MILGRO GREENHOUSES
NEWCASTLE, UTAH

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Figure 1. Milgro greenhouses.

INTRODUCTION

Milgro greenhouses in Newcastle, Utah may be among the most successful commercial application of geothermal water for space heating in the United States. This report describes a variety of factors that affect direct use of geothermal water for agriculture in arid regions such as Utah.

THE MILGRO COMPANY

The Milgro commercial nursery operation is located in Utah's Escalante Valley, 35 miles (56 km) west of Cedar City. Operations began in 1993 with 527,400 sq ft (4.9 ha) of greenhouse space for production of cut flowers for retail sale. Facility expansion occurred in large increments in subsequent years, resulting in a current total of more than 1.1 million sq ft (10 ha) of enclosed space as of 2004. The Newcastle facility is part of more than 3.3 million sq ft (30.6 ha) of greenhouse space currently owned by Milgro. The Newcastle site is now the nation's largest producer of chrysanthemums, and Milgro recently acquired Royal Van Zanten, a Dutch company that was one of three major sources of chrysanthemum cuttings in the United States. Milgro now ships 30 million cuttings to other growers each year. In fact, thanks to the Newcastle site, the Milgro family of greenhouse operations is now one of the nation's largest growers of flower bulbs, after having produced no bulbs prior to Newcastle development.

Milgro's total covered area at Newcastle currently amounts to about 26 acres (10.5 ha), along with more than 200 acres (81 ha) in bare land overlying the geothermal zone. An existing total of wells on the property enable further expansion and perhaps further diversification of product lines. The combined production of Milgro's greenhouses ranks as the 11th largest in the United States. Currently, Milgro produces a total of more than 13 million potted plants and cut flower per year.

GEOTHERMAL RESOURCE

Location

The Newcastle geothermal resource is located at the southeastern margin of the Escalante Valley, in the transition zone between the Basin and Range and Colorado Plateau physiographic provinces (Blackett, et al., 1997). The geothermal upwelling is associated with the Escalante aquifer, and may be connected to the Cedar Valley aquifer at the northern edge of the northeast-running Antelope Range fault.

Geothermal energy in this area was accidentally discovered by the Christensen brothers in 1975 while drilling for irrigation water. Well temperatures reached 226ºF (108ºC) at a depth of about 300 ft (91 m). The outfall plume runs northwesterly, producing 197ºF (92ºC) water at the Milgro facility.

Milgro operations are located at the base of an alluvial fan on the north slope of the Bull Valley Mountains at an elevation of about 5,310 ft (1,620 m) above sea level. Surrounding slopes are composed of Tertiary ash flow, with the Antelope Range fault delineating the south and eastern boundaries of the valley. Geothermal production wells at Milgro run from 600 to 1,000 ft (180 - 305 m) deep, with the primary production zone at 300 to 600 ft (90 - 180 m,). At present, wells on Christensen property produce the hottest fluid, at about 250EF (121ºC). Exploratory drilling 20 years after original resource discovery yielded slightly lower temperatures and deeper water table. Those observations are consistent with the operational history at Milgro that indicates declining water level, and the predictable effect of drought conditions over the past five years. Geothermal fluid reaches 125EF (52ºC) at a church building in Newcastle, located at the eastern edge of the geothermal resource, which circulates geothermal water for space heating.

Investigations

The Newcastle geothermal resource is located at the southern end of Escalante Valley, an area of about 800 square miles (2,070 km^2). Groundwater levels in the area have declined steadily since 1950, showing no recovery during periods of above average precipitation (Christiansen, 2003). The declines are believed to be a result of continued large withdrawals for farm irrigation. Studies have defined a shallow, unconfined aquifer that channels the outflow of geothermal fluids into the subsurface of the Escalante Valley. The fluid cools by conduction and probably mixes with shallow groundwater at system margins. A maximum temperature of 266EF (130ºC) was measured in a 1981 geothermal exploration well that penetrated the upper edge of the geothermal aquifer outflow plume. Well water sometimes flashes to steam at the surface.

The Newcastle area was at one time listed within one of 13 designated KGRAs (known geothermal resource areas) in Utah, a designation that allowed competitive leasing for energy development on federal land, some of which overlies the higher elevations of the Newcastle resource (Blackett and Wakefield, 2001). As of 2004, only three KGRAs areas remain, two of which now host geothermal power generation facilities. As demonstrated by the accidental discovery at the Christensen farm, the Newcastle geothermal anomaly is considered a cryptic, or blind resource, with no natural surface manifestation. Geothermal fluid rises into apparent Quaternary alluvial fill, and then runs northwesterly at a shallow depth. Peak heat flow reaches nearly 9,800 milliwatts per square meter (mW/m^2), declining to about 500 mW/m^2 within a mile in any direction. Geothermal fluid contains approximately 1,100 parts per million total dissolved solids, with a pH of about 8.0, which is tolerably alkaline for most pipe types.

Chemical signatures of geo-thermometers placed intermittently since then also suggest a maximum resource temperature of about 266EF (130ºC). Exploratory drilling in the same location during the summer of 2001 yielded 243EF (117ºC). Two fresh-water, non-geothermal wells are located within 300 yards (275 m) of Milgro's geothermal production wells. That cold-water resource exhibits a pH of about 7.0 and very low conductivity. It is widely believed that farming operations in the region have been over-producing this ground water for more than 40 years. Long-term decline of the water table may have accelerated during drought conditions that are now in their sixth year. Groundwater moves northward from the slopes of the Dixie National Forest across the Escalante valley en route to a terminus underneath Sevier Lake. Much of that migration is intercepted by agricultural pumps in the Beryl area.

Indications are that the Newcastle geothermal reservoir is primarily meteoric, so it should recharge by atmospheric precipitation. If so, then regional drought conditions could indeed account for a large portion of the 90 ft (27m) of total head lost since 1990. Otherwise, a continuing steady loss of water table could indicate that the resource is either all, or part Pleistocene water, which originated from glacial flow. As such, the resource would be considered a relatively closed system, and less likely to recharge after drawdown.

Bore hole temperature gradient profiles from 1976 to the present exhibit a mixed picture of changes in temperature and water table level, from which conclusions regarding well production cannot be deduced (Blackett, et al., 1997). Persistent regional drought conditions complicate the picture by apparently accelerating water table declines and possibly causing some loss of production well temperature. However, in the absence of definitive flow testing, there is some indication from Milgro that an increase in pump withdrawal results in an increase, rather than a decrease, in resource temperature

Major declines in ground water in the region are accepted as fact, but seldom precisely measured. The Utah Geological Survey (UGS) has not been able to install monitoring equipment in any of the existing Milgro wells wells due to potential entanglement of cables and probes. However, several years ago, about 30 thermal gradient bores were made by the Utah Geological Survey to create a log of the vapor zone, or unsaturated area above the water table. Many bore holes have since collapsed, leaving perhaps five to eight holes in usable condition.

Tests of remaining holes in April, 2004 confirm that geothermal water levels have declined by an additional 15 to 30 ft (5 to 10 m) over levels measured in 1999 and 2001. As an alternative to using existing commercial wells and additional bore holes, UGS has suggested placing a separate monitoring well at the same 16-in. (41-cm) size as Milgro's two production wells, at a cost of up to $100,000. A 4-in. (10-cm) slim hole design is an alternative, at about $50,000.

In any case, isotopic shifts can be subtle, and finding a deuterium signature could require sophisticated evaluation. Results could indicate that the Newcastle resource is binary, a Pleistocene aquifer that is also permeated by meteoric flow. Additional study would be needed to determine the size of the reservoir and the permeability of its structure. Shutting down all geothermal pumps for several days could provide an opportunity to measure the rate of recovery in the immediate drawdown area, or cone of depression.

Milgro Company Issues

Milgro operations in California have not grown in recent years. Indeed, a number of independent greenhouse companies in California have closed, due to high cost of business in that state. That trend is consistent with strong business cycles in California that account for a large portion of overall economic growth in Iron County and other parts of southern Utah and Nevada. At the Newcastle site, land acquisition since 1998 totals more than 100 acres (40 ha), and greenhouse space expanded by about 500,000 sq ft (4.6 ha). Recent acquisition of Royal Van Zanten added sales along with some vertical integration of the market for plant cuttings. The opening of a Milgro-related trucking facility in St. George, 50 miles (80 km) south of Newcastle, assures adequate tractor-trailer capacity to meet required shipping requirements for volume and flexibility. In the past year, Milgro has expanded its refrigerated space by 20,000 sq ft (0.18 ha), for a current total of 80,000 sq ft (0.74 ha). Climate controls can be zoned to range from freezing to near ambient air temperature for forcing bulbs, hardening plant starts and storing product.

As is typical of western U.S. agriculture, Milgro relies upon a combination of migrant labor and highly skilled horticulturalists. Together, average Milgro employee income is well above minimum wage. Iron County business development incentives are intended to reward enterprises that help prevent social service burdens on hard-pressed public budgets.

In addition to its 1.1 million sq ft (10 ha) of enclosed space, Milgro leases a total of 140,000 sq ft (1.3 ha) of additional greenhouse space located 0.25 miles (400 m) east of Milgro's main operation. Due to persistent difficult business conditions, Milgro has no discretionary money for new plant investment, nor for geothermal investigative studies. The company has been soliciting potential business partners, particularly for cascade users of geothermal outfall. According to Milgro, the Utah tax structure is similar to, but more moderate than in California. Workman's compensation fund levies, in particular, are much lower in Utah. Fees and performance requirements for state, local and special district permits are both fewer and easier to meet than in California.

As noted for climate and transportation issues, the Newcastle location presents a mixed picture of advantages and disadvantages. On one hand, Iron County economic development strategy builds on the fact that Cedar City lies within one day's motor transport of 86 percent of the urban area of the mountain west and southern coast. Milgro ships to all 50 states, and substantial product deliveries reach as far east as Denver. However, the vast majority of deliveries are to southern California and San Francisco.

Newcastle is at a competitive disadvantage in being located almost 400 miles (644 km) from the wide variety of specialized services and supplies available in southern California. In recent years, business diversification in the Salt Lake City area has meet more of Milgro's needs, but is also relatively distant, at about 280 miles (450 km) from Newcastle. Milgro acknowledges that Cedar City has successfully developed a strong industrial economic base, but has little diversity in products and services of value to Milgro.

Regional transportation conditions may have influenced Milgro to acquire its own fleet of long-haul tractor-trailers as an independent, dedicated arm of the greenhouse business. At present, local industry makes heavy use of economical rail transportation for receiving large, homogeneous shipments of raw materials. However, most finished products are shipped out by tractor-trailer in smaller, more heterogeneous loads. The result is that the number of loaded outbound trucks outnumbers inbound traffic, requiring that additional empty trucks "dead head" into Cedar City to make up the difference. Premiums, or surcharges by trucking companies are considered by County officials to have a material effect on local manufacturing profitability. Meanwhile, Milgro recently expanded its own fleet from 15 to 18 tractor-trailers.

GREENHOUSE OPERATIONS

Introduction

The Milgro business commenced in 1980 with the Oxnard, California plant. The Newcastle facility is now the largest of their four greenhouse operations.. Land acquisition at Newcastle began in 1991, based on the region's desirable climate, low cost of land, relatively light regulatory burden and the presence of high quality geothermal water.

Acquisitions of additional land in 1998 and 1999 led to a 500,000 sq ft (4.6 ha) expansion of greenhouse space. Covered by arched, twin-shell plastic roof supported by fiberglass walls, Milgro's five greenhouse zones now total 1.2 million sq ft (11 ha), each zone capable of distinct climate control, including temperature, humidity and hours of sunlight. The "double poly" roof provides a dead air separation zone requiring fan-boosted pressurization and represents the industry's most cost-effective configuration for climate containment in this high-sunlight region.

Geothermal fluid is distributed through a series of pumps, actuated valves, forced air heaters, plastic tubing. Finned aluminum tubing was installed overhead in years past, when certain plant species required warm air, but cooler soil. That system is no longer in use.

Greenhouse zones are up to 1,400 ft (427 m) in length, with elevated rolling benches running crosswise above bare soil. Radiant heat is supplied by geothermal water running through 0.5-in. (1.3-cm) extruded polyethylene plastic pipe on 6.0 in. (15 cm) centers (Figure 2). In some zones, new cuttings are grown directly in bare soil, then transferred to pots for final growth in other zones (Figure 3).

Figure 2. ***Bench heating system.***

Figure 3. Bare soil heating system.

Due to the mild nature of Newcastle geothermal water, heat exchangers have been by-passed and the fluid is run directly to greenhouse use. At any given time, any combination of four production wells may be in use. Well pump motors range in size from 30 to 100 hp (22 - 75 kW), with zone-level pumps of three to 15 hp (11 kW) supplying additional localized pressure. Production wells use "down-hole" or line shaft pumps that are less efficient than submersible pumps but are able to withstand the combination of temperature and pressure experienced at more than 300 ft (91 m) below ground. One production well motor is controlled by variable frequency drive (VFD) circuitry, which acts as an energy-efficient throttle.

Climate Automation

Quality control is vital to Milgro profitability. Uniformity in the number of leaves, buds and plant height are evidence of successful control of growing conditions. Newcastle's cold desert climate, characterized by low humidity and large seasonal and daily temperature swings, is hostile to outdoor plant growth, but helpful for controlling humidity and insect pests. A mild insect infestation can spread quickly, causing vast plant loss. Even in optimal conditions, plant loss averages 5.0 percent.

The geothermal system uses Q-Comm™ to control hundreds of valves for irrigation and heat control. This total includes main valves at geothermal pumps, 10 zone gates in each of three ranges, plus two other ranges with 40 controls each. Extensive controls are required in any greenhouse operation. At Newcastle, controls are relatively more extensive and precisely managed, resulting in somewhat higher cost for electricity and maintenance. Software also monitors outdoor conditions from a weather station installed on the roof, and can account for changes in wind as well, including potentially damaging high wind. Digital sensors can alter system settings in three minutes.

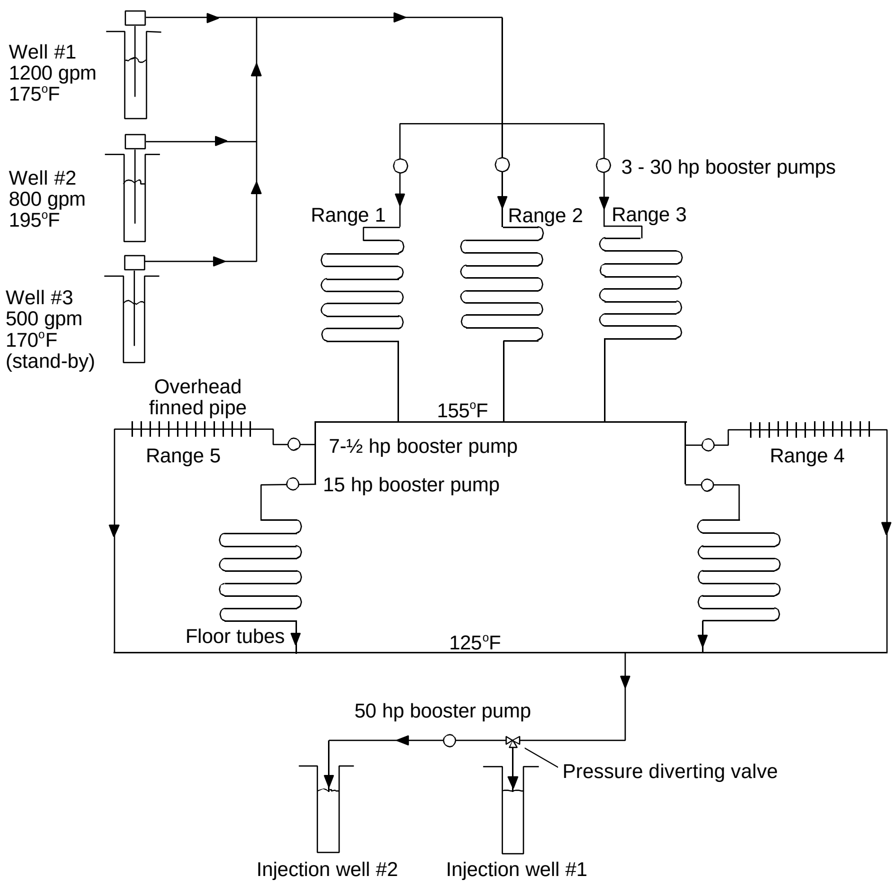

Figure 4. Milgro greenhouse geothermal fluid flow. (Geo-Heat Center)

Milgro has found that it is easier to screen out excessive sunlight in Newcastle than it is to add artificial light for plant growth when sunshine is lacking in climates with shorter days or more frequent cloud cover. Likewise, Milgro has found that it is far easier to induce necessary humidity in a dry climate than it is to remove excess atmospheric moisture during humid conditions often found in more temperature climates.

As noted, annual heating load is greater than cooling load because space heating is needed during cool evenings that prevail even in summer. Actual cooling load is also larger than indicated by average daily temperatures because strong day-night temperature swings are characteristic of Newcastle's climate. Milgro uses a variety of methods to cool the greenhouses and the energy implications are important.

First, automated vents, augmented by fans force unwanted air across the top of the shade cloth and out of buildings. The energy implications are important. Greenhouses in relatively humid climates may require natural gas heating to drive off humidity as a means of reducing pathogens. By contrast, excess humidity is not an issue at Newcastle. In fact, Milgro uses micro-mist equipment, running at water pressure up to 1,100 pounds per sq in, (7.6 MPa), and pad-and-fan evaporative coolers to simultaneously reduce greenhouse temperatures and increase humidity level. Air misting is designed to achieve full evaporation before leaf contact, thus achieving optimal air temperature reduction while avoiding leaf stains caused by minerals in irrigation water. Atomized moisture can achieve a 10EF (6ºC) temperature reduction at the leaf surface. Evaporative cooling can reduce indoor air temperatures by more than 20EF (11ºC). Both of these systems use water and electricity economically and can target individual greenhouse zones to closely match changing plant needs throughout different growth cycles.

Typically, Milgro's central digital processor seeks relative humidity at 75 percent on air temperature of 75EF (24ºC). Dead zones for digital response are 4EF (2ºC) and four percent humidity. Required humidity for forcing bulbs can be as high as 96 percent, and is economically provided by spraying water inside refrigeration units that total about 80,000 sq ft (0.74 ha) in floor area.

Milgro has nine available geothermal wells. Seven wells were developed for production, four of which were acquired as part of property purchases subsequent to initial development. Water temperatures coming out of the different wells vary from 170 to 240EF (77 to 116ºC). Wells are drilled to depths ranging from 500 to 1,000 ft (150 to 300 m), and completed with 16-in. (41-cm) slotted casing. The geothermal well production zone ranges in depth from 300 to 600 ft (90 to 180 m) underground. In 2004, Milgro plans to close and fill-in three production wells where sedimentation has reduced efficiency, and install three entirely new wells. Six other wells are in use or reserve, some of which can be used for either production or re-injection.

Milgro believes that, ideally, re-injection of geothermal water should occur 1.2 miles (1.9 km) up-gradient to ensure adequate access to the aquifer. Without formal analysis, they estimates a cost of $200,000 for the facility, which includes pipe, pump, land lease and other associated equipment. Milgro accepts the risk that re-injection of cooled water could have an effect on output temperature of production wells down-gradient. If that occurs, Milgro anticipates being able to regulate re-injection at an acceptable level.

The initial design of the greenhouse production system was based upon the use of plate heat exchangers to isolate radiant heating pipe from geothermal fluid. However, due to slow system response time, these heat exchangers were removed from the system in 1998. The benign chemical quality of Newcastle geothermal water causes little scaling or corrosion, also helping eliminate the need for heat exchangers. Milgro briefly used gas-fired boilers for supplying greenhouse heat, but found that response time was too slow to account for weather changes. Cycling boiler operation early only wasted energy.

Outdoor wind has not been a big problem for the greenhouse, even though high wind conditions are observed up to several times per year. A recent 70 mph (113 km/h) wind event caused no damage to the double-poly roof of greenhouse areas. An occasional micro burst is also observed, one of which pulled off a portion of fiberglass panel that was easily replaced. Automation software is also able to account for windy conditions, by closing wall vents as needed to protect equipment from damage.

Milgro's extensive use of automated mechanical means to control climate, adds somewhat to capital cost and operating expense. However, in relative terms, almost all greenhouses require extensive mechanical venting anyway, and digital control of motorized dampers results in slow, relatively inexpensive mechanical movements. Each of five climate zones is separated by vertical curtains. Retractable overhead shade cloth regulated solar insolation, and an additional overhead insulation curtains helps prevent heat loss during cold periods. These vertical separations are in additional to the two roof films that are themselves separated by a forced air current. The result is the ability to maintain temperature within 1-2EF (0.5 to 1ºC) of optimal, even as seasonal outdoor temperatures vary from –10EF to 105EF (-23 to 41ºC), and diurnal changes may swing by 40EF (22ºC). Without intervention, even a moderate outside temperature of 65EF (18ºC) can produce interior temperatures of 100EF (38ºC) or more.

In the past, Milgro burned natural gas for production of carbon dioxide (CO_2) to enhance plant growth in a portion of one greenhouse zone that totals 80,000 sq ft (0.74 ha). Gradual expansion of CO_2 use has been considered, but not decided, due to its potential value relative to cost of natural gas.

Water Quality

Ion control (pH) in Milgro irrigation water is considered the single most important chemical factor in successful control of production. Milgro tests irrigation water monthly, to account for seasonal fluctuations in salts. Newcastle irrigation water is moderate in sulfates, iron, and other precipitates. Boron is occasionally a problem. Geothermal water is not tested, as geothermal water is not in direct contact with plant materials. Observations of geothermal pipe interiors, and anecdotal reports by Milgro indicate that TDS, dissolved gases, including CO_2 and H_2S, are low to moderate in quantity. The result is a mild potential for precipitate deposition. Removal of plate heat exchangers some years earlier improved response time for overall geothermal heat transfer without incurring appreciable loss of wetted area for heat exchange at capillary ends of EPDM pipe. Tight bends, low velocity and potential air intrusion have apparently not caused appreciable mineral deposition, nor has Milgro reported persistent problems with heat transfer performance.

Maintenance

Maintenance is done on the geothermal heating system during summer, when geothermal load is low. Likewise, maintenance of the shade cloth system occurs during winter when shading requirements are low. Periodic change-out of geothermal production and re-injection pumps is required more frequently now than in the past, apparently due to increasing intrusion of sand into pump assemblies. The pump for the original well went six years without maintenance of any kind. More recently, overhaul of production pumps is expected to occur every three years, at a cost of about $10,000 if no problems are encountered. Overhaul of the re-injection well pump is similar. However, well maintenance is based on a sealed column of 200 ft (61 m) in depth, rather than 60 ft (18 m) to assure that re-injection waters go deep enough before dispersion. Re-injection pressures have caused well shaft erosion, resulting in the drilling of a second re-injection well further north, probably further from the aquifer recharge zone. Initial problems with corrosion at geothermal pipe valves was cured by use of Teflon parts.

Milgro #2 and #3 Greenhouses

As mentioned earlier, in addition to the main area of 25 acres (10 ha) of greenhouses owned by Milgro, they also lease two other complexes in the area. Milgro #2 consists of 60,000 ft^2 or 1.38 acres (0.56 ha), and Milgro #3 consists of 74,000 ft^2 or 1.70 acres (0.69 ha). Each has their own well, and both surface dispose of the wastewater into a pond. The wells, which vary from 170 to 220ºF (77 to 104ºC) use as much as 350 gpm (22 L/s). The estimated load factor is 0.44.

SUMMARY

Geothermal energy presents an opportunity to avoid fossil fuel expense. The added value of dry, sunny weather and the low cost of doing business in southern Utah are important coincident conditions. At present, geothermal savings by avoiding natural gas are offset by greater motor fuel expenses, so the qualitative advantages of the desert climate for greenhouse production stands-out as a factor in site location.

Milgro people emphasizes that geothermal should not be viewed as a basis for starting a business, but as an optional resource for an established, profitable activity. As such, even though geothermal energy and dry, sunny weather are phenomena of completely distinct origin their strong geographic coincidence in the United States suggests the value of considering them together, as Milgro has done. Milgro's relatively mild concern over the uncertainty of geothermal stability could be accounted for by the constancy of weather conditions that may be as much a factor in success as the geothermal resource.

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