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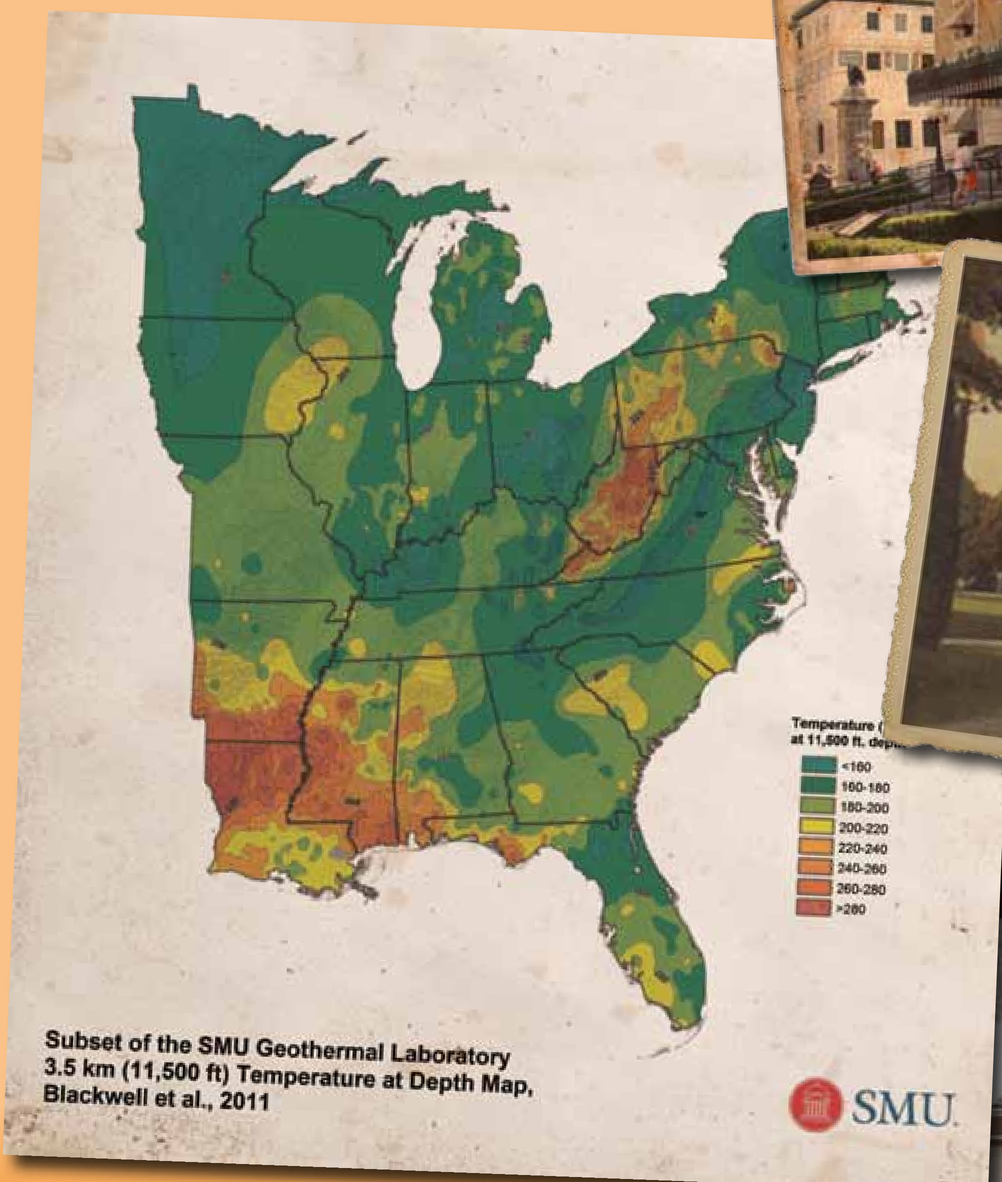
GEO-HEAT CENTER QUARTERLY BULLETIN

GEOTHERMAL USE IN THE EASTERN UNITED STATES



Subset of the SMU Geothermal Laboratory 3.5 km (11,500 ft) Temperature at Depth Map, Blackwell et al., 2011

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A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

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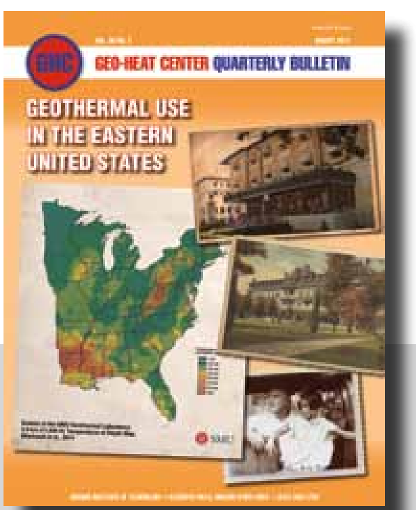

Cover Mosaic: Temperature at depth map of the eastern United States; postcard of Bath House Row at Hot Springs, Georgia; postcard of the Mountain Park Hotel at Hot Springs, North Carolina; photograph of President Franklin Delano Roosevelt and Miss Harriet Golden, 1931 at Warm Springs, Georgia, courtesy National Archives Collection.

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THE ECONOMIC, ENVIRONMENTAL, AND SOCIAL BENEFITS OF GEOTHERMAL USE IN THE EASTERN UNITED STATES

Andrew Chiasson, Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, Oregon

Geothermal waters in the Eastern United States have been used by many people for centuries. Today, the documented direct uses of geothermal waters are mostly related to spas and resorts, with some space heating. In this report, the Eastern United States refers to the states east of the Mississippi River.

A Brief Note on Past Studies and the Occurrence of Geothermal Resources in the Eastern U.S.

For most people, "geothermal" conjures images of geysers and volcanoes. Naturally, geothermal resources are commonly associated with volcanic features of the Western States. Exploitable geothermal resources occur in geologic environments other than in areas of recent volcanism, and with the current resurgence in interest in direct uses of geothermal energy, low-temperature electrical power generation, and in enhanced geothermal systems, the Eastern States are receiving considerable attention.

In 1967, a Geothermal Program was started at Virginia Tech University, and heat flow determinations in the southeastern United States were begun with funding by the National Science Foundation. In the late 1970s and early 1980s, the United States Department of Energy (DOE) funded a large number of research projects on the geothermal resources of the Eastern States. The results of these projects are described in reports by Renner and Vaught, (1979), Dunn Geoscience (1981), and Costain and Glover (1982), to name a few. These studies identified a few models of geothermal resource occurrence in the Eastern U.S.: (1) radiogenic granitic plutons beneath thick sediment covers, (2) warm spring systems, (3) abnormally warm aquifers, and (4) deep sedimentary basins with normal temperature gradients.

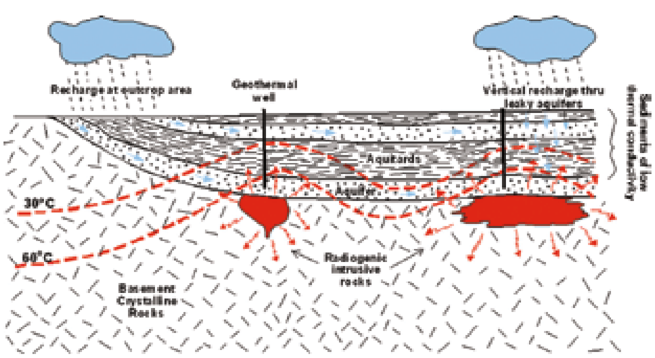

Fig. 1. Conceptual diagram of a radiogenic geothermal system (Lund, 2007).

More recently, the Chesapeake Bay area has been discovered to be a crater formed by a meteorite impact. The impact crater explains anomalous occurrences of groundwater aquifers and flow patterns there, and may be related to some geothermal features in the area.

ECONOMIC BENEFITS

The spa/resort industry in some Eastern States enjoys significant economic benefits of geothermal energy, and some resorts owe their existence to warm springs. Documented direct uses of geothermal energy currently exist in the states of Arkansas, Florida, Georgia, North Carolina, and Virginia. A number of spas are located at natural springs in other states, but do not represent true direct uses of geothermal energy; these spas heat mineral waters using fossil fuels or other means. Some examples of spas using mineral water that is artificially heated are located in Florida, Illinois, Indiana, Massachusetts, New York (e.g., Saratoga Springs), Tennessee, and West Virginia (e.g., The Greenbrier).

ARKANSAS

Hot Springs, Arkansas was perhaps at one time the most popular commercial spa area in the United States. The geothermal resource consists of 47 springs, producing a total of about one million gallons per day of 143°F water. The National Park Service estimates that these hot springs have been used by humans for at least 10,000 years. In the early 1800s, European settlers developed the area with bathhouses to imitate spas in Europe, and the area became popular enough that it was made into a Federal Reservation in 1832. It became a National Park in 1921, and is the only national park in the U.S. created just to protect hot springs for spa use (Lund, 1993).

During the "Golden Age of Bathing" and the health spa craze of the late 19th and early 20th centuries, numerous extravagant bathhouses existed at the heart of Hot Springs National Park. Known as "Bathhouse Row," the bathhouses were a popular destination for the wealthy from around the world seeking help from the hot spring waters for a variety of ailments. They hosted many famous (and infamous) people of the era, including Franklin Delano Roosevelt, Babe Ruth, and Al Capone. As with most of the bathhouse industry in the U.S., the popularity of Bathhouse Row saw a steady decline in usage throughout the 20th century, and now, the Buckstaff Bathhouse is the only original active facility in Bathhouse Row remaining from its heyday. The Buckstaff Bathhouse has been in continuous service since 1912, and currently employs about 40 people. The Fordyce Bathhouse has been restored by the National Park Service and is open for tours.

The Hot Springs Arkansas National Park Service Visitor Center building serves as the collection point for the various thermal springs, and users of the thermal waters must purchase the water from the National Park Service as enacted by law. From the Visitor Center, geothermal water is pumped to customers in the park, including the Buckstaff Bathhouse for spa use, and for direct-use heating of the Visitor Center itself and the Administrative Building. The Hot Springs National Park in Arkansas employs about 50 people permanently, and about 100 during the summer season. Geothermal spring water from the national park Visitor Center is also pumped to spas at the Arlington Resort Hotel, The Springs Hotel and Spa (formerly the Downtowner Hotel and Spa), Quapaw Baths and Spa, and the Austin Hotel, all in downtown Hot Springs, Arkansas.

Fig. 2. Bathhouse Row in Hot Springs, Arkansas

FLORIDA

Warm Mineral Springs, located in North Port, is the only warm water mineral spring in the State of Florida, and is claimed to be the largest warm water mineral spring in the world. The surface area of the spring is approximately 1.4-acres, and is nearly 250 feet deep in the center. The hourglass shaped sinkhole is the result of a subsurface cave-in that occurred some 20,000 years ago. The spring's main water source originates from over 3,000 feet deep, which is believed to be in hydraulic connection to the Floridian Aquifer. The spring produces 9 million gallons of 87˚F mineral rich water per day, which is used directly for swimming, soaking, and therapy.

GEORGIA

Warm Springs, Georgia is the most famous of Georgia's seven known warm springs. It has the largest flow of up to 914 gpm with an average temperature of 88˚F. The springs issue from at least 12 separate locations along a 500-ft long belt in the edge of a quartzite hillside.

A number of resorts were built in the area, including the Meriwether Inn, known mainly for the treatment of polio from the early 1920s to the 1960s. The Inn was promoted by President Franklin Delano Roosevelt, who had polio and established the "Little White House" on the premises in 1932. The Georgia Warm Springs Foundation, who managed the springs, dedicated itself to the conquest of polio. It provided treatment in various pools supplied by warm springs. With the advent of polio vaccines in the 1950s and 60s, use of the facility declined.

Today, the Roosevelt Warm Springs Institute for Rehabilitation provides medical rehabilitation and therapy for a broad range of disabilities. The Institute also uses the water for bathing.

Fig. 3. Photograph of Meriwether Inn, Warm Springs, GA, 1894. The Inn closed in the 1920s.

NORTH CAROLINA

The Natural Hot Mineral Springs, located in the Great Smokey Mountains, is the only one known in North Carolina. Prior to 1778 when European settlers discovered the area, it is believed that the Cherokee Indians used these springs for centuries for their magical curative powers. Thermal waters issue from the springs at about 110˚F at a flow rate of several hundreds of gallons per minute.

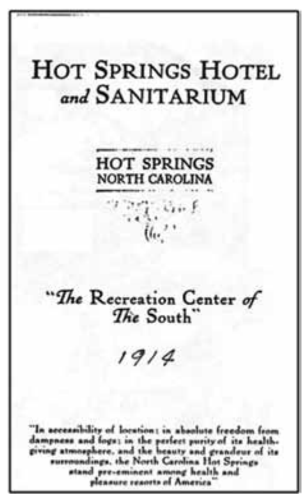

Fig. 4. Brochure for the Hot Springs and Sanitarium, circa 1914.

Two hundred acres of land including the springs were deeded in 1788, and a tavern was established, making the area a popular stopping point for travelers during the American Revolution. This tavern also became legend and was an infamous site for robberies and many murders.

Today, the Hot Springs Resort and Spa offers modern spa services and mineral baths using the geothermal water. The water cools to about 103˚F by the time it reaches the facility. The facility also offers a campground with camp sites ranging from primitive, to full RV hookups, to cabins that include indoor/outdoor soaking tubs. The Appalachian

Trail runs between the camp sites and the pools. The facility employs about 45 people.

The Mountain Magnolia Inn also uses the geothermal resource at Hot Springs, NC for spa therapy. The Mountain Magnolia Inn is the former residence of Colonel James Henry Rumbough who owned the 350-room Mountain Park Hotel in Hot Springs, which was the site of North Carolina's first golf course (the Wanna Luna) as well as a popular vacation resort. Built in 1886, the Mountain Park Hotel boasted 16 marble pools surrounded by landscaped lawns with croquet and tennis courts and was known as one of the most lavish resorts in the Southeast. The hotel and grounds were leased to the U.S. Government in 1917 to be used as a World War I internment camp. That hotel burned in 1920, and two more were built, neither as large nor as lavish. Both later burned as well.

Fig. 5. Post Card for the Mountain Park Hotel in Hot Springs, NC circa early 1900s.

VIRGINIA

Three major springs are located in the Warm Springs Valley of the Allegheny Mountains in western Virginia along U.S. route 220: the Warm, the Hot, and the Healing - all now owned by Virginia Hot Springs, Inc. The Homestead, a large and historic luxurious resort, is located at Hot Springs. The odorless mineral water used at The Homestead spa flows from several springs at temperatures ranging from 102˚F to 106˚F (Gersh-Young, 2003). It is piped to individual, one-person bathtubs in separate men's and women's bathhouses, where it is mixed to provide an ideal temperature of 104˚F. Tubs are drained and refilled after each use so that no chemical treatment is necessary. Mineral water from the same springs is used in an indoor swimming pool maintained at 84˚F, and an outdoor swimming pool maintained at 72˚F.

Five miles away to the northeast, but still within the 15,000-acre Homestead property, are the Jefferson Pools at Warm Springs, which flow at 98˚F. The rate of discharge is so great, 1000 gpm (Muffler, 1979) that the two large Warm Springs pools, in separate men's and women's buildings, maintain the temperature on a flow-through basis requiring no chemical treatment. The men's pool was designed by Thomas Jefferson and opened in 1761; the women's pool was opened in 1836. The adjacent "drinking spring" and two covered pools have been preserved in their original condition.

Fig. 6. Photo of the Jefferson Pools (Source: thehomestead.com).

Healing Springs located approximately five miles southwest of Hot Springs is reported at 86˚F with a flow rate of 15 gallons per minute (Muffler, 1979).

The facilities at The Homestead include 700 bedrooms, a conference center, restaurants, shops, and tennis courts. Skiing and ice skating are available in the winter. It is the only Virginian spa still in operation as a public resort.

NEW YORK

No known direct uses of geothermal energy currently exist in the State of New York, but it is worth mentioning the prior use of a deep well in Auburn, Cayuga County for direct heating of the East Middle School and Cayuga Community College. The Auburn Well was drilled in 1982 by the New York State Energy Research and Development Authority (NYSERDA), the original well owner, and DOE to explore for low-temperature geothermal resources for direct-use heating.

The Auburn area was chosen for the exploration well because of its anomalously high geothermal gradient and proximity to two educational facilities. The well was drilled to 5,250 feet into Precambrian basement rocks. The relatively high geothermal gradient was explained by a radiogenic heat source. The well produced warm water and natural gas. According to the Geo-Heat Center data base for New York, the well produced 600 gpm of 125˚F water. Today, the well produces only natural gas, and the Cayuga Community College has converted to geothermal heat pumps.

The numerous geothermal-related businesses across the Eastern U.S. employ many people. Using a standard multiplier of 2.5, geothermal businesses create an estimated 450 direct, indirect, and induced jobs in the Eastern U.S.

ENVIRONMENTAL BENEFITS

In addition to energy savings, geothermal energy usage prevents the emissions of greenhouse gases (GHG) and air pollutants, helping to keep a healthy living environment. If these businesses used fossil fuels to generate the heat that geothermal water provides, not only would most be unable to afford to stay in business, but they would emit at least 7,333 tonnes of carbon dioxide each year — the equivalent of 17,300 barrels of oil. In addition, they would emit 12 tonnes of nitrogen oxides and 13 tonnes of sulfur dioxides each year into our air (Table 1).

SOCIAL BENEFITS

Social benefits are difficult to measure quantitatively. One key social benefit from geothermal energy use in the Eastern U.S., however, is improved quality of life through recreation and spa therapy. Geothermal provides many unique recreational opportunities enjoyed by tens of thousands of people each year, attracting tourists to the area. Given the rich history of the geothermal spa industry, social benefits have been evident for many past generations.

THE FUTURE

The Eastern States have significant geothermal potential for future uses, from new and expanding applications of direct use heating, to resurgence in mineral spa therapy, to development of low-to-moderate temperature resources for electrical power generation.

Cornell University has proposed to develop a potential geothermal energy resource for the production of campus power and heat in Ithaca, New York. West Virginia University has proposed a retrofit and expansion to a district heating system in a community redevelopment project at West Virginia University campus.

In West Virginia, researchers uncovered the largest geothermal hot spot in the eastern United States. According to a unique collaboration between Google and geologists, West Virginia sits atop geothermal hot spots, some as warm as 392˚F at depths as shallow as five kilometers (Fig.7). If this geothermal energy could be feasibly tapped, the state could become a significant producer of geothermal energy for the region.

ACKNOWLEDGEMENTS

This material is based upon work supported by the Department of Energy under Award Number DE-EE0002741.

DISCLAIMER

Table 1. Energy Production and Carbon Emissions offsets by Geothermal Energy Utilization in the Eastern United States of America.

Site	Location	Application	Temp. (˚F)	Annual Energy Use		Annual Emission offsets (metric tonnes)		
				(10^9 Btu/yr)	(10^6 kWh)	NOx	SOx	CO_2
Hot Springs National Park	Hot Springs, AR	Space Heating	143	1.0	0.3	0	0	271
Bathhouses, spas, resort hotels	Hot Springs, AR	Resort/Pool	90 to 143	6.5	1.9	3	3	1,764
Roosevelt Warm Springs Institute for Rehabilitation	Warm Springs, GA	Resort/Pool	88	7.0	2.1	3	3	1,899
Homestead Resort	Hot Springs, VA	Resort/Pool	104	2.9	0.8	1.3	1.4	787
Hot Springs Resort	Hot Springs, NC	Resort/Pool	110	6.0	1.8	2.7	2.9	1,628
Mountain Magnolia Inn	Hot Springs, NC	Resort/Pool	110	1.6	0.5	0.7	0.8	441
Warm Mineral Springs	North Port, FL	Resort/Pool	87	2.0	0.6	0.9	1.0	543
TOTALS				27	8	12	13	7,333

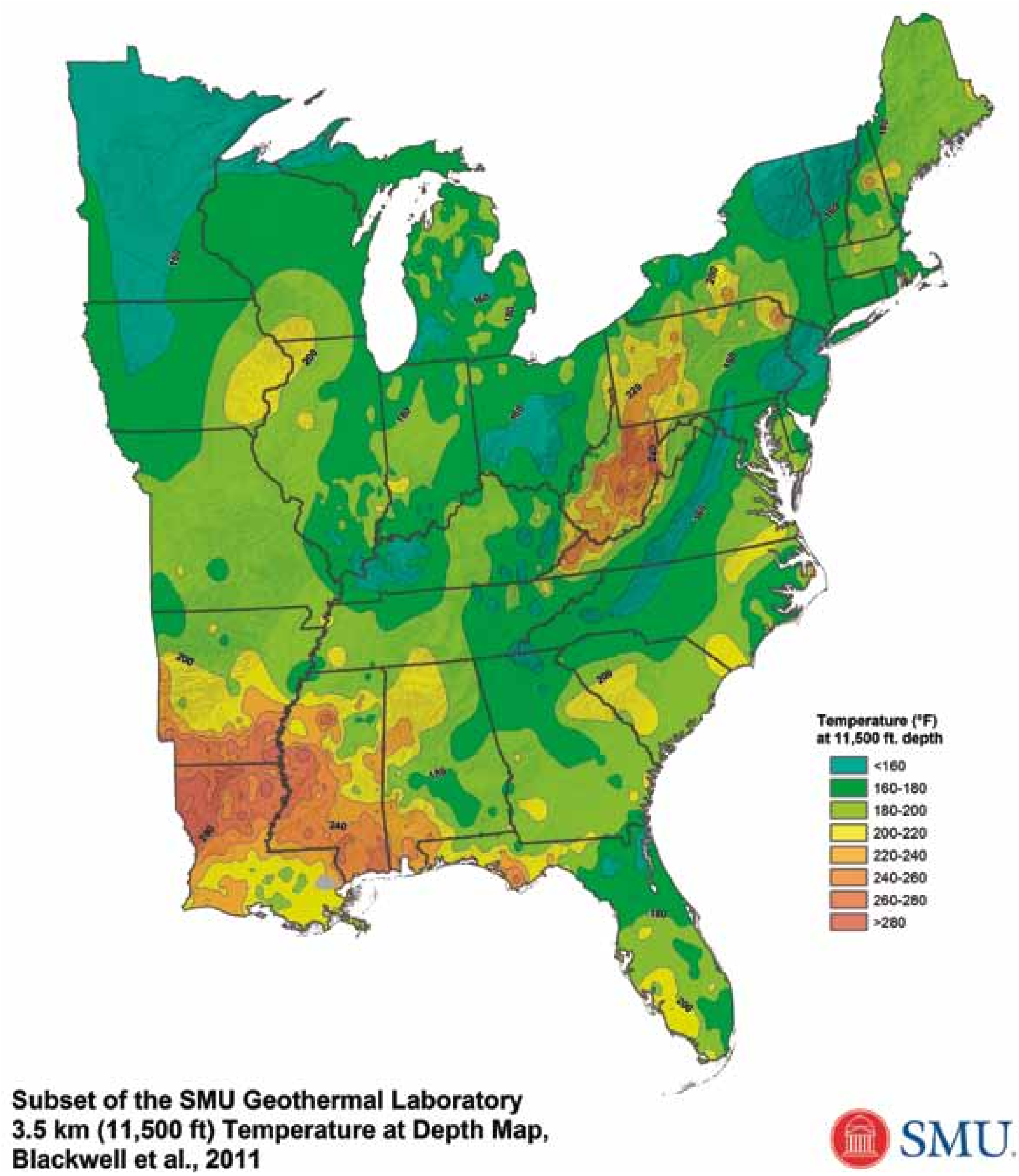

Fig. 7. Temperature-at-Depth Maps for 3.5 to 9.5 km, Google.org/EGS (Blackwell, D.D., M. Richards, Z. Frone, J. Batir, A. Ruzo, R. Dingwall, and M. Williams, 2011).

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TRIALS AND TRIBULATIONS OF THE OREGON INSTITUTE OF TECHNOLOGY SMALL-SCALE POWER PLANT

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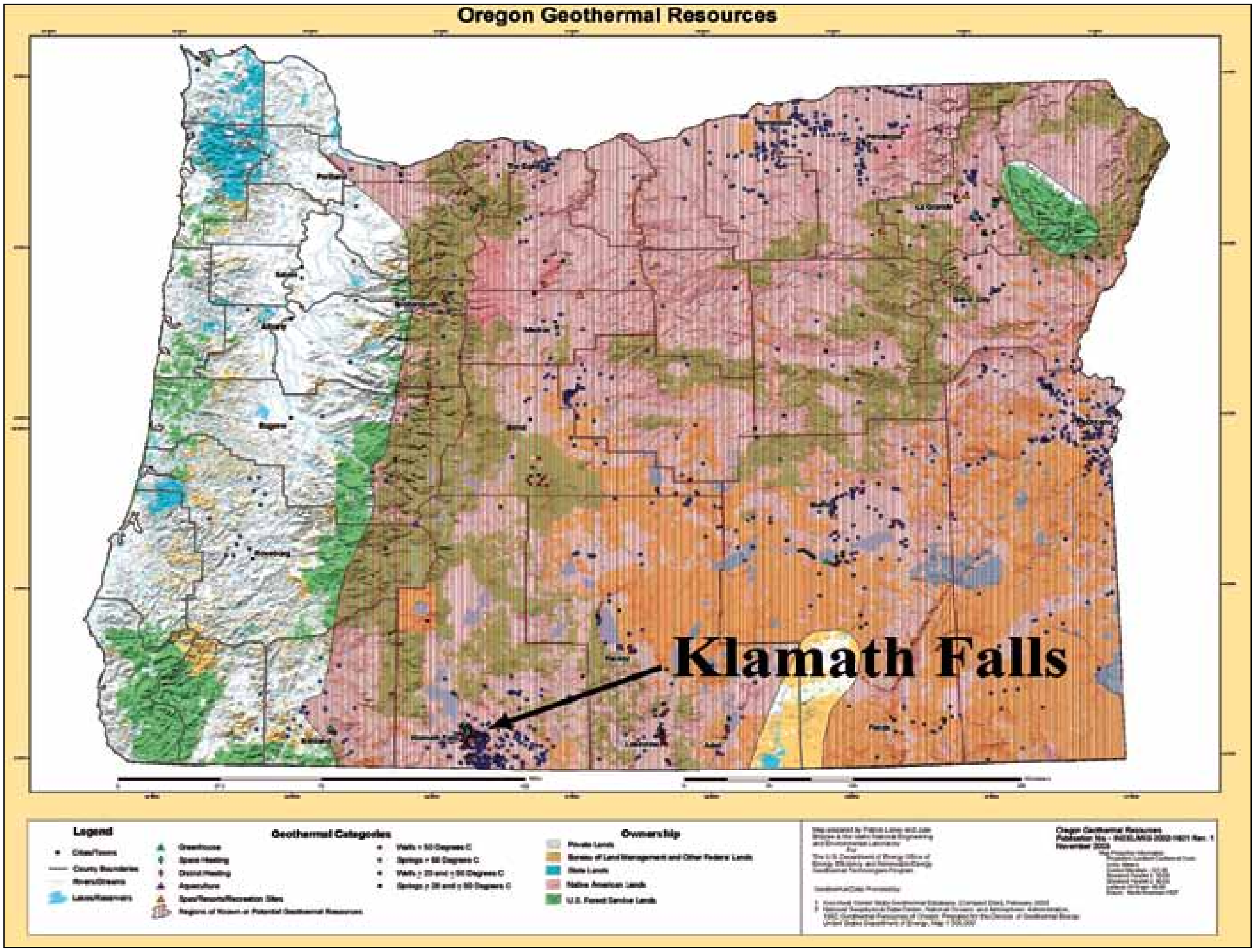

Fig. 1. Oregon geothermal resource map courtesy of Idaho National Laboratory. Geology and Geothermal Resource

ABSTRACT

This paper provides information on the trials and tribulations Oregon Institute of Technology (OIT) overcame to start producing power on their campus in Klamath Falls, Oregon. OIT started on their adventure in 2008 to develop a small-scale low-temperature geothermal power plant using its existing geothermal wells. The temperatures of the wells are 192˚F with a maximum flow of 950 gpm. During the course of developing the plant they have encountered many different aspects of the project from drilling, water rights, Purchase Power Agreement (PPA), interconnection agreement, to incentive forms (Energy Trust of Oregon, Business Energy Tax Credit and Blue Sky grant) that they have never dealt with before. The power plant was completed in February of 2010 and interconnected into the grid in April 2010.

INTRODUCTION

The Oregon Institute of Technology is located in southern Oregon just to the east of the Cascade Range in the high desert country at an elevation of about 4,500 feet (Fig. 1). The campus has been heated with 192˚F geothermal water since 1962, when the campus was relocated from the site of the WWII Marine Rehabilitation Center in the hills east of the city. This new site was selected based on a high angle normal fault, typical of the Basin and Range physiographic province of the West, running along the west side of the City of Klamath Falls, where many geothermal wells had been drilled for space heating of residences and schools. Three geothermal wells were drilled, one around 1,200 deep and the other two around 1,800 feet deep taping into an upflow zone of hot water in the fault system. The hot water, after running through a settling tank, gravity flows to each building on campus where the heat is transferred to benign cold secondary water through a plate heat exchanger. The heat exchanger is necessary as the geothermal water contains about 2.0 ppm of hydrogen sulfide that will attack solder and produced stress cracking in copper tubing. The geothermal water is then injected back into the reservoir through two wells that are around 1,800 feet deep. The geothermal water supplies all the heat and domestic hot water to the campus at an energy savings of around one million dollar annually. The present campus has about 828,092 feet of floor space with a student enrollment of around 3,000.

HISTORY OF THE POWER PLANT PROJECT

In 2003, a proposal was presented to the OIT Facilities Services to use some of the heat energy from the existing geothermal water to run a small binary (organic Rankine cycle) geothermal power plant. Systems West Engineers, Inc. was hired to evaluate the energy use on campus in 2005. Their conclusions were that there was sufficient energy to both run a 200 to 300 kW power plant and still heat campus (Systems West Engineers, 2005). They stated: "The existing geothermal system is capable of operating with a reduced supply of water temperature of 177˚F during most operating conditions with minimal upgrade of system piping and equipment." As a result, a campus team was put together to write a proposal and obtain bids for a power plant and to provide the auxiliary equipment needed to complete the project.

In the latter part of 2006, there was only one company that could provide a low temperature geothermal power plant in the 200 to 300 kW range, United Technology Corporation (UTC) of East Hartford, CT. We started looking into obtaining a UTC unit to use on our existing wells as they had recently provided a 200 kW plant to Chena Hot Springs, thus some historical operating experience was available. We started initial discussions, but did not get into development discussions until later in 2007. Oregon Department of Justice had to review the contract and the Non Disclosure Agreement to make sure the language was suitable and passed legal sufficiently. The final contract was not signed until January 2009. During our discussions with UTC, they recommended that we use stainless steel heat exchangers for the module to help improve the life of the unit and improve the long-term reliability. The additional cost would have increased by $50,000 and delayed the shipment of the unit by 3 months. OIT already uses standard heat exchangers for heating purposes and we have not seen any signs of deterioration, so we elected to go with the standard heat exchanger design. The unit was delivered to our campus in March 2009. The plant was placed in the heat exchange building on the southeast side of campus (Fig. 2, 3, and 4). The plant was dedicated in early 2010.

Fig. 2. Delivery of the UTC Pure Cycle© 280 kW binary power plant.

Fig. 3. The 280 kW binary power plant with the turbine-generator set (covered). The condenser shell-and-tube heat exchanger is on top and the evaporator on the bottom.

Fig. 4. The control panel for the 280 kW binary power plant.

A wet cooling tower, controls, piping and circulating pumps were ordered separately, as they were not included with the UTC plant. The cooling tower uses water from the cold wells on campus located on the up-throw side of the normal fault (Fig. 5). The cooling tower, at 827 nominal tons, is able to cool 1500 gpm of cooling water from 82˚F to 70˚F, at 65˚F entering wet-bulb temperature. We also elected to go with a non-chemical treatment for the cooling tower, since we would have to look at the disposal of the water if we used chemically treated water. We attached a

Pulse Pure device to the cooling water entering the power module. The Pure Pulse Device is a water treatment system that offers an alternative to treating the cooling tower water and it controls bacteria and formation of mineral scale. Approximately 12 gpm of makeup water is required to replace water lost through evaporation from the wet cooling tower. The tower was ordered in April 2009 and delivered in June of that year.

Fig. 5. The building on the OIT campus housing the 280 kW power plant, with the wet cooling tower on the left.

While we were working on the power plant project we were notified by the state energy office that the power plant would require a SEED (State Energy Efficeient Design) Certification. The following components had to be analyzed for efficiency according to the program:

- Cooling tower design
- Sump heater
- Condenser water pump
- Variable frequency drives
- Digital controls for optimization and control under varying and operating situations

We were able to satisfy the SEED program in April of 2009.

There were several other permits and approvals that OIT needed to complete for the operation of the power plant. We had to get the normal building permits, which were issued by Klamath County. We also had to look at our water right certificates and Underground Injection Control permits. OIT has two certificates for water rights, which were approved in 1974 and 1991. The total amount of water available for geothermal heating from our geothermal wells is 1,095 gpm and the domestic water uses is 300 gpm from the cold wells. The certificates also specified how much irrigation water was available for use. The exiting water rights did not allow for power generation so OIT applied for a water rights transfer to include power generation as a use. OIT also applied for a limited use permit to cover us until the water rights transfer is approved. The water rights transfer is on hold at this time, which will allow us to make sure we have all the uses and places of use identified so we will not have to complete this transaction again in the near future.

OIT also currently has an Underground Injection Control permit, which allows the school to reinject the water back into the geothermal reservoir instead of disposing of the water on the surface. The City of Klamath Falls passed an ordinance in the early 1990s that requires geothermal water to be reinjected back into the ground it the system is pumped and no surface disposal is allowed unless the well is artesian. Once OIT decided to include power generation into a use for the geothermal water we were required to apply for a new Underground Injection Control permit. The permit was applied for and approved in 2010.

In order to generate power on campus while interconnecting to the utility system, approvals were required from OITs local utility, Pacific Power. Pacific Power had a specific procedure for obtaining this approval that involved completion of a Small Generation Interconnection Request. OIT applied for a Generation Interconnection Fast Track Study in November 2008. The study was completed in January 2009. This provided the information on what we needed to complete before we were allowed to be connected to Pacific Power. One of the outcomes of the study was that geothermal power generation was not eligible for net metering. We started working on the Purchase Power Agreement soon afterwards. Since OIT was not sure of how much energy would be going to the grid from the power plant we elected to go with a non-guaranteed power purchase agreement. The Interconnection and Power Purchase Agreements had to go through our Department of Justice, which slowed this part of our project. Unfortunately, the price we get for the power going to the grid is less than what we pay for electricity ($0.06/kWh).

While the plant was being specified, ordered and delivered, funding sources were investigated. The Energy Trust of Oregon provides resources and incentives to help install electric power systems. These incentives are based on a project's above-market costs. Our first application was submitted in early 2008 and was turned down due to the incompletion of the application. The Energy Trust of Oregon recognized that we had a good project so they provided assistance in the beginning for us to hire a consultant to help us through the process of developing the power plant. The consultant mainly helped with the interconnection agreement and Power Purchase Agreement (PPA). The Energy Trust of Oregon also provided an incentive of $487,000. The opportunity for a Blue Sky Grant through Pacific Power presented itself next. We submitted the grant application in May 2008 and received notification later that year that we were awarded $100,000. The State of Oregon offered a Business Energy Tax Credit (BETC) that can subsidize the project cost. We applied for the BETC in the middle part of 2008. Being a public institution, OIT would not be eligible to get the full 50 percent on the credit but would get a portion using a pass-through option. The total amount received from the BETC after the project was completed was $254,148.

The geothermal power plant was designed to take approximately 15˚F off the top of the geothermal water as it was pumped from the well, and the remaining 192-15˚F = 177˚F temperature water used to heat campus. In warmer weather, when space and domestic hot water heating in demand is less, then a greater temperature drop is taken from the geothermal water for the plant. Approximately 600 gpm of geothermal water is used to operate the plant.

After the plant was operating, we were required to have an inspection from the Energy Trust. The outcome of the inspection is shown in Table 1.

Table 1. Inspection Summary for Energy Trust of Oregon.

Ambient air temperature:	37.9˚ Fahrenheit
Water flow through PureCycle Module:	448 gpm
Water temperature into PureCycle Module:	192.5˚ F
Water temperature from PureCycle Module:	154.0˚ F
PureCycle module power production :	213.0 kW
PureCycle module power factor:	96.8%
Circulating water pump load:	7.7 kW
Cooling tower fan load:	5.8 kW
Net power plant production:	199.5 kW
Well pump #2 load:	14.7 kW
Well pump #5 load:	58.9 kW
Well pump #6 load:	65.6 kW
Total well pump load:	159.4 kW
Net power delivered to PacifiCorp:	40.1 W
Water temperature to campus:	170.7˚ F
Well pump #2 flow rate:	88.8 gpm
Well pump #5 flow rate:	389 gpm
Well pump #6 flow rate:	314 gpm
Total geothermal water flow:	792 gpm

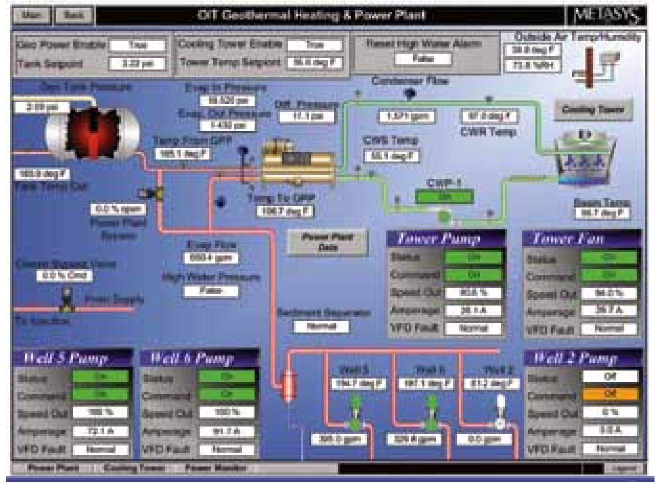

Fig. 6. A screenshot of the control system for the UTC power plant.

The Facilities Services people at OIT have since been doing some trouble shooting with the system to make it more efficient and still be able to heat our campus. They are no longer using Well #2 as the power draw from the pump was more that it was producing. Well #2 has a lower temperature (192˚F) than well #5 (195˚F) or #6 (197˚F). They will still be troubleshooting it to see if they can optimize the power output.

CONCLUSIONS

The total cost for the power plant and auxiliary equipment was $1,100,000 and supplies approximately 10% of the campus electrical energy needs. Very few problems have been encountered during the approximately one year of operation; however, we are still learning how to operate the plant efficiently. We are very proud to be the first campus in the world to receive both geothermal heat and power from a resource directly under the campus. In the future, we hope to have an additional 2.0 MWe (gross) power plant online using a deep (5,300 feet) geothermal well drilled on campus in 2009. This unit along with the UTC plant will provide approximately 90% of the campus electrical needs.

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THE FEASIBILITY OF GEOTHERMAL POTENTIAL IN THE RIO GRANDE RIFT AREA OF NEW MEXICO AND TEXAS

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ABSTRACT

This paper will summarize the feasibility findings for the geothermal potential of the Rio Grande Rift in New Mexico and Texas by the Oregon Institute of Technology (OIT) Team at the Geo Heat Center, Klamath Falls, Oregon. The Rincon and Hatch area was selected as having the highest prospects for geothermal development, specifically for cascading geothermal power production and district heating. The following criteria were investigated: estimated reservoir temperature, reservoir volume, flow-rate, drilling feasibility, environmental effects, local infrastructure, social considerations, diversity and efficiency of end use, and maximum potential cost including estimated time of payback.

INTRODUCTION

The Rio Grande Rift is a location of great interest for geothermal utilization. The forces that shaped the region have created a high thermal gradient at relatively shallow depths. The initial site location in northern Doña Ana County, near the towns of Rincon and Hatch presents good thermal gradients resulting in an estimated 250ºF (121ºC) at 2,000 ft. (610 m) with a potential of flow rates exceeding 1,000 gpm. The water quality found in the Rincon and Hatch region is significantly high in dissolved ions causing a high corrosion factor for piping.

The State of New Mexico currently uses geothermal heat to produce approximately 0.24 MW of electricity with two more projects in the development phase. Future projections for the state estimate a capacity increase of approximately 15 MW with many different incentives supporting these programs. These factors suggest the immediate possibility for the large-scale utilization of geothermal energy in New Mexico, including power generation (Jennejohn, 2011).

The financial assessment holds the most authority over the feasibility of the proposed power plant and direct use applications. The simple payback time of the capital investment is subject to the power plant's output, the cost of electricity sold to the consumers, and revenue generated from direct use applications. The simple payback can also be further reduced through exercising cascading options between the power plant and district heating.

GEOLOGY AND GEOTHERMAL RESOURCE

The Rio Grande Rift (RGR) is a prominent geophysics element dividing the craton of North America and the Basin and Range Province. With a recent history of volcanism (Plocene-Late Pliestocene), a large thermal structure is not a surprise. Gravity surveys suggest that an up warp in the underlying layer of the athenosphere, causing dense igneous intrusions, is present along the length of the Rio Grande Rift (Ramberg, 1978). The underlying crustal thickness at this location is expected to be 6.2-9.3 mi (10-15 km) thinner than the surrounding regions (Cook, 1978).

Geothermal energy use requires the presence of a high geothermal gradient and fluid medium. Near Rincon NM, the shallow temperature gradient of 33.4˚F/100 ft. extended through the Camp Rice Formation. These formations are depicted in Fig. 1. This value is substantially above the RGR average. Near the stratigraphic boundary at 330 ft. (100.6 m), a temperature inversion occurs between 185-162˚F (85-72˚C), likely due to a localized outflow plume. Below this point, a linear gradient of 7˚F/100 ft. extends the length of the test well and is likely to continue through the Thr Formation to a depth approximately 2,500 ft. (762 m) dependent on the inclination of the East Rincon Hills fault.

Rincon is south of the Albuquerque Basin where the rift is divided into a series of smaller north trending grabens (Seager, 1973), one of which is the Rincon Valley with the primary basin deposits being of the mid-to-upper Santa Fe group (Witcher, 2011).

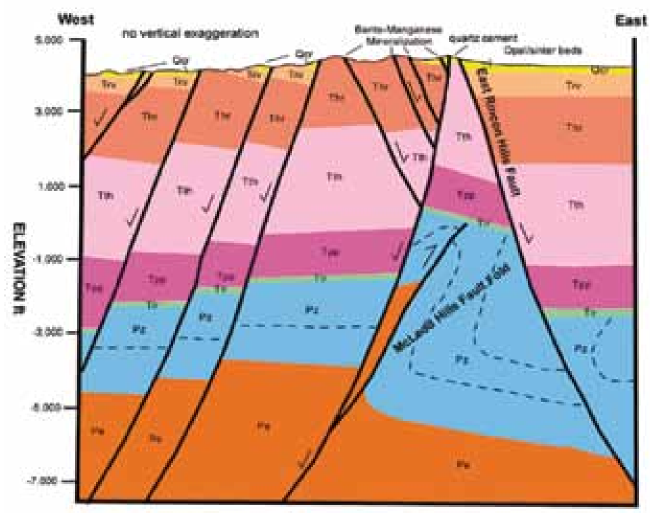

Fig. 1: Estimated Geologic Cross Section of the Rincon Valley, NM (Witcher, 2011).

The hydrothermal chemistry, while not directly sampled during the test well construction, is likely similar to the Radium Springs KGRA given its proximity and similar composition (Witcher, 2011). As such the dissolved chemical content is likely to have excessively high values for chlorine, sodium, calcium, and silicon ions.

SOCIAL AND CULTURAL CONSIDERATIONS

The land around Rincon and Hatch is primarily used for agricultural needs and cattle ranges for dairy purposes. The main exports produced by the agricultural lands are: chili peppers; alfalfa; onions; pecans; and wheat. The local populous is mainly located at the northern part of the city, the farming and dairy lands can be found south of the residential dwellings.

The current unemployment rate in Rincon is 7.2%, which is below the U.S. average of 10.2%; even so, the recent job growth in the area has shrunken by 3.98% (Onboard Informatics, 2009).

Hatch is demographically and economically similar to Rincon, but about six times its size with a population of 1,667 as of July 2009, spread out over a land area of 3.1 square miles. The top industries in Hatch are agriculture, construction and educational services. They have an unemployment level of 8.1%. Furthermore, Hatch has a median household income of $28,864 and an estimated per capita income of $11,376 (Onboard Informatics, 2009).

ENVIRONMENTAL CONSIDERATIONS

The environmental assessment of the geothermal project proposed for the Rincon site is critical to ensuring all local, state, and federal regulations are complied with. These regulations are outlined in the Geothermal Resources Conservation Act (Sections 71-5-1 to 24) of the 1978 New Mexico State Acts (NMSA). As a renewable resource, geothermal energy focuses on generating power and direct-use in a clean, responsible way. All potential hazards and dangers associated with using geothermal energy must be thoroughly inspected and addressed for a successful project. The affected areas in the environmental assessment are: air quality, geology and soils, biological resources, water resources, noise, human health and safety, and social and cultural considerations.

Because the site is located in a desert region, water rights can be difficult to acquire and water usage must be closely monitored. The option of having an air-cooled system to condense the refrigerant is a better option than the water cooled system because of the demand for the scarce resource. The re-injection of the fluid must also be very closely regulated according to all state and federal standards. The permitting for a re-injection well is acquired from the Oil Conservation Division (OCD). The re-injection temperature can be regulated depending on the diversity of the fluid's heat utilization. A re-injection well of geothermal fluid in New Mexico is considered to be a Class V injection well based on 20,6.2 NMAC (New Mexico Administration Code).

OWNERSHIP AND LAND USE

In general, the primary concern when trying to obtain land-use and ownership rights for implementing a geothermal resource is its location. The four primary categories of land ownership for geothermal resources within the United States are federal land, public land, private land, and tribal land. Where the geothermal resources lie determines which set of regulations that must be adhered to, which agencies have jurisdiction, and what permits need to be obtained.

Rincon is mainly under the control of the Bureau of Land Management (BLM), an agency of the U.S. Department of the Interior. Due to the Geothermal Steam Act of 1970, the BLM leases and controls permit applications for any geothermal development on most federal lands, and also private land where mineral rights are held by the Federal Government. All geothermal operations on BLM-managed land must meet environmental, operational standards, prevent unnecessary impacts to surface and subsurface resources, conserve geothermal resources and minimize waste, protect public health, safety and property, and comply with Title 43 of the Code of Federal Regulations (CFR) 3200.4.

Leasing is another very important aspect when considering land use and ownership for developing geothermal resources at any location. Leasing can be both competitive and noncompetitive, each with their own price index and stipulations for leasing regulations. When the BLM issues a lease for geothermal development, it gives the lessee the right to use geothermal resources under the provisions of the Geothermal Steam Act of 1970, Sec. 3 (30 USC 1002). For a competitive lease, property is given to the highest and most qualified bidder; if the land is not sold it can then be obtained as a noncompetitive lease which is available for two years after the original bid (Witherbee, 2011).

If the geothermal plant is to be used as a direct use plant, then, in addition to a geothermal lease, a direct use lease is required. A direct use lease can be obtained through an application process in which a description of the structures (well and pipelines), utilization process, analysis of anticipated production/ injection, and other aspects of the site are included. There is a limit on the amount of land granted for geothermal direct use, which is determined by what the BLM deems necessary within a maximum amount of 5,120 acres (Braff, 2009).

EQUIPMENT AND CAPABILITIES

Drilling varies depending on reservoir depth, hydrology, and geology unique to the location. Only one slim-hole well and several radon gas anomaly and temperature gradient borehole sites have been drilled in the hills to the north of Rincon. Data from these test sites show potential for geothermal development. Currently, no active geothermal operations exist in Rincon and its incorporation into local industry requires further exploration.

For this geologic makeup, the OIT team recommends either dual-wall drilling, or the combination of dual wall and reverse rotary drilling. The additional casing placed during dual-wall drilling may prevent project threatening circulation losses, but will require costly titanium materials for the casing. According to the Geothermal Direct-Use Engineering and Design Guidebook (1998), dual-wall and reverse circulation drilling are suitable for the geophysical characteristics of Rincon. Dual-wall reverse circulation drilling, according to the Layne Christensen Company, addresses the issue of circulation losses, containing highly corrosive water chemistries from potentially contaminating other water tables. The boreholes can be drilled at diameters ranging from 4.5-30 in. in diameter (10-76 cm) which is large enough to accommodate a flow rate between 500 and 1,000 gpm.

Dual-wall reverse circulation drilling values provided at the Geothermal Resource Council's, An Introduction to Geothermal Resource Exploration and Development Conference, estimate production wells between 3,500 ft. and 13,000 ft. to cost between \$857/ft. and \$537/ft., respectively. The deeper the well is drilled, the less the cost of drilling per foot. By interpolation, a 2,000 ft. (610 m) well will cost approximately \$1.8 million (\$908/ft.) (Suemnicht, 2011). This cost estimate does not factor in titanium components.

Titanium will have to be used in the casing. Any materials that are not as durable will corrode away, resulting in a loss of flow and exposure to shallow aquifers. Before drilling operations begin, the drilling company will provide quotes and recommendations for materials used and borehole diameters. The desired flow rate for power generation based on predicted reservoir temperatures will be between 500 and 1,000 gpm. Larger well diameters are more expensive than smaller diameters (OSHA, 2009).

Slim-hole SLH1, in the Rincon hills, requires blowout prevention equipment (BPE) consisting of double gate rams, an annular device, and an accumulator shut-in. The accumulator shut-in provides hydraulic pressure to close a blowout prevention valve in an emergency blowout situation. The double gate rams and the annular device both seal the well bore when a blowout does occur (Witcher, 1995).

Potential power generation is shown in Fig. 2. The graph in Fig. 2 was calculated assuming a geothermal water output of 160°F (71°C) which is a reasonable estimate and allows for many cascading options (Rafferty, 2000). The pump power requirement, assuming a well depth of 2,000 ft. (610 m), is 617 hp (460 kW). The output temperature can be changed to maximize the options of a cascading system, but will decrease the power output of the power plant. A closed system could be used to supply hot water for direct use.

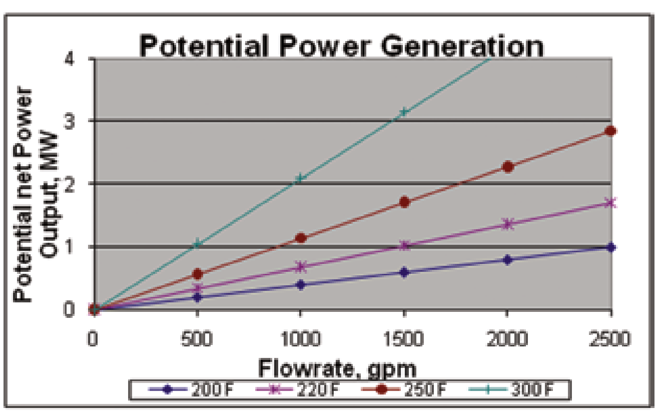

Fig. 2: Net Potential Power Generation (Lund & Boyd, 1999)

The cascading system could be a separate closed system using water, or an open system with water and an injection well in Hatch, at a temperature that can be transported by a less expensive piping system. Due to the pressure that will occur by the drop in elevation from the site to the usable areas, and with the major losses, such as friction and heat loss, insulated steel piping needs to be used because of the pressure required to pump the water back in a closed system.

The distance from the resource to Hatch, where the hot water could be most utilized, is approximately 7.7 mi. (12.4 km) via the most direct road route. The elevation change from the resource to Hatch will result in a 550 ft. (168 m) head difference 238.15 psi (1,642 kPa). The power required to overcome the elevation difference is 69.44 hp (51.8 kW) for 500 gpm (1,893 L/m) and 138.89 hp (103.6 kW) for 1,000 gpm (3,785 L/m). Minor losses were not calculated due to the large variation in how the piping system could be installed and manufactured. The head loss, due to major friction losses, in a pipe that would carry hot water to Hatch is shown in Table 1 below.

Table 1: Pressure Drop to Hatch (Engineering Toolbox, 2011)

Flow gpm)	Diameter (in)	Pressure loss (psi/1000ft.)	Total Pressure (psi)
500	8	1.732	69.28
500	10	0.6495	25.98
750	8	3.897	155.88
750	10	1.299	51.96
1000	8	6.928	277.12
1000	10	2.165	86.6

Fig. 3 shows the heat loss of the piping. The assumed conditions are: 150˚F (71˚C) starting temperature, a ground surface temperature of 25˚F (3.9˚F), pipe depth of 48 in.

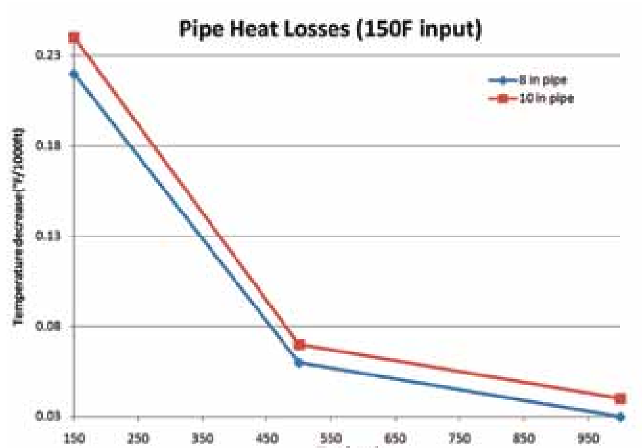

Fig. 3: Heat Loss (Lienau, 2007)

(1.22 m), approximately 3 in. (7.6 cm) of insulation, and 0.2 in. (5.1 mm) of sand around the pipe. The closed system highest temperature can be assumed to be 10˚F less than the input temperature from the hot geothermal side of the heat exchanger (Lund J. W., *Development of Direct-Use Projects*, 2010). Table 2 shows the thermal values assumed (Engineering Toolbox, 2011). Table 3 shows the estimated heat losses in the Rincon and Hatch area assuming an 8 in. pipe with a resource temperature of 150˚F (66˚C).

The heat exchanger characteristics needed for the cascading system to heat the direct use water back to 150˚F (65.6˚C), at the different flow rates can be seen in Table 4 (Rafferty, 1990). The assumed overall heat transfer coefficient was 1000 Btu/(hr∗ft²∗˚F), the hot side input temperature was 160˚F (71.1˚C), and the hot and cold fluids were assumed to be water (Lund, et al., 1998).

Table 2: Thermal Conductivity Values (Engineering Toolbox, 2011)

Material	Thermal conductivity (Btu/ft.∗h∗˚F)
Steel pipe	24.850
Insulation (Polyurethane foam)	0.012
Jacket (PVC)	0.110
Sand fill	0.670
Soil	0.231

INFRASTRUCTURE

Rincon and Hatch are located near a railway line and an interstate highway (I-25), which could serve as primary methods for transportation of construction and drilling supplies. These infrastructural benefits cut down on overall costs of transportation of any major materials required to be imported or exported. It should be noted that when the geothermal pipeline is installed there is a good chance that it would need to cross over or under I-25.

ECONOMIC AND FINANCIAL CONSIDERATIONS

The cost analysis of the binary power plant assumes a resource temperature of 250ºF, and a flow rate of 500 or 1,000 gpm. The cost per kWh is derived from the binary power plant currently in operation on the campus of OIT (Geo-Heat Center, 2010). A 30% increase per kWh for Titanium piping through the power plant was also added to the total cost per kWh yielding $5,107/kWh. The cost for both a 0.5 MW (net) and a 1.0 MW (net) were considered with an estimated parasitic load of 500 kW for both power plant scenarios. Production well pump was also estimated at $300,000 for both power plants. The prices that were used to sell the produced electricity for the cost analysis were $0.05/kWh and $0.07/kWh for each power plant.

Table 3: Heat Losses

	Site B Temperature (˚F) (South of Rincon) 3.4 mi	Site C Temperature (˚F) (intersection of 140 and 185) 4.7 mi	Site D Temperature (˚F) (Hatch) 7.7 mi	Site E Temperature (˚F) (187 river crossing north of Hatch) 10.4 mi	Site F Temperature (˚F) (Salem) 12.8 mi
150 gpm flow	146.19	144.76	141.54	138.71	136.84
500 gpm flow	148.84	148.40	147.40	146.50	145.89
1000 gpm flow	149.42	149.20	148.69	148.24	147.83

Table 4: Heat Exchanger Areas

Hot side flow rate (GPM)	Cold side flow rate (GPM)	Cold side input temperature (˚F)	Heat exchanger surface area (ft²)
500	150	115	133
500	500	115	880
500	150	105	153
500	500	105	1130
1000	150	115	122
1000	500	115	505
1000	1000	115	1750
1000	150	105	139
1000	500	105	590
1000	1000	105	2250

Table 5: System 1: District Heating for Rincon, 150 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 82 Residential Homes	$2,211,496	$8,990	3.09	8.93	$66,852	$57,862	38.2
100% (no retrofit costs)	$1,990,836	$8,990	3.09	8.93	$66,852	$57,862	34.4
75% hookup 61 Residential Homes	$2,125,374	$6,742	2.32	6.70	$50,139	$43,397	49.0
75% (no retrofit costs)	$1,959,879	$6,742	2.32	6.70	$50,139	$43,397	45.2
50% hookup 41 Residential Homes	$2,039,252	$4,495	1.54	4.47	$33,426	$28,931	70.5
50% (no retrofit costs)	$1,928,922	$4,495	1.54	4.47	$33,426	$28,931	66.7

Table 6: System 2: District Heating for Hatch, 500 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 280 Residential Homes	$5,410,251	$30,847	10.60	30.64	$229,386	$198,539	27.3
100% (no retrofit costs)	$4,653,108	$30,847	10.60	30.64	$229,386	$198,539	23.4
75% hookup 210 Residential Homes	$5,114,744	$23,135	7.95	22.98	$172,039	$148,905	34.3
75% (no retrofit costs)	$4,546,887	$23,135	7.95	22.98	$172,039	$148,905	30.5
50% hookup 140 Residential Homes	$4,819,237	$15,423	5.30	15.32	$114,693	$99,270	48.5
50% (no retrofit costs)	$4,440,666	$15,423	5.30	15.32	$114,693	$99,270	44.7

The 0.5 MW (net) power plant would annually produce 4,161 MWh. Selling this electricity at $0.05/kWh yields a net income of $203,050, giving a simple payback of 35.7 years. Selling the electricity at $0.07/kWh yields a net income of $286,270, giving a simple payback of 25.3 years.

The 1.0 MW (Net) power plant would annually produce 8,322 MWh. Selling this electricity at $0.05/kWh yields a net income of $416,100, giving a simple payback of 23.8 years. Selling the electricity at $0.07/kWh yields a net income of $577,540, giving a simple payback of 17.0 years.

To provide heating for the nearby cities of Rincon and Hatch a geothermal pipeline needs to be constructed. The distance from the power plant site to the city of Rincon is approximately 3.4 mi. and 7.7 mi. to Hatch. The insulated supply pipeline is estimated to cost $63/ft. The un-insulated return pipeline is estimated to cost $41/ft. The total geothermal pipeline cost to Rincon is $1.87 million. The total geothermal pipeline cost to Hatch is $4.2 million.

The cost analysis for district heating was based on the following assumptions: the targeted region was the residential sector with an average size of 1800 ft^2 ;the average residence heat load was estimated to be 37,800 Btu/hr; and the annual heating loading factor used was 0.33 (Lund, 2010).

To accommodate the geothermal heating a building retrofit must be done, as well as a cost for the geothermal distribution pipeline. The building retrofit was estimated to be $2,700/house and a distribution pipeline cost of $1,515/house.

Three cascading district heating systems were considered. Each system assumes an initial district heating temperature of 160˚F, and power plant costs are excluded in the total capital cost for each system. For Rincon the flow rate was set at 150 gpm, yielding a ΔT of 41.19˚F providing equivalent heating for 82 homes (Table 5). The second system is for heating Hatch at 500 gpm, this provides a ΔT of 42.4˚F heating up to 280 homes (Table 6). The third system is for heating Hatch at 1,000 gpm, this system provides ΔT of 43.69˚F heating up to 578 homes (Table 7). Assuming the natural gas costs are $0.94/therm (U.S. Energy Information Administration, 2011), the cost for the district heating would be 80% (Brown, 2007) of the natural gas costs yielding $0.75/therm.

Table 7: System 3: District Heating for Hatch, 1,000 gpm

SYSTEM	TOTAL CAPITAL COST	O & M $/YR	PEAK ENERGY (mill. Btu/hr)	ANNUAL ENERGY (bill. Btu/hr)	GROSS GEOTHERMAL INCOME/YR	NET GEOTHERMAL INCOME/YR	SIMPLE PAYBACK YEARS
100% hookup 578 Residential Homes	$6,664,202	$63,570	21.85	63.15	$472,730	$409,160	16.3
100% (no retrofit costs)	$5,103,845	$63,570	21.85	63.15	$472,730	$409,160	12.5
75% hookup 433 Residential Homes	$6,055,208	$47,678	16.38	47.36	$354,547	$306,870	19.7
75% (no retrofit costs)	$4,884,940	$47,678	16.38	47.36	$354,547	$306,870	15.9
50% hookup 289 Residential Homes	$5,446,213	$31,785	10.92	31.57	$236,365	$204,580	26.6
50% (no retrofit costs)	$4,666,035	$31,785	10.92	31.57	$236,365	$204,580	22.8

Table 8: Cascading Best/Worst Case, Simple Payback.

Scenario	Case	Simple Payback
Scenario 1: District Heating for Rincon, 150 gpm	Best Case:	**18.5 years**
	Worst Case:	**40.0 years**
Scenario 2: District Heating for Hatch, 500 gpm	Best Case:	**18.6 years**
	Worst Case:	**39.9 years**
Scenario 3: District Heating for Hatch, 1,000 gpm	Best Case:	**19.5 years**
	Worst Case:	**31.1 years**

The simple paybacks for the district heating systems are not great. In fact if the district heating costs included the drilling capital costs, they would be considered not feasible. However when the district heating system is based off the exit temperature of the power plant, and the costs for wells, power plant, geothermal pipeline, and district heating are viewed as a complete system, then the system simple payback brings the project feasibility into a new light. This uses the combined revenue of the district heating and power plant to reduce the time needed to pay off the total capital cost of the system. This was viewed in two ways for each scenario, best case and worst case as seen in Table 8. The best case uses the larger power plant (1.0 MW net) selling power at the higher rate ($0.07/kWh) and 100% hookup with no retrofit costs. The worst case uses the smaller power plant (0.5 MW net) selling power at the lower rate ($0.05/kWh), and 50% hookup with retrofit costs.

CONCLUSION

The area of Rincon and Hatch has all the necessities of a comprehensive, all-inclusive, geothermal power system. The resource has an expected temperature of 250˚F (121˚C) at 2,000 ft. (610 m) deep, and could have a flow rate from 500 to 1,000 gpm. Since the proposed site is on BLM land, obtaining rights and permissions to drill and produce should not be difficult. With the main use of the resource being electricity production (from 0.5 MW to 1.0 MW), the resource may also be easily cascaded into direct-use applications. A closed-loop pipeline will transport the heat from the site through Rincon to Hatch distributing the resource to the local communities with little loss of heat and power consumed.

Although the water chemistry of the resource is harmful to traditional equipment used in geothermal production, using titanium piping on site will not only resist the corrosiveness of the ionized and dissolved solids, but also increase the lifetime of the binary power plant. There are no detrimental environmental, social, or cultural issues that could halt progress on the project; the community has a history of accepting geothermal applications and other renewable energies. The implementation of geothermal power into the community will stimulate the economy through employment opportunities, decreased utility costs, and science oriented educational opportunities aimed at teenagers.

Through utilizing cascading geothermal systems the project feasibility becomes quite possible. By using the waste geothermal fluid from the power plant for district heating, the annual revenue can be combined to reduce the long simple payback of the power plant. Between the three proposed scenarios the overall best case is a payback of 18.5 years, with a worst case being 31.1 years.

Along the whole Rio Grande Rift, a production well in Rincon is the best place to implement a complete geothermal system. The site poses little issues to development, the resource has a good temperature and flow and the community will benefit from the project. The Rincon site has the highest possibility of success that stretches further than utilizing a geothermal resource. The project will demonstrate the wide-ranging effectiveness of utilizing a low-temperature resource in small communities and serve as a basis for a community-focused geothermal system internationally.

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NREL NATIONAL GEOTHERMAL STUDENT COMPETITION JUNE 2011

Jim Evans, Geo-Heat Center, Oregon Institute of Technology, Klamath Falls, OR

The inaugural competition of the 2010-2011 National Geothermal Student Competition, sponsored by the National Renewable Energy Laboratory and the U.S. Department of Energy, was held in Santa Fe, NM, on June 23rd, 2011. All 11 teams presented their respective reports in a 20 minute presentation followed by a 10 minute question and answer section. The report titles and winners of the competition were:

Colorado School of Mines: *Investigation of Geothermal Resource Potential in the San Luis Basin*. 2nd place.

Faculty/Team Head: Dr. Richard (Ric) Wendlandt, rwendland@mines.edu, Department of Geology and Geological Engineering; Student Team Members: Graduate Students: Laura Garchar (M.S.), Elisabeth Easley (M.S.), Mitchell Bennett (M.S.), Joyce Hoopes (M.S.), Rachel Woolf (M.S.); Undergraduate Student: Banks Beasley

Oregon Institute of Technology: *The Feasibility of Geothermal Potential in the Rio Grande Rift Area of New Mexico and Texas*.

Professor/Team Head: Tonya "Toni" Boyd, toni.boyd@oit.edu, Senior Engineer, Geo-Heat Center, Oregon Institute of Technology; Student Team Members: Undergraduate Students: Jonathan Hall, Reginald Boyle, Samuel Cole, Phillip Maddi, Kevin McBride, Callen Hass, Aleena Anderson ,Joseph Miranda, Michael Benedict, James Evans, Casey Coulson.

Pennsylvania State University: *Resource Assessment and Utilization of Low-Through High-Enthalpy Geothermal Fluids From the Rio Grande Rift Region of New Mexico and Colorado*.

Professor/Team Head: Dr. Derek Elsworth, elsworth@psu.edu, Penn State, Sarma Pisupati, Penn State, Uday Turaga, ADI Analytics and Penn State; Student Team Members: Graduate Student Advisor: Ghazal Izadi (Ph.D. Candidate); Graduate Students: Divya Chandra, Caleb Conrad, Vaibhav Rajput, Anukalp Narasimharaju; Undergraduate Students: Derek Hall, Nick Montebello, Emilia Phelan, Andrew Weiner.

San Diego State University: *Geophysical Evaluation by the SAGE Group of a Newly Discovered Geothermal Prospect Near Santa Fe, New Mexico*.

Faculty/Team Head: Dr. George Jiracek, george.jiracek@geology.sdsu.edu, Professor Emeritus, Department of Geological Sciences, San Diego State University; SAGE Faculty/Collaborators: Shawn Biehler, University of California-Riverside; Scott Baldridge, Los Alamos National Laboratory; John Ferguson, University of Texas-Dallas; Larry Braile, Purdue University; Louise Pellerin, Green Engineering; Paul Bedrosian, USGS; Darcy McPhee, USGS; Cathy Snelson, National Center for Nuclear Security; Student Team Members: Graduate Students: Jason Chang, University of California - Berkeley; Daniel Feucht, University of California - Berkeley; Christian Hardwick, University of Utah; Undergraduate Students: Karl Bloor, San Diego State University; Ben Phrampus, Baylor University; Emily Tursack, Brown University; and approximately 30 graduate and undergraduate students who will attend SAGE 2011.

Stanford University: *Exploration and Development Plan for the Eastern San Luis Basin Rio Grande Rift, Colorado*.

Professor/Team Head: Sarah Pistone, MS; Student Team Members: Graduate Students: Matt Ganser (Ph.D.), mpganser@stanford.edu, Pablo Garcia Del Real (Ph.D.), John Murphy (M.S.), Lena Perkins (Ph.D.).

Texas A&M University: *Assessment of the Geothermal Potential of the Rio Grande Rift*.

Faculty/Team Head: Dr. George Moridis, GJMoridis@lbl.gov, Visiting Professor, Department of Petroleum Engineering, TAMU Deputy Program Lead for Energy Resources - Staff Scientist - Earth Sciences Division, Lawrence Berkeley National Laboratory (LBNL); Student Team Members: Graduate Students: Daegil Yang (PhD), Akkharachai Limpasurat (PhD), Mojtaba Ardali (PhD), Olufemi Olorode (MS), Tioluwanimi Odunowo (MS), Nimish D. Pandya (MS), Manuel Cossio (MS).

University of California, Davis: *A Unique Approach to Managing Complex Geothermal Datasets: An Integrated Multidisciplinary Re-evaluation of the Geothermal System at Valles Caldera, New Mexico, Using an Immersive Three-Dimensional (3D) Visualization Environment*. 1st place.

Faculty: Dr. Peter Schiffman, pschifman@ucdavis.edu, Professor, Department of Geology, UCD; Dr. Robert Zierenberg, Professor, Department of Geology, UCD; Dr. James McClain, Professor, Department of Geology, UCD; Dr. Bill Glassley, Director, California Geothermal Energy Collaborative; Student Team Members: Graduate Students: Scott Bennett, Austin Elliott, Andrew Fowler, Maya Wildgoose, Amy Williams; Undergraduate Students: Leslie Barnes, Carolyn Cantwell, Kevin Delano, Sam Hawkes, Rachael Johnson, Rita Martin, Kevin Renlund.

University of Idaho: *Evaluating the Geothermal Potential of the Rio Grande Rift using Spatial-Statistical Methods*. 3rd place.

Professor/Team Head: Travis Kelsay, kels8638@vandals.uidaho.edu; Jennifer Hinds, U-Idaho Geological Sciences staff from Tullahoma, Tenn.; Jerry Fairley, Associate Professor of Geological Science; Student Team: Graduate Students: Jessica Osterloh, Ryan Pollyea, Alex Wagner.

University of North Dakota: *Evaluation of Geothermal Potential for Selected Resources in the Rio Grande Rift: Albuquerque Basin*.

Faculty/Team Head: Dr. Will Gosnold, William.gosnold@email.und.edu, Professor of Geophysics and Chair of the

Department of Geology and Geological Engineering; Student Team Members: Graduate Students: Kirtipal Barse, James Crowell, Anna Crowell, Samir Dahal, Rob Klenner, Mark McDonald, Dilojan Senanayake, Eric Zimny; Undergraduate Students: Bailey Bubach, Alexander Padgett, Angelle van Oploo, Preston Wahl.

University of Utah: *Geothermal Potential of the Rio Grande Rift: From Exploration to Production*.

Team Head: Dr. David S. Chapman, david.chapman@utah.edu, Distinguished Professor of Geophysics, Dean Emeritus, The Graduate School, Department of Geology and Geophysics, University of Utah; Supporting Faculty: Dr. Rick Allis, Director, Utah Geological Survey Adjunct Professor, Department of Geology and Geophysics, University of Utah; Dr. Joe Moore, Research Professor, Department of Civil and Environmental Engineering, and Adjunct Professor, Department of Geology and Geophysics, University of Utah; Student Team Members: Graduate Students: Danielle D'Afonso (M.S.), Christian Hardwick (M.S.), Becky Hollingshaus (M.S.), Michal Kordy (Ph.D.), Kevin Smith (Ph.D.), Stan Smith (M.S.); Undergraduate Student: Ruthann Shurtleff.

Virginia Polytechnic Institute and State University: *Assessment of the Scientific, Technical, Socio-Economic and Cultural Issues Associated with the Development of Geothermal Resources in the Rio Grande Rift Region of the Southwest United States*.

Faculty/Team Head: Dr. Robert J. Bodnar, rjb@vt.edu, University Distinguished Professor and C. C. Garvin Professor of Geochemistry; Student Team Members: Undergraduate Students: Shelbie Bennett, Michael Ciampa, Meg Collins, Craig Cunningham, David Dorsett, Kerry Anne Douglas, Anthony D. Frayne, Kaylee Hershfeld, Rebecca Horne, Nicholas Higgins, Matt Kadilak, Steven Langhi, Heather Scott, Joshua Seay, Mark Stamper, Alli Vallowe, Michael Vliet, James Ward.

The prize for the winners included sending two of the teams members to the GRC, October 23-26, 2011, in San Diego, CA. The teams presenting their reports at the GRC are:

Presentation: Oregon Institute of Technology, Pennsylvania State University

Poster: University of California, Davis; Colorado School of Mines; Oregon Institute of Technology; Pennsylvania State University; San Diego State University; University of North Dakota; University of Utah

Additional information can be found at the NREL Geothermal Competition website: http://www.nrel.gov/geothermal/competition.html

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