

GREENHOUSE HEATING WITH LOW TEMPERATURE GEOHERMAL RESOURCES IN LAKE COUNTY, CALIFORNIA

by

Mark Dellinger and Gib Cooper
Lake County Planning Department, Resource Management Division

ABSTRACT

The County of Lake recently completed the first phase of a geothermally heated "agricultural park" located southeast of Kelseyville, California. This cooperative effort with the Mendocino-Lake Community College District has been largely funded by the California Energy Commission and includes a 7000 square foot greenhouse, irrigation system, geothermal production and injection wells, transmission piping, heat exchangers, pumps, and valves. The initial phase of development includes the College's program in greenhouse management, plant propagation and other vocational activities. The 500 foot deep geothermal production well yields 100 gallons per minute (GPM) of 153°F water. This volume is capable of supply heat for about 20,000 - 40,000 square feet of greenhouses in addition to the College's existing facility. A second production well is capable of producing 150 GPM of 145°F water which could heat another 40,000 - 50,000 square feet of greenhouse space. The second phase of development will include expanding the irrigation system, bring the second geothermal well into production, reservoir analysis, and conducting an intensive marketing effort for the Agricultural Park's facilities.

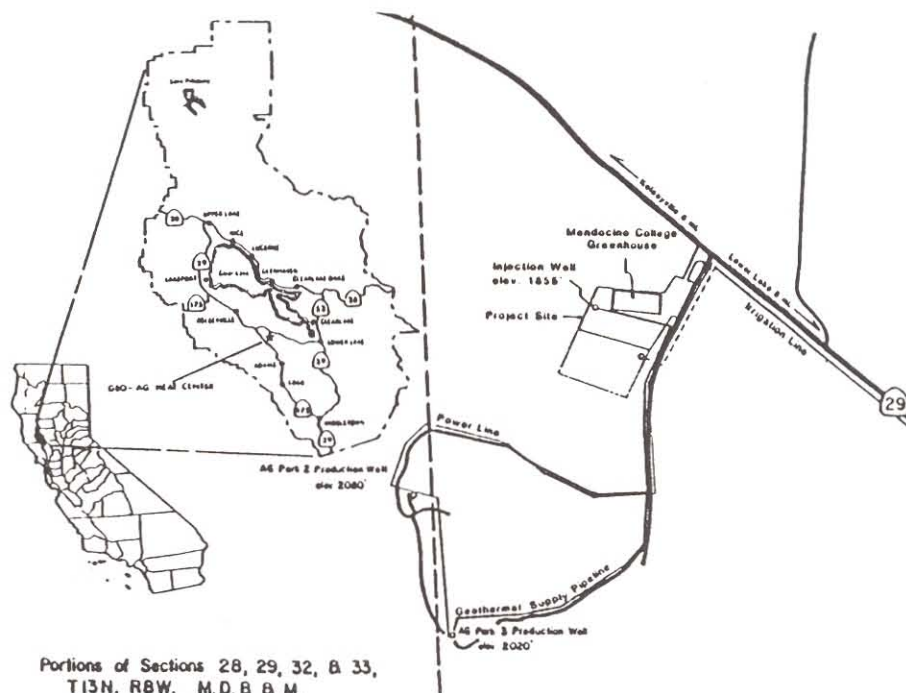
INTRODUCTION

Lake County has long been known for its substantial geothermal steam resource in the Geysers for power generation. However, the County has few examples of direct use applications of its low temperature resources.

In 1989, the County completed the first phase of a geothermally heated agricultural park, located 6 miles southeast of Kelseyville, California (Figure 1). In an attempt to diversify the economy, demonstrate the low temperature potential and provide vocational training, the County and the Mendocino-Lake Community College joined together in this California Energy Commission (CEC) funded project. Table 1 shows the project budget summary.

BACKGROUND

Initial site evaluation and resource assessment was conducted in 1984, in a previous study (also funded by CEC) entitled "Utilization of Geothermal Resources in Lake County: Phase 1" (Nolte, 1984). The S-Bar-S Quarry area, 2 miles south of Mt. Konocti, was selected because of its geothermal potential and negotiations were entered into with the private land/resource owners.



Portions of Sections 28, 29, 32, & 33,
T13N, R8W, M.D.B. & M.

Figure 1. Geothermal Agricultural Park Site Plan.

Table 1 Project Budget Summary & Funding Sources

<u>Phase I:</u>	
Drilling, Completion, Testing (Including Permits & Bonding)	\$ 236,574
Geology & Geophysical Survey	13,000
Geothermal and Irrigation Supply Systems (Including engineering design and contingencies)	216,830
Greenhouse	79,972
<u>FUNDING SOURCES</u>	
California Energy Commission (Grant Dollars)	492,000
County of Lake (Personnel & Dollars)	162,855
Mendocino-Lake Community College District (Personnel)	73,220
<u>CONTRIBUTIONS</u>	
Geysers Geothermal Company (Dollars & Materials)	10,000
Pacific Gas & Electric Company (Materials)	500
Phase I Total Project Budget	702,479
<u>Phase II:</u>	
Geothermal & Irrigation Systems Expansion	170,000
Facility Marketing Program	64,664
<u>FUNDING SOURCES</u>	
California Energy Commission (Forgivable Loan)	170,000
California Energy Commission (Grant)	64,664
County of Lake (Personnel & Dollars)	39,600
Phase II Total Project Budget	274,264

Following lease acquisition an environmental impact report was prepared and permits were obtained from the California Regional Water Quality Control, California Division of Mines and Geology, Lake County Air Quality Management District, Lake County Department of Public Works, Lake County Building Department and Lake County Planning Department.

GEOLOGY

The site geology is strongly influenced by the Clearlake Volcanics in general and specifically by Mt. Konocti, a composite cone. Colluvium and recent non-marine sediments have concealed most of the ring fracturing associated with Sugarloaf Mountain, northeast of the site (Figure 2). A geophysical analysis of the area confirmed these fractures as well as identification of a shallow conductive layer of water. The most significant structural feature in the area is a fault zone near the south end of the study area. This zone lies in an east-west direction and dips steeply to the south. The fault contains evidence of recent geothermal activity such as hydrothermal alteration, hydrogen sulfide emissions and slickensides. In addition, native sulfur is being deposited in the altered dacites along this feature. The reservoir rock is a rhyolite (Pleistocene) with permeability confined to weathered surfaces between flows or regional fractures.

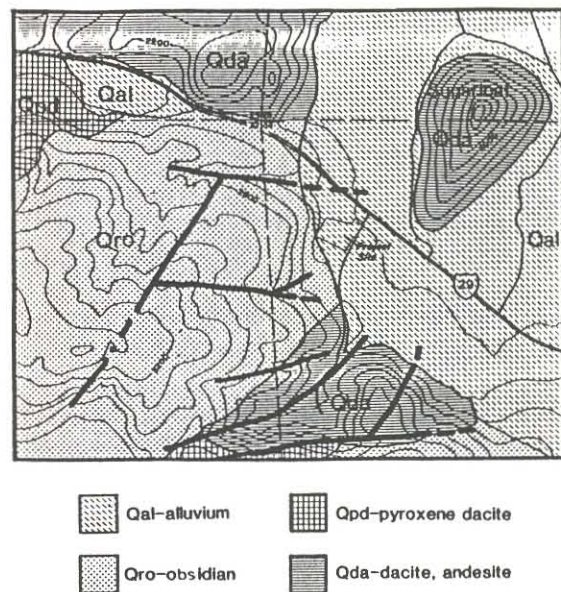


Figure 2. Area geology and structure.

DRILLING/TESTING

Thermal Source, Inc., consulting engineers, were retained by the County to manage the production and injection well drilling and testing. Figure 3 shows well profiles and casing programs for Ag Park No. 1 (injection) and Ag Park 2 and 3 (production). Ag Park 1 was drilled by Well Tech, Inc. of Woodland, California with a rotary oil/gas work over-type rig. After the resource was identified at shallower depths than previously thought, Weeks Drilling of Sebastopol, California drilled Ag Park 2 and 3 with a Gardner-Denver air rotary drill rig commonly used for water well drilling. Wilson and Sons Pump Company from Nevada, conducted pump tests on the wells. Relevant pump test data is included in Figure 4. An "under ream" drilling process was performed on Ag Park No. 3 and is discussed later in this paper. A chemical analysis for the production wells is provided in Table 2.

Table 2 Geothermal Production Well Chemistry

Ag Park 2	Ag Park 3	Production	Production
Arsenic	<0.05 mg/l	Ammonia	11.8 ppmw
Barium	<1.0 mg/l	Arsenic	<0.05 mg/l
Boron	30.5 mg/l	Barium	<1.0 mg/l
Cadmium	<0.01 mg/l	Boron	50 ppmw
Chromium	<0.05	Cadmium	<0.01 mg/l
Chloride	88 mg/l	Chloride	71.9 ppmw
Fluoride	0.26 mg/l	Chromium	<0.05 mg/l
Lead	<0.05 mg/l	Fluoride	28.8 ppmw
Mercury	<0.002 mg/l	Hydrogen Sulfide	17.2 ppmw
Nickel	<0.05 mg/l	Lead	<0.05 mg/l
pH	6.6	Mercury	<0.002 mg/l
Selenium	<0.01 mg/l	Nickel	<0.05 mg/l
Silver	<0.05 mg/l	Nitrate	<11 ppb
Sulfate	8.8 mg/l	Oxygen	<0.1 ppmw
		pH	6.5
		Phosphate	0.9 ppmw
		Selenium	<0.01 mg/l
		Silver	<0.05 mg/l
		Sulfate	2.1 ppmw

ENGINEERING DESIGN

The basic objective in designing the geothermal and irrigation supply systems was to achieve simplicity and reliability. Brown and Caldwell Consulting Engineers of Pleasant Hill, California were retained by the County to prepare the plans and specifications. During this time, the College developed specifications for a 7000 square foot pre-manufactured greenhouse. Through CEC, the Geo-Heat Center of Klamath Falls, Oregon provided technical assistance for plan review and materials selection. Their support was invaluable.

Geothermal System Design

Figure 4 is a process piping and instrumentation diagram of the system. A submersible pump installed in the Ag Park No. 3 well pumps hot water to an underground storage tank. The pump is operated by a level control system located in the storage tank. As the water level in the tank drops below the low level setting, the pump will start. The water level will rise until the high level setting is reached and the pump stops. In the future, high and low level alarm signals will be provided through a phone modem and computer system for remote alarm indication.

Geothermal water flow from the storage tank to the Ag Park is by gravity. Flow through a plate type heat exchanger in the College's greenhouse is controlled by a temperature control valve located on the outlet side of the heat exchanger. When the temperature of the outlet water rises, indicating lower heat demand at the greenhouse, the temperature control valve starts to close and geothermal water flow decreases. When the temperature of the outlet water drops, indicating higher heat demand at the greenhouse, the temperature control valve starts to open and geothermal water flow increases. A small bypass valve (HV 240) around temperature control valve (TCV 201) allows a small flow of geothermal water to continue when no demand for heat exists. This flow assures that the piping system is maintained at operating temperatures and allows TCV 201 to accurately sense an increase in heat demand. Flow from the heat exchanger discharges to the reinjection well by gravity. Connections are provided for a future reinjection pump if required. A manual valve (HV 250) is provided to allow the minimum required flow to maintain system temperature if the heat exchanger is manually isolated for maintenance or repair.

Heating demand supplied by the geothermal system is recorded by a BTU totalizer. The BTU totalizer processes signals received from temperature transmitters installed at the heat exchanger inlet (TT 205) and outlet (TT 207), and flow meter (FM 203) and provides a display of total BTU usage and total flow.

The greenhouse is a 7000 square foot pre-manufactured building by Conley Systems and contains three chambers which can be separated by polyethylene walls. The roof is composed of two layers of 6 mil. polyethylene sheet plastic. Small blowers provide an eight inch air layer between sheets for insulation. The forced-air heating system consists of three Lanco hot water fan coil units, with one unit mounted in each zone and hung from the ceiling. Heated air is carried from each unit through 18" plastic tubes with holes running the entire length of the greenhouse. Hot water circulation is maintained by a 1/2 horsepower Armstrong Pump. At peak design heat load, the fan coils utilize 24 GPM (8 GPM/unit) of 115°F supply water. This water is cooled to about 90°F, providing a total of 300,000 BTU/hour.

Cooling is accomplished through an evaporative-type "kool-cel" cooling pad located at the west end of the greenhouse. Outside air is drawn into the "kool-cel" by six 36-inch fans (2 fans/zone) on the east end of the greenhouse.

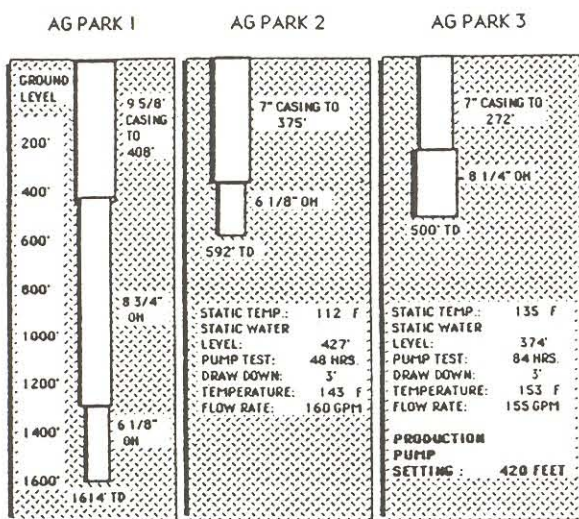


Figure 3. Well profiles, casing programs, and pump test data.

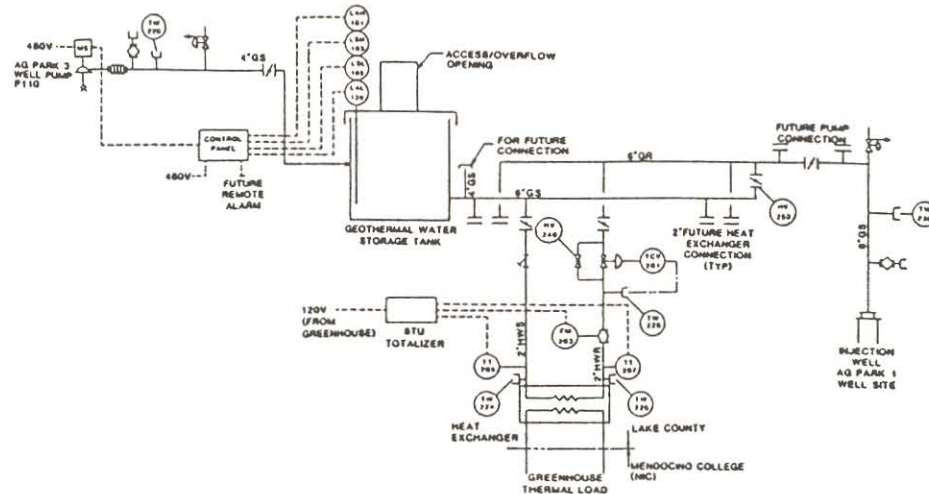


Figure 4. Geothermal System.

Both heating and cooling is modulated by a Priva Systems climate control system. Each zone contains one environmental data monitor designed to record solar intensity, temperature, dry and wet bulb humidity, and maintain set points and irrigation schedules. A total of 100 days of data collection can be stored.

Due to budget limitations only a small irrigation supply and pressure system was constructed to meet the needs of the College greenhouse. In Phase II of the project, a larger irrigation system will be completed.

MATERIALS SELECTION

Because the geothermal fluid contains high levels of Boron, it was decided to utilize a heat exchanger for the College greenhouse. Other considerations such as the presence of oxygen, hydrogen sulfide and low pH also influenced materials selection.

Production Equipment

Due to the small diameter (6 1/8") of the Ag Park No. 3 well, a submersible type pump was utilized. Although the well can produce greater quantities of fluid, budget constraints resulted in down sizing the pump. Reda Pump of Long Beach, California supplied a 30 H.P. 10 stage pump (5.4" O.D. diameter) with variable speed drive capable of producing 70 GPM. As discussed later, several modifications were made to these specifications during construction and installation. Pump tubing was supplied by the Centron Corporation of Mineral Wells, Texas. This tubing is a thick-walled FRP tubing with threaded ends made in 29 foot lengths.

After the fluid is brought to surface, it is carried through 4-inch SCH 40 carbon steel pipe a distance of approximately 15 feet and into a storage tank which is buried to grade. The piping is covered with 2-inch fiberglass insulation and encased with an aluminum jacket.

The storage tank is a 1250 gallon pre-cast, two compartment concrete tank which is commonly used in residential septic applications. Prior to being delivered to the site, the tank was coated with an 8 millimeter thickness of Napko Thixapoxy coating. This is intended to protect the

concrete from chemical and thermal breakdown. The tank opening is covered with a 3-foot diameter manhole section and 2-foot diameter bolt down steel cover. The tank is entirely insulated with 2-inch thick sheet polystyrene foam. In addition, the tank lies in 12 inches of compacted sand and is drained with flexible drain pipe.

Transmission Piping

Centron Corporation supplied threaded FRP piping to carry the geothermal fluid from the production well to injection well. Both 6-inch and 2-inch pipe was utilized. Budget limitations affected specific selections. Initially, the pipe was to be insulated and buried. However, insulating the pipe doubled the per foot cost and with 2800 feet of pipe in the system, it was considered too expensive. Heat loss through the 6-inch pipe is discussed later in this paper. The pipe was laid in an 18-inch wide trench with depths of 48 inches (without traffic loads) to 60 inches (with traffic loads). A 50-foot span of pipe under a main road was "sleeved" with a welded piece of 12-inch Geysers type well casing. Used truck tire inner tubes were wrapped around the FRP where it entered and exited the steel sleeve to prevent damage. In the trench, the pipe was bedded in 6 inches of sand and covered with 3 - 4 inches of sand and backfilled to surface. Low lying portions of the trench also contained drain rock and 3-inch flex drain pipe. In areas requiring additional compaction, hydro-jetting was used.

Heat Transfer, Control, Metering Equipment

A plate type heat exchanger was selected because of its superior heat transfer capabilities and expandability. A Tranter Superchanger with a capacity of 300,000 BTU/Hr was specified. The plate material is 316 stainless steel. The temperature drop (ΔT) across the exchanger was designed at 25°F.

As mentioned earlier, a temperature control valve (TCV) controls geothermal flow through the exchanger. A Terice adjustable TCV with temperature gauge was used. The TCV is double seated with bronze body and stainless steel trim. Flow rate and energy consumption on the geothermal side of

the exchanger are monitored by a Hersey model 7003 BTU measurement system. Temperature sensors, 50 GPM turbine flow meter and a control/display instrument are included. The display unit shows instantaneous flow rate, temperature difference and BTU/hr. In addition, 5 digit BTU and gallons totalizers are provided.

Disposal Equipment

After heat is extracted geothermal fluid continues to flow by gravity to the injection well. Blind flanges are located along this portion of piping for future connections. Pipe rises above ground and is the same SCH 40 carbon steel pipe with insulation as at the production well. The injection well is capable of accepting approximately 400 GPM by gravity, but currently the maximum is 70 GPM. Injection pressure (gravity head) is approximately 50 - 60 PSI.

Greenhouse Distribution System

Service loop piping for greenhouse fan coil units is high temperature SCH 40 CPVC in sizes from 2 inch down to 3/4 inch diameter. A 5 gallon pressure tank and 1/2 h.p. Armstrong pump and motor pressurize the supply system. Supply and return temperature and pressure gauges are also provided.

CONSTRUCTION

Greenhouse

Mendocino College originally planned to have the greenhouse supplied and constructed by one contractor. However, all bids received were much higher than budgeted. Innovative solutions were required to make this portion of the project a reality. The College hired a construction manager with greenhouse experience to oversee purchase of materials and construction. A service contract was signed with Konocti Industries of Lakeport, California, a nonprofit organization employing developmentally disabled residents, to build the greenhouse. This arrangement allowed construction to be completed within the limited budget and time schedule.

Geothermal System

While the College was building the greenhouse, the County went to bid for construction of the geothermal system. Only one bid was received and a contract was negotiated with Richelieu-Werner Construction Services of Redding, California. The project was originally designed to have two production wells connected to the system along with a large irrigation system which included a 21,000 gallon storage tank and pressure booster package. As mentioned earlier, the budget limited the existing system to a small irrigation system and connection of only one production well to the system. Table 3 shows construction costs for various system components.

The first stage of construction included installation of the geothermal piping. The contract was signed in October 1988, and the pipe was on site within 6 weeks. The mechanical subcontractor installed approximately 2600 feet of pipe within 8 working days. This was completed by two laborers and 1

backhoe operator. The installation went smoothly. To assure proper field assembly of pipe joints, a field representative from Petroleum Specialties (West Coast Centron Distributor) and an engineer from the Oregon Institute of Technology (OIT) provided technical assistance. Construction was proceeding smoothly when it was discovered that the subcontractor incorrectly calculated the amount of 6-inch pipe needed. The order was short by approximately 200 feet. The necessary pipe was ordered from Mineral Wells, Texas, in early December, 1988 and a 6 week delivery was anticipated. Because of the small size of the order, Centron Corporation hired a common carrier to transport the pipe. Then the project became somewhat frustrating. Figure 5 is a map showing the delivery route followed by the carrier. After many phone calls and attempts to locate the pipe, the County was assured that the pipe would be in Sacramento by mid-March 1989. It was fortunate that the hauler in Sacramento was contacted prior to leaving for the site because the hauler was planning to deliver the pipe to a small town on the coast near Eureka, approximately 200 miles north of the project. While the pipe was finding its way to Lake County, other portions of the project were completed. The geothermal storage tank was installed along with all aboveground geothermal piping and insulation.



Figure 5. Delivery route of geothermal pipe.

The first attempt to install the well pump was unsuccessful because the well was too narrow to accept the pump. A caliper survey was run on Ag Park No. 3 and an under ream drilling process was performed in the open hole portion of the well. When completed the open hole was enlarged from 6 1/8 inches to 8 1/2 inches (see Figure 4).

The electric cable originally specified for the pump had a 250°F rating but failed. The pump was installed with 350°F rated steel armored cable which has worked for over 1 year and is presently working.

Other problems occurred with the variable speed drive unit (VSD). An Emerson Laser VSD was installed but never worked consistently. After many visits from various field representatives, it was decided to remove the VSD and allow the pump to operate at constant speed. For future expansion, more storage tank capacity will be added to reduce pump cycling.

Table 3 Actual Construction Costs for Phase I Activities

<u>Resource Confirmation</u>	<u>Amount</u>
Geology & Geophysics	\$ 13,000
Drilling, Completion Logging, Testing:	
Ag Park 1	170,000
Ag Park 2	25,000
Ag Park 3	25,000
Ag Park 3 under ream (including caliper survey)	16,000
<u>Geothermal Supply System*</u>	
General Requirements, Bond & Insurance	20,650
Mechanical Components (includes heat exchanger, valves, geothermal piping (w/field rep.), trenching/backfilling)	119,550
Electrical Components (including electrical panel, level control system and BTU measurement system)	13,541
Geothermal Well Pump & Drive	22,000
Geothermal Well Pump Tubing	11,345
Pump Service Representative	2,000
Pump and Tubing Installation	3,000
Concrete Work (including geo. storage tank, pads, aboveground pipe supports)	2,950
Testing	1,500
Annual Fees for Bonds, Permits and Geothermal Water Sampling/Analysis	2,000
* This work includes a contractor's profit of 14%	
<u>Irrigation System</u>	
Storage Tanks, Pressure System and 900 feet of 3" PVC including labor	5,000
<u>Greenhouse</u>	
Materials	56,000
Labor	16,000
Irrigation System	1,500

The original level control system installed in the storage tank was manufactured by Warrick Controls of Royal Oak, Michigan and included 4 stainless steel level probes with relays and connections. Two problems were evident with this system. First, the control rods were too sensitive to wave action within the storage tank and this problem was not eliminated with the addition of a stilling well. Second, the steel box holding the rods and wires was continually exposed to condensation. This resulted in relay "chatter" and short circuiting of the control system. Although the latter problem could have been solved by moving it outside of the tank, the sensitivity problems were not solved. After numerous visits by electricians and the contractor, it was decided to replace the system. A Frank W. Murphy Liquid Level Switch Gage and controller was installed. This system monitors water level via column pressure exerted on a small diameter piece of CPVC

attached to the inner wall of the storage tank. The relay controller, level gauge, and purge pump are contained in a weather proof box located outside the tank and above grade on a wooden post. This system is not as sophisticated as the previously installed system, but has provided about 3 months of continuous service.

SYSTEM MODIFICATIONS AND PERFORMANCE

After construction was completed and prior to initial start-up, a prolonged leak test was conducted on the entire geothermal system. After filling the supply system, water levels in the geothermal storage tank were measured daily for two weeks. No leaks were identified. During this time the College had completed installation of the irrigation system and students began horticultural activities in the greenhouse. Unusually cold weather in April 1989, forced the geothermal system into operation before testing was complete. Although the geothermal system did not operate efficiently due to problems with the variable speed drive unit and the level control system, the temperature within the greenhouse ranged between 60°F and 65°F. Cold-sensitive crops grew quite well through the spring season until they were large enough for transplanting outdoors.

The system was fine tuned in the following months. In November 1989, it was discovered that the 2 inch geothermal supply and return lines had been installed in a reverse manner. This resulted in erroneous output of flow rate, temperature difference and energy use data at the BTU meter. This was easily repaired and the energy metering system has worked well since.

Figure 6 is a plot of minimum outside temperature vs. total BTU consumption on the geothermal side of the heat exchanger. The data represents the months of December 1989 and January 1990. A linear regression analysis was performed on the data and is represented by the solid regression line. The results indicate a statistically valid relationship exists between the two data sets. Those points furthest from the regression line are the result of level control system mal-

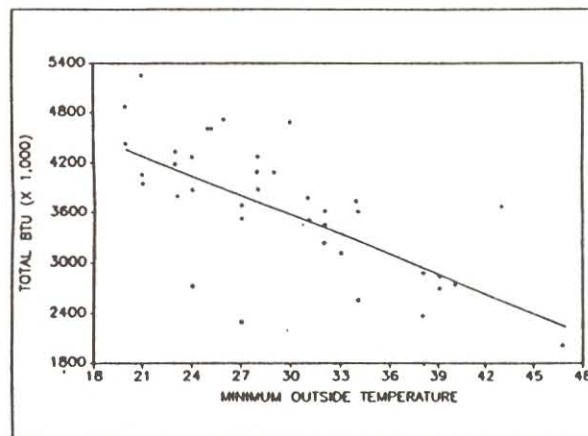


Figure 6. Minimum outside temperature vs. BTU.

functions and/or electrical power failures. The supply system then requires several hours to fill the pipeline and come into thermal equilibrium. For December 1989, approximately 104.9 million BTU were consumed to meet a set point of 65°F. In January 1990, 115.2 million BTU were consumed to meet the same set point conditions.

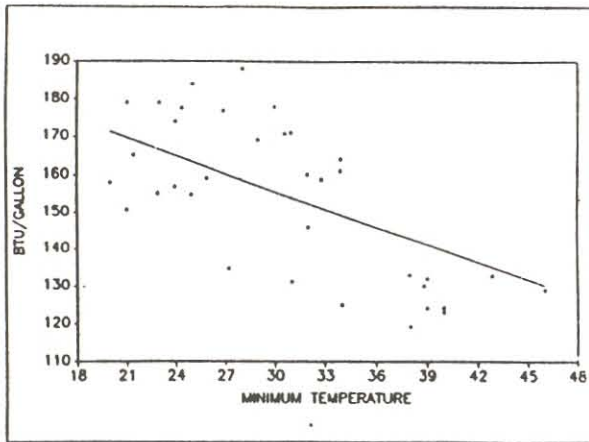


Figure 7. Minimum outside temperature vs. BTU/gal.

Figure 7 illustrates the overall performance of the geothermal system. The graph is a plot of minimum outside temperature vs. BTU/gallon on the geothermal side of the heat exchanger. The data is from December 1989 and January 1990. The results of a regression analysis are represented by the solid line and as in Figure 7, a statistically valid relationship exists. System malfunctions and power failure explain the large data variability from the regression line. The graph shows that as outside temperature drops and heat demand increases the system extracts more energy per gallon of geothermal fluid. Stated another way, the system becomes more efficient when needed or when demand is high. As the system continues to operate, further collection and analysis are expected to increase confidence in this relationship. Refinements in the greenhouse heating system will further improve efficiency and system reliability.

MARKETING STRATEGY

Mendocino College's involvement in the direct use development of geothermal resources in Lake County is a key ingredient to the marketing and establishment of commercial greenhouse operations. A market survey was conducted in 1987 to gain an understanding of the Central and Northern California greenhouse industry. The information obtained from the fifty-two businesses that responded forms the basis for the region's industry heating costs (see Figure 8). A key component of the survey was to identify businesses interested in further information on geothermal greenhouse sites to lease.

During this time, a curriculum survey of California colleges with substantial horticultural programs was undertaken. Special attention was given to designing a four semester sequence of study at the geothermal greenhouse for a student certification program. Students in the program

represent another important marketing tool for the facility. The Mendocino College greenhouse, shade frame and support area utilize about one third of an acre or about ten percent of the total acreage of the Ag Park. With seven thousand square feet of greenhouse space, it was necessary to implement a program that provided daily maintenance, a variety of training situations and state-of-the-art greenhouse equipment.

Designing the greenhouse to contain three zones allows custom climate control for a particular type of crop. Only one zone is necessary for educational purposes. The other two zones are leased out to tenants. In most cases the tenants are students utilizing the space to engage in entrepreneurial ventures utilizing the instructor in an advisory capacity. Those students with successful results may go on to be future tenants of the Ag Park. Other space is available for outside parties to test and evaluate the performance of a particular crop in the local climatic region.

AG PARK MARKETING

As mentioned previously, the greenhouse facility is controlled by computers capable of storing and transmitting collected data to a central computer. For the second phase of the Ag Park development, detailed data collection and evaluation will occur through this computer system. Much of this data will be utilized in the marketing effort. Figure 8 provides results of the Market Survey. It shows the average cost per square foot of greenhouse area for four 10 degree Fahrenheit ranges. The temperature ranges were selected from the major groupings of reported interior temperatures. The total area within each temperature range was then divided by the respective total annual cost of heating to develop the average cost per square foot. By comparing Lake County's heating costs to this graph, the Ag Park appears to be quite competitive while maintaining the highest indoor temperature range. This information will also be used in marketing the facility.

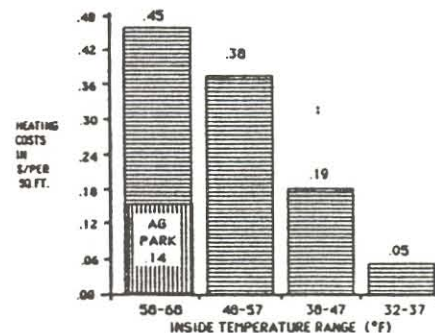


Figure 8. Comparison of heating cost and inside temperature.

With the assistance of OIT, a table of estimated lease rates was developed (Table 4). These rates were calculated to address heating costs for two sizes of greenhouses (one acre, three acres), two common construction types of glazing materials (single layer fiberglass and double plastic) and three indoor temperature combinations. Interior temperatures were

given a day and night value. Added to these costs were the calculations to supply irrigation water based on the larger irrigation storage and supply system. Finally, land costs, royalties to the land/owners and systems operation and maintenance costs were added.

Table 4 Lake County Geothermal Agricultural Park
Estimated Lease Rates

The rates for each square foot of land per year follow in an easy to read table. Provided to the tenant in the rates shown is the following:

1. Geothermal and irrigation system operation and maintenance costs (including electricity for pumping)
2. Irrigation water costs
3. Royalties to the land and resource owners.
4. Heating costs

COST FOR EACH SQUARE FOOT OF SPACE PER YEAR (IN DOLLARS)

Inside day inside night	60 degrees 50 degrees		60 degrees 60 degrees		70 degrees 60 degrees	
	DP	SF	DP	SF	DP	SF
ONE ACRE	.49-.55	.50-.55	.51-.56	.52-.58	.52-.57	.54-.59
THREE ACRES	.45-.50	.46-.51	.48-.53	.50-.55	.48-.53	.50-.55

DP = Double poly roof
SF = Single fiberglass roof

Using the above expenses as a base, Mendocino College calculated further to develop a lease for greenhouse tenants. Additional factors, such as telephone, security, site improvements, administration, regulatory compliance, insurance, property tax, toilet facilities, backup heating system and depreciation were totaled in to result in meaningful costs.

The ultimate goal of the Geothermal Ag Park is to have full occupancy with commercial greenhouse tenants. A vigorous campaign is underway to ensure that greenhouse growers from Canada and the USA know of the availability of sites to lease. Results of publicity have brought the facility to national attention; however, it is necessary to continue advertising the Ag Park's availability to the targeted growers. One main tool for this purpose is a brochure which provides important information about the facility and Lake County. Contained in the brochure is information on typical lease rates, geothermal and irrigation water systems design, water quality, Lake County climatology, location and site maps, residential and labor availability. The brochure is printed on glossy paper with color photographs of the greenhouse, heat exchanger and the site.

A position of Ag Park Manager/Marketing Specialist has been established to promote the lease potential to the commercial grower. The marketing of the Ag Park will focus on several areas. Articles and press releases to horticultural trade magazines will supplement paid advertising and mailers. A seminar format is available for presentation to trade organizations. By attending trade shows, the Ag Park Manager will establish personal contacts with potential growers.

The County intends to have full occupancy of the Geothermal Agricultural Park by the completion of the Phase II activities.

CONCLUSIONS

The County of Lake and Mendocino College are pleased with the facility's reliability and efficiency. As more performance data is acquired, the system will be further improved.

The close working relationship between the College and County, along with strong support from the local community and state agencies has been especially rewarding. It is anticipated that commercial greenhouse facilities will locate to the Geo Ag Heat Center within the next 18 months. The project's ultimate success will be reflected in the diversification of Lake County's agricultural economy.

Many lessons have been learned from this project which hopefully can be applied to other similar projects. Following is a brief summary of recommendations in four subject areas.

Budgeting

1. When resource and site conditions are known, it is preferable to prepare the budget based on manufacturer's and contractor's estimates rather than using engineering estimate guides. Even these estimates will not be exact, and therefore, a contingency of 20% to 25% should be used.
2. Local government-initiated construction projects are regulated by California's public contract laws. These laws specifically require prevailing wage to be paid to laborers. Lake, Mendocino and Sonoma Counties are tied to the San Francisco Bay area prevailing wage rate which is substantially higher than other areas of Northern California. These costs should be recognized and factored into the budget because they will significantly alter the total budget of a project.
3. For projects such as this, an effort should be made to develop community and industry support. The County and College were able to acquire approximately \$10,000 in donations from Geysers area developers and utilities because the project has high visibility which results in positive public relations for local industries.

Scheduling

1. Commit as much staff and resources as economically possible to see the project through to completion within schedule. For the County and College, this was not a viable solution due to limited staff and budgets.
2. Always be flexible and creative in scheduling. This can to some degree offset shortages in staff and budget.

Drilling

1. Use a geophysical analysis to support existing geological, geochemical and related data. In areas where the geothermal resource is believed to be shallow (<800 feet), an electrical resistivity survey (i.e., Pseudo-Schlumberger) may be useful.
2. When constructing geothermal wells, allow for a diameter which can easily accommodate the anticipated production well pump. However, remember that the cost of drilling a well increases dramatically as diameter increases.
3. Conduct a caliper survey after completing and testing each well. This data is useful for future pump installation and production formation lithology.
4. Use geologists and drillers with knowledge of local geologic and hydrologic conditions.

Construction

1. Be sure to have sound engineering plans and specifications prepared because the project will be no better than these plans. Utilize competent engineering firms with specific experience in geothermal applications, well pumps, heat transfer, and corrosion/scaling engineering.
2. When available, utilize specialized consultants such as the California Energy Commissions' Technical Assistance subcontractors from OIT. This provides the necessary quality control during design and construction. In addition, valuable information on materials selection and types of problematic components can be acquired from these experts.
3. Where possible, simplicity of the system design should be a major consideration when preparing plans and specifications. In this context simplicity is defined as systems or components: 1) with fewer moving parts; 2) that can be repaired or replaced locally and quickly, and 3) which have field representatives located near the project. This will allow for easier operation and maintenance by technical people who may not be familiar with the system.
4. Staff should be on site during all phases of construction to insure proper installation and quality control. When materials are lost during shipment, time must be committed to tracking the location and delivery schedule of materials.
5. When projects lend themselves to a phased development approach, the design should be equally flexible to allow for phasing. For example, the Geothermal Agricultural Heat Center is ultimately designed to have two production wells, and a much larger irrigation system. One well has been brought into production earlier and a small irrigation "module" installed to supply the greenhouse. This phasing allows for the system expansion at a later date.

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