of nonfarm proprietors 5/	1953	2005	2338	2613	2636	2700	2744	2604	2603	3198	3279	3575	3788	4000	4132	4263
Box Elder	Crystal-Madsen HS	Number of farm proprietors	1166	1143	1112	1082	1079	1094	1104	1104	1212	1205	1249	1238	1249	1269	1303	1304
Box Elder	Crystal-Madsen HS	Average earnings per job (dollars)	21128	22761	24495	24803	25294	26321	26863	29230	29692	28743	29354	29628	29488	30209	29724	30994
Box Elder	Crystal-Madsen HS	Average wage and salary disbursements	21482	22879	24200	24510	25004	25752	26186	27734	27600	27755	28252	28752	29224	30511	30190	32181
Box Elder	Crystal-Madsen HS	Average nonfarm proprietors' income	11226	10744	8349	7428	7499	8366	8285	9889	12315	12665	16010	18010	16035	13598	14067	14576
Davis	Hooper HS	Personal income (thousands of dollars)	1991743	2105604	2205358	2337478	2539963	2832394	3025646	3210340	3419869	3670142	3957324	4280028	4712698	5056497	5381520	5790266
Davis	Hooper HS	Nonfarm personal income	1990283	2104312	2198073	2323832	2527298	2815629	3010400	3189604	3398571	3657389	3946499	4271653	4704202	5044962	5372961	5783863
Davis	Hooper HS	Farm income	1460	1292	7285	13646	12665	16765	15246	20736	21298	12753	10825	8375	8496	11535	8559	6403
Davis	Hooper HS	Net earnings 1/	1515426	1594006	1664108	1776063	1915199	2171705	2315978	2474218	2639789	2809132	3013727	3263771	3583701	3837938	4128798	4452568
Davis	Hooper HS	Transfer payments	132025	144223	158170	167593	187083	214882	239846	266468	292705	309582	334878	355639	385909	405311	428618	456734
Davis	Hooper HS	Income maintenance 2/	8489	8653	9949	11178	12560	15075	17989	21755	22594	24341	26128	25743	27672	27505	27187	27911
Davis	Hooper HS	Unemployment insurance benefit payments	6731	6163	6732	5203	4692	4971	6390	9722	8941	6302	5692	6222	6702	7511	8260	9507
Davis	Hooper HS	Retirement and other	116805	129407	141489	151212	169831	194836	215467	234991	261170	278939	303058	323674	351535	370295	393171	419316
Davis	Hooper HS	Dividends, interest, and rent	344292	367375	383080	393822	437681	445807	469822	469654	487375	551428	608719	660618	743088	813248	824104	880964
Davis	Hooper HS	Population (number of persons) 3/	169887	174267	179746	181733	185236	188841	193773	199199	204936	210164	214622	219687	224871	230937	235912	240259
Davis	Hooper HS	Per capita personal income	11724	12083	12269	12862	13712	14999	15614	16116	16687	17463	18439	19482	20957	21896	22812	24100
Davis	Hooper HS	Per capita net earnings	8920	9147	9258	9773	10339	11500	11952	12421	12881	13366	14042	14856	15937	16619	17501	18532
Davis	Hooper HS	Per capita transfer payments	777	828	880	922	1010	1138	1238	1338	1428	1473	1560	1619	1716	1755	1817	1901
Davis	Hooper HS	Per capita income maintenance	50	50	55	62	68	80	93	109	110	116	122	117	123	119	115	116
Davis	Hooper HS	Per capita unemployment insurance benefits	40	35	37	29	25	26	33	49	44	30	27	28	30	33	35	40

County/Area Name	Geothermal Site(s)	Line Title	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Davis	Hooper HS	Per capita retirement and other	688	743	787	832	917	1032	1112	1180	1274	1327	1412	1473	1563	1603	1667	1745
Davis	Hooper HS	Per capita dividends, interest, and rent	2027	2108	2131	2167	2363	2361	2425	2358	2378	2624	2836	3007	3305	3522	3493	3667
Davis	Hooper HS	Earnings by place of work ($000)	1514344	1569922	1569745	1649483	1789780	1916949	2026353	2103826	2216813	2318010	2496635	2614576	2809806	2990375	3179032	3470007
Davis	Hooper HS	Wage and salary disbursements	1132416	1179554	1169925	1234937	1343644	1435023	1509243	1562834	1643028	1732139	1896159	2008640	2126747	2261484	2406941	2636588
Davis	Hooper HS	Other labor income	275887	279116	280400	287810	317500	334864	356733	369154	375594	378412	392877	401370	413013	427345	446703	491240
Davis	Hooper HS	Proprietors' income	106041	111252	119420	126736	128636	147062	160377	171838	198191	207459	207599	204566	270046	301546	325388	342179
Davis	Hooper HS	Nonfarm proprietors' income	107173	112429	114641	116008	119160	134090	148857	154898	181325	200373	202839	202175	268239	296912	323610	343579
Davis	Hooper HS	Farm proprietors' income	-1132	-1177	4779	10728	9476	12972	11520	16940	16866	7086	4760	2391	1807	4634	1778	-1400
Davis	Hooper HS	Total full-time and part-time employment	71365	73535	75538	77868	81765	85921	86149	87139	90736	97566	99485	105344	110734	113682	116752	120350
Davis	Hooper HS	Wage and salary jobs	60219	61760	61384	62520	66204	69487	69562	71241	75148	77669	80123	84176	88098	89870	92079	94880
Davis	Hooper HS	Number of proprietors	11146	11775	14154	15348	15561	16434	16587	15898	15588	19897	19362	21168	22636	23812	24673	25470
Davis	Hooper HS	Number of nonfarm proprietors 5/	10447	11093	13492	14714	14941	15817	15976	15291	14942	19272	18730	20556	22034	23201	24045	24842
Davis	Hooper HS	Number of farm proprietors	699	682	662	634	620	617	611	607	646	625	632	612	602	611	628	628
Davis	Hooper HS	Average earnings per job (dollars)	21220	21349	20781	21183	21889	22311	23521	24143	24431	23758	25096	24819	25374	26305	27229	28833
Davis	Hooper HS	Average wage and salary disbursements	18805	19099	19059	19753	20296	20652	21696	21937	21864	22302	23666	23862	24141	25164	26140	27789
Davis	Hooper HS	Average nonfarm proprietors' income	10259	10135	8497	7884	7975	8478	9318	10130	12135	10397	10830	9835	12174	12797	13459	13831
Iron	Newcastle	Personal income (thousands of dollars)	175936	182259	188851	200246	224627	249388	262479	288034	317916	347590	377388	403954	465152	501265	518171	546902
Iron	Newcastle	Nonfarm personal income	174252	179683	184426	191983	216865	240368	255980	279913	305039	337112	371448	401420	452845	485467	504999	535023
Iron	Newcastle	Farm income	1684	2576	4425	8263	7762	9020	6499	8121	12877	10478	5940	2534	12307	15798	13172	11879
Iron	Newcastle	Net earnings 1/	111593	114135	119170	130001	145742	164814	168520	188591	212357	234446	254064	271598	316394	341058	356400	370901
Iron	Newcastle	Transfer payments	23019	25319	28158	30339	33956	39068	44826	50843	55240	56658	61651	65015	71575	76176	78919	86489
Iron	Newcastle	Income maintenance 2/	1923	2325	2328	2649	2926	3005	3601	4355	4857	5566	5736	5797	6435	6487	6341	6655
Iron	Newcastle	Unemployment insurance benefit payments	1143	983	960	634	577	644	784	889	984	726	663	836	876	1020	1076	1183
Iron	Newcastle	Retirement and other	19953	22011	24870	27056	30453	35419	40441	45599	49399	50366	55252	58382	64264	68669	71502	78651
Iron	Newcastle	Dividends, interest, and rent	41324	42805	41523	39906	44929	45506	49133	48600	50319	56486	61673	67341	77183	84031	82852	89512
Iron	Newcastle	Population (number of persons) 3/	19970	20057	20058	20123	20495	20927	21688	22626	24227	25791	27707	28981	30171	31653	32883	33960
Iron	Newcastle	Per capita personal income	8810	9087	9415	9951	10960	11917	12102	12730	13122	13477	13621	13939	15417	15836	15758	16104
Iron	Newcastle	Per capita net earnings	5588	5691	5941	6460	7111	7876	7770	8335	8765	9090	9170	9372	10487	10775	10838	10922
Iron	Newcastle	Per capita transfer payments	1153	1262	1404	1508	1657	1867	2067	2247	2280	2197	2225	2243	2372	2407	2400	2547
Iron	Newcastle	Per capita income maintenance	96	116	116	132	143	144	166	192	200	216	207	200	213	205	193	196
Iron	Newcastle	Per capita unemployment insurance benefits	57	49	48	32	28	31	36	39	41	28	24	29	29	32	33	35
Iron	Newcastle	Per capita retirement and other	999	1097	1240	1345	1486	1693	1865	2015	2039	1953	1994	2014	2130	2169	2174	2316
Iron	Newcastle	Per capita dividends, interest, and rent	2069	2134	2070	1983	2192	2175	2265	2148	2077	2190	2226	2324	2558	2655	2520	2636
Iron	Newcastle	Earnings by place of work ($000)	117116	119581	124891	135995	151863	171449	173471	196506	220017	241692	262948	280784	327492	351678	367736	381719
Iron	Newcastle	Wage and salary disbursements	89765	90282	93105	98949	113295	127451	129571	146040	159885	181426	206348	225160	250960	271371	286700	299604
Iron	Newcastle	Other labor income	11918	12432	13254	14106	16772	19758	21267	24618	27506	30639	32505	34546	35598	38814	40993	42109
Iron	Newcastle	Proprietors' income	15433	16867	18532	22940	21796	24240	22633	25848	32626	29627	24095	21078	40934	41493	40043	40006
Iron	Newcastle	Nonfarm proprietors' income	15538	15982	15807	16586	16059	17572	18398	19991	22704	23319	22966	23658	34671	31905	33005	35062
Iron	Newcastle	Farm proprietors' income	-105	885	2725	6354	5737	6668	4235	5857	9922	6308	1129	-2580	6263	9588	7038	4944
Iron	Newcastle	Total full-time and part-time employment	8367	8174	8638	9163	9676	10265	10461	11211	12159	13906	14774	15713	17084	17968	18497	19071
Iron	Newcastle	Wage and salary jobs	6738	6542	6837	7162	7766	8229	8425	9188	9930	10828	11816	12458	13520	14155	14516	14956
Iron	Newcastle	Number of proprietors	1629	1632	1801	2001	1910	2036	2036	2023	2229	3078	2958	3255	3564	3813	3981	4115
Iron	Newcastle	Number of nonfarm proprietors 5/	1217	1231	1413	1626	1539	1663	1662	1649	1824	2681	2552	2857	3171	3414	3571	3705
Iron	Newcastle	Number of farm proprietors	412	401	388	375	371	373	374	374	405	397	406	398	393	399	410	410
Iron	Newcastle	Average earnings per job (dollars)	13997	14629	14458	14842	15695	16702	16583	17528	18095	17380	17798	17870	19170	19572	19881	20016
Iron	Newcastle	Average wage and salary disbursements	13322	13800	13618	13816	14589	15488	15379	15895	16101	16755	17463	18074	18562	19171	19751	20032
Iron	Newcastle	Average nonfarm proprietors' income	12767	12983	11187	10200	10435	10566	11070	12123	12447	8698	8999	8281	10934	9345	9243	9463
Juab	Drum Mountains	Personal income (thousands of dollars)	53411	53697	54056	58760	62138	67872	73777	78992	84289	87756	93348	101254	107048	118432	121570	125979
Juab	Drum Mountains	Nonfarm personal income	53144	52937	51679	55047	58303	63779	70769	75287	79675	85159	91344	100234	106610	114246	117249	124638
Juab	Drum Mountains	Farm income	267	760	2377	3713	3835	4093	3008	3705	4614	2597	2004	1020	438	4186	4321	1341
Juab	Drum Mountains	Net earnings 1/	32369	31438	31857	37373	38970	43147	47365	52095	54982	56968	59943	65032	68166	78003	80177	82195
Juab	Drum Mountains	Transfer payments	8895	9898	10761	10848	11560	13133	14676	15839	18210	18538	19676	21111	22541	22930	23933	24761
Juab	Drum Mountains	Income maintenance 2/	437	495	531	584	617	675	803	1004	1137	1153	1380	1517	1718	1646	1646	1626
Juab	Drum Mountains	Unemployment insurance benefit payments	621	993	859	490	346	330	472	922	840	488	454	421	454	543	655	631
Juab	Drum Mountains	Retirement and other	7837	8410	9371	9774	10597	12128	13401	13913	16233	16897	17842	19173	20369	20741	21632	22504

County/Area Name	Geothermal Site(s)	Line Title	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Juab	Drum Mountains	Dividends, interest, and rent	12147	12361	11438	10539	11608	11592	11736	11058	11097	12250	13729	15111	16341	17499	17460	19023
Juab	Drum Mountains	Population (number of persons) 3/	6245	6196	5950	5742	5798	5820	5911	5978	6141	6477	6813	7213	7460	7832	8076	8285
Juab	Drum Mountains	Per capita personal income	8553	8666	9085	10233	10717	11662	12481	13214	13726	13549	13701	14038	14350	15122	15053	15206
Juab	Drum Mountains	Per capita net earnings	5183	5074	5354	6509	6721	7414	8013	8714	8953	8795	8798	9016	9138	9960	9928	9921
Juab	Drum Mountains	Per capita transfer payments	1424	1597	1809	1889	1994	2257	2483	2650	2965	2862	2888	2927	3022	2928	2963	2989
Juab	Drum Mountains	Per capita income maintenance	70	80	89	102	106	116	136	168	185	178	203	210	230	210	204	196
Juab	Drum Mountains	Per capita unemployment insurance benefits	99	160	144	85	60	57	80	154	137	75	67	58	61	69	81	76
Juab	Drum Mountains	Per capita retirement and other	1255	1357	1575	1702	1828	2084	2267	2327	2643	2609	2619	2658	2730	2648	2679	2716
Juab	Drum Mountains	Per capita dividends, interest, and rent	1945	1995	1922	1835	2002	1992	1985	1850	1807	1891	2015	2095	2190	2234	2162	2296
Juab	Drum Mountains	Earnings by place of work ($000)	25457	23869	25459	31560	32974	35803	42827	45070	46946	48710	50892	55778	59423	69306	71993	74170
Juab	Drum Mountains	Wage and salary disbursements	19689	18255	18877	21810	23790	25679	32190	33251	33747	36458	38576	43660	47199	51384	53275	57739
Juab	Drum Mountains	Other labor income	2387	2304	2519	2879	3251	3646	4604	5087	5310	5641	5595	6160	6448	6824	6783	7092
Juab	Drum Mountains	Proprietors' income	3381	3310	4063	6871	5933	6478	6033	6732	7889	6611	6721	5958	5776	11098	11935	9339
Juab	Drum Mountains	Nonfarm proprietors' income	3794	3197	2341	3906	2899	3321	3933	3947	4218	5070	5694	5767	6122	7718	8408	8910
Juab	Drum Mountains	Farm proprietors' income	-413	113	1722	2965	3034	3157	2100	2785	3671	1541	1027	191	-346	3380	3527	429
Juab	Drum Mountains	Total full-time and part-time employment	2161	2116	2126	2285	2320	2500	2700	2726	2833	3045	3125	3338	3412	3585	3625	3685
Juab	Drum Mountains	Wage and salary jobs	1587	1554	1545	1688	1756	1884	2054	2076	2172	2259	2304	2445	2494	2608	2623	2667
Juab	Drum Mountains	Number of proprietors	574	562	581	597	564	616	646	650	661	786	821	893	918	977	1002	1018
Juab	Drum Mountains	Number of nonfarm proprietors 5/	333	327	355	379	349	401	431	438	425	551	575	648	671	727	745	761
Juab	Drum Mountains	Number of farm proprietors	241	235	226	218	215	215	215	212	236	235	246	245	247	250	257	257
Juab	Drum Mountains	Average earnings per job (dollars)	11780	11280	11975	13812	14213	14321	15862	16533	16571	15997	16285	16710	17416	19332	19860	20128
Juab	Drum Mountains	Average wage and salary disbursements	12406	11747	12218	12921	13548	13630	15672	16017	15537	16139	16743	17857	18925	19702	20311	21649
Juab	Drum Mountains	Average nonfarm proprietors' income	11393	9777	6594	10306	8307	8282	9125	9011	9925	9201	9903	8900	9124	10616	11286	11708
Millard	Drum Mountains	Personal income (thousands of dollars)	165616	147368	128703	132753	139313	152603	161868	157281	170791	167111	167419	180858	185875	203345	206461	209576
Millard	Drum Mountains	Nonfarm personal income	164354	141788	118836	115870	120631	128456	138852	136770	142965	151125	155445	164960	171413	177826	180524	191742
Millard	Drum Mountains	Farm income	1262	5580	9867	16883	18682	24147	23016	20511	27826	15986	11974	15898	14462	25519	25937	17834
Millard	Drum Mountains	Net earnings 1/	122096	102923	86024	91217	94892	106383	113905	107986	118691	112111	108050	117553	119043	134189	137471	135785
Millard	Drum Mountains	Transfer payments	13914	15297	16167	16172	17094	19293	21370	24018	27311	28387	30858	32738	33341	34184	35153	36779
Millard	Drum Mountains	Income maintenance 2/	707	917	911	977	1082	1285	1530	1981	2194	2695	3044	3202	3291	3182	3141	3147
Millard	Drum Mountains	Unemployment insurance benefit payments	920	1204	1001	625	508	471	616	999	921	589	548	535	548	642	638	725
Millard	Drum Mountains	Retirement and other	12287	13176	14255	14570	15504	17537	19224	21038	24196	25103	27266	29001	29502	30360	31374	32907
Millard	Drum Mountains	Dividends, interest, and rent	29606	29148	26512	25364	27327	26927	26593	25277	24789	26613	28511	30567	33491	34972	33837	37012
Millard	Drum Mountains	Population (number of persons) 3/	13626	13518	12399	11759	11508	11310	11471	11571	11783	11932	12167	12187	12284	12295	12416	12416
Millard	Drum Mountains	Per capita personal income	12154	10902	10380	11289	12106	13493	14111	13593	14495	14005	13760	14840	15131	16539	16629	16880
Millard	Drum Mountains	Per capita net earnings	8961	7614	6938	7757	8246	9406	9930	9332	10073	9396	8881	9646	9691	10914	11072	10936
Millard	Drum Mountains	Per capita transfer payments	1021	1132	1304	1375	1485	1706	1863	2076	2318	2379	2536	2686	2714	2780	2831	2962
Millard	Drum Mountains	Per capita income maintenance	52	68	73	83	94	114	133	171	186	226	250	263	268	259	253	253
Millard	Drum Mountains	Per capita unemployment insurance benefits	68	89	81	53	44	42	54	86	78	49	45	44	45	52	51	58
Millard	Drum Mountains	Per capita retirement and other	902	975	1150	1239	1347	1551	1676	1818	2053	2104	2241	2380	2402	2469	2527	2650
Millard	Drum Mountains	Per capita dividends, interest, and rent	2173	2156	2138	2157	2375	2381	2318	2185	2104	2230	2343	2508	2726	2844	2725	2981
Millard	Drum Mountains	Earnings by place of work ($000)	158347	127088	99785	104237	108816	122264	132779	122343	133489	127244	123050	133346	133734	148206	151418	150454
Millard	Drum Mountains	Wage and salary disbursements	133853	99970	71211	70341	73602	80054	90197	82006	84121	89490	90988	96396	97076	98745	100143	106467
Millard	Drum Mountains	Other labor income	15152	12717	9979	9542	10085	11443	13462	12943	13843	14491	13653	13957	13530	13965	13961	14616
Millard	Drum Mountains	Proprietors' income	9342	14401	18595	24354	25129	30767	29120	27394	35525	23263	18409	22993	23128	35496	37314	29371
Millard	Drum Mountains	Nonfarm proprietors' income	10735	11191	10957	10550	10241	11557	11292	12524	13850	14673	13802	13928	15804	17328	18619	19801
Millard	Drum Mountains	Farm proprietors' income	-1393	3210	7638	13804	14888	19210	17828	14870	21675	8590	4607	9065	7324	18168	18695	9570
Millard	Drum Mountains	Total full-time and part-time employment	7644	6484	5573	5408	5351	5571	5509	5415	5445	5799	5728	6028	6249	6196	6266	6233
Millard	Drum Mountains	Wage and salary jobs	6210	5028	3956	3778	3809	4023	4003	3930	3956	4086	4037	4208	4294	4201	4219	4147
Millard	Drum Mountains	Number of proprietors	1434	1456	1617	1630	1542	1548	1506	1485	1489	1713	1691	1820	1955	1995	2047	2086
Millard	Drum Mountains	Number of nonfarm proprietors 5/	782	822	1000	1033	952	951	906	885	824	1045	993	1123	1250	1279	1311	1350
Millard	Drum Mountains	Number of farm proprietors	652	634	617	597	590	597	600	600	665	668	698	697	705	716	736	736
Millard	Drum Mountains	Average earnings per job (dollars)	20715	19600	17905	19275	20336	21947	24102	22593	24516	21942	21482	22121	21401	23920	24165	24138
Millard	Drum Mountains	Average wage and salary disbursements	21554	19883	18001	18619	19323	19899	22532	20867	21264	21902	22539	22908	22607	23505	23736	25673
Millard	Drum Mountains	Average nonfarm proprietors' income	13728	13614	10957	10213	10757	12152	12464	14151	16808	14041	13899	12402	12643	13548	14202	14667
Weber	Utah HS, Ogden HS	Personal income (thousands of dollars)	1979621	2072003	2114558	2190755	2320952	2562783	2720462	2878273	3018807	3203297	3410810	3633060	3843310	4078260	4218755	4489107

County/Area Name	Geothermal Site(s)	Line Title	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Weber	Utah HS, Ogden HS	Nonfarm personal income	1977919	2069088	2108949	2181870	2312653	2550961	2711510	2868226	3006527	3193498	3407021	3629143	3841440	4073480	4215148	4488366
Weber	Utah HS, Ogden HS	Farm income	1702	2915	5609	8885	8299	11822	8952	10047	12280	9799	3789	3917	1870	4780	3607	741
Weber	Utah HS, Ogden HS	Net earnings 1/	1338546	1396093	1429391	1488687	1572513	1756591	1864634	1981671	2073588	2180070	2327703	2470853	2616177	2793569	2946045	3144221
Weber	Utah HS, Ogden HS	Transfer payments	220989	236406	243766	257166	275690	305902	337122	376564	411975	415608	440039	464804	485824	496404	514897	535686
Weber	Utah HS, Ogden HS	Income maintenance 2/	20488	21101	22038	24015	27016	29797	34411	39468	42450	44026	46385	45584	47039	46395	46430	47010
Weber	Utah HS, Ogden HS	Unemployment insurance benefit payments	10550	9966	10709	8530	7521	8387	10240	18280	16874	11294	9640	11248	11370	12729	12756	15134
Weber	Utah HS, Ogden HS	Retirement and other	189951	205339	211019	224621	241153	267718	292471	318816	352651	360288	384014	407972	427415	437280	455711	473542
Weber	Utah HS, Ogden HS	Dividends, interest, and rent	420086	439504	441401	444902	472749	500290	518706	520038	533244	607619	643068	697403	741309	788287	757813	809200
Weber	Utah HS, Ogden HS	Population (number of persons) 3/	156087	156913	157605	157228	157847	158860	162186	166479	171055	176032	180546	184584	188334	190846	193697	197264
Weber	Utah HS, Ogden HS	Per capita personal income	12683	13205	13417	13934	14704	16132	16774	17289	17648	18197	18892	19682	20407	21369	21780	22757
Weber	Utah HS, Ogden HS	Per capita net earnings	8576	8897	9069	9468	9962	11057	11497	11903	12122	12385	12893	13386	13891	14638	15210	15939
Weber	Utah HS, Ogden HS	Per capita transfer payments	1416	1507	1547	1636	1747	1926	2079	2262	2408	2361	2437	2518	2580	2601	2658	2716
Weber	Utah HS, Ogden HS	Per capita income maintenance	131	134	140	153	171	188	212	237	248	250	257	247	250	243	240	238
Weber	Utah HS, Ogden HS	Per capita unemployment insurance benefits	68	64	68	54	48	53	63	110	99	64	53	61	60	67	66	77
Weber	Utah HS, Ogden HS	Per capita retirement and other	1217	1309	1339	1429	1528	1685	1803	1915	2062	2047	2127	2210	2269	2291	2353	2401
Weber	Utah HS, Ogden HS	Per capita dividends, interest, and rent	2691	2801	2801	2830	2995	3149	3198	3124	3117	3452	3562	3778	3936	4130	3912	4102
Weber	Utah HS, Ogden HS	Earnings by place of work ($000)	1199647	1270454	1312667	1382911	1460732	1601302	1730190	1877112	1988653	2113483	2254471	2479411	2655138	2781313	2948589	3024872
Weber	Utah HS, Ogden HS	Wage and salary disbursements	955137	1014284	1047611	1108466	1169344	1266616	1357428	1467884	1544107	1653371	1782283	1991035	2160388	2262064	2396578	2458289
Weber	Utah HS, Ogden HS	Other labor income	144521	154246	164039	173181	190824	216875	245578	276189	296428	306448	310202	317426	310882	317429	335135	339648
Weber	Utah HS, Ogden HS	Proprietors' income	99989	101924	101017	101264	100564	117811	127184	133039	148118	153664	161986	170950	183868	201820	216876	226935
Weber	Utah HS, Ogden HS	Nonfarm proprietors' income	100270	100830	97195	94478	94590	108766	120985	125782	138896	147534	161919	170507	185683	200844	217003	230503
Weber	Utah HS, Ogden HS	Farm proprietors' income	-281	1094	3822	6786	5974	9045	6199	7257	9222	6130	67	443	-1815	976	-127	-3568
Weber	Utah HS, Ogden HS	Total full-time and part-time employment	70802	73292	75635	78519	80483	82696	84168	85224	86655	93380	97698	104422	108241	108580	111097	111863
Weber	Utah HS, Ogden HS	Wage and salary jobs	60821	63102	63769	65772	67874	69765	71079	72653	74173	77513	82275	87852	91288	91173	93052	93245
Weber	Utah HS, Ogden HS	Number of proprietors	9981	10190	11866	12747	12609	12931	13089	12571	12482	15867	15423	16570	16953	17407	18045	18618
Weber	Utah HS, Ogden HS	Number of nonfarm proprietors 5/	8995	9230	10933	11827	11681	11978	12114	11579	11409	14816	14347	15516	15906	16344	16952	17526
Weber	Utah HS, Ogden HS	Number of farm proprietors	986	960	933	920	928	953	975	992	1073	1051	1076	1054	1047	1063	1093	1092
Weber	Utah HS, Ogden HS	Average earnings per job (dollars)	16944	17334	17355	17612	18150	19364	20556	22026	22949	22633	23076	23744	24530	25615	26541	27041
Weber	Utah HS, Ogden HS	Average wage and salary disbursements	15704	16074	16428	16853	17228	18155	19097	20204	20818	21330	21663	22664	23666	24811	25755	26364
Weber	Utah HS, Ogden HS	Average nonfarm proprietors' income	11147	10924	8890	7988	8098	9080	9987	10863	12174	9958	11286	10989	11674	12289	12801	13152

Source: Regional Economic Information System (REIS), U.S. Department of Commerce, Economics and Statistics Administration, Bureau of Economic Analysis

Footnotes for Table CA30 Regional Economic Profiles

1. Total earnings less personal contributions for social insurance adjusted to place of residence.
2. Consists largely of supplemental security income payments, family assistance, general assistance payments, food stamp payments, and other assistance payments, including emergency assistance.
3. Census Bureau midyear population estimates.
4. Type of income divided by population yields a per capita measure for that type of income.
5. Excludes limited partners.

(L) Less than $50,000 or less than 10 jobs, as appropriate, but the estimates for this item are included in the totals.
(N) Data not available for this year.