GEOTHERMAL USES AND PROJECTS ON THE OREGON INSTITUTE OF TECHNOLOGY CAMPUS

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ABSTRACT

Oregon Institute of Technology moved their campus to the present location in the early 1960s to take advantage of the geothermal hot water that could be used for heating the buildings. Three wells between 1,200 and 1,800 feet (365 and 550 m) deep were drilled, producing 192˚F (89˚C) water at a maximum flow of 980 gpm (62 L/s). There are presently 12 buildings being geothermally heated covering approximately 732,000 ft2 (68,000 m2) of floor space, saving approximately $1,000,000 annually in heating costs. Lineshaft pumps with variable frequency drives are used to produce the geothermal fluids from the well, and then the hot water is gravity fed to all buildings on campus. Plate heat exchangers are located in each building to separate the potentially corrosive geothermal fluids from the secondary "clean" water for heating the various rooms. The geothermal water is finally injected into two injection wells located approximately 2,000 feet (610 m) from the production wells. A 280 kWe (gross) binary power plant was installed on campus to use the existing well water to provide some of the electricity needs for the campus. In addition, a 5,300 foot (1,600 m) deep well was drilled to tap into a 196˚F (91˚C) geothermal resource in the fault system on the east edge of campus. The fluids would be used to power a 1.0 to 1.2 MWe (gross) binary plant to provide some of the electricity needs for campus. Thus, the campus would become the first in the world to provide some of its energy needs from a geothermal resource found on its property. Finally, the "waste" fluid from the heating system would be used to provide heat for experimental greenhouses and aquaculture facilities on campus. All of these future uses would be available for student projects and as a demonstration site for interested investors and developers of geothermal energy.

HISTORICAL BACKGROUND (PURVINE, 1974, LIENAU, 1996)

In 1959 the Oregon State Board of Higher Education was awarded a State appropriation of $150,000 for use in exploration related to the selection of a new campus for Oregon Institute of Technology. The old campus was a military facility, built for the treatment of malaria victims from World War II. These funds were to be used for the master plan of the new campus and for exploration to determine the availability of geothermal water for space heating. At that time, approximately $100,000 per year was spent on coal and oil heating for the campus. Since the Board wished this to be a decision based on good information, a study was made as to the location of hot wells, hot springs, faults, and other factors useful in determined the potential location of the campus. This study was carried out by Gene Culver, a Mechanical Engineering Technology faculty member and later one of the founders of the Geo-Heat Center. One of the early observations was the existence of a broad series of normal faults running from Ft. Klamath (south of Crater Lake) in the north to Alturas in northern California in the south. At various locations along this broad fault zone were hot springs and hot water wells. The fault zone seemed to be the source of subsurface hot water which many of the wells had encountered.

Local well drillers were interviewed based on their experience with drilling geothermal wells in the area. In addition the Oregon State Engineer's Office was consulted, and based on a US. Geological Survey map that was in preparation, it indicated that the fault system in the area consisted on northwest-southeast trending fracture zone with perpendicular offsets producing faults in echelon. Finally, to confirm the locations of these faults and the potential for producing hot water, then President Winston Purvine noticed that for one area being considered for the new campus, the frost and light snowfalls would be melted off by as early as 8:30 to 9:30 in the morning, too early to be influenced by the sun. This was assumed to indicate that the soil was being warmed by subsurface hot water, and thus the site was a prime candidate for geothermal drilling.

After these preliminary studies the location for the geothermal wells and potential campus was selected in the northern edge of the City of Klamath Falls. The first well (OIT #1) was drilled in 1959 to a depth of 1,200 feet (366 m) and produced 510 gpm (32 L/s) of 78˚F (26˚C) water, which was later used for the domestic water supply. Moving further west and south within the border of the new campus, a second 1,200-foot (366 m) well (OIT #2) was drilled in 1960. This was more successful, producing 170 gpm (11 L/s) of 176˚F (80˚C) geothermal water (Fig. 2). Two other wells (OIT #5 and #6) were later drilled in 1963 in the same area to depths of 1,716 feet and 1,800 feet (523 and 549 m) both producing 191˚F (88˚C) geothermal water at 442 gpm and 250 gpm (28 and 16 L/s) of geothermal water respectively (Fig. 2). This temperature, with time, increased to 192˚F (89˚C). We later learned that the first or cold water well was drilled into the up-throw (hanging wall) of the normal fault and the latter three in the down-throw (foot wall) of the fault block tapping the outflow zone of the geothermal water from the fault. At the time, these two deeper wells were drilled for about $32,000 each or $18 per foot!!! The wells penetrated at mixture of volcanic ash (tuff) and diatomaceous earth (locally called "chalk rock"), then into various layers of dense basalt and andesite, clayey tuffs, broken lava and cinders. The casing varied from 12 inches (30.5 cm) at the surface to 6 inches (15 cm) at the bottom. The static water level was at 358 feet (109 m) for the deeper wells. The original wells were set in a cellar, but were later raised to ground level and enclosed in a building in 1970 (Fig. 3).

Enclosed lineshaft pumps with the bowls set at around 550 feet (168 m) with 26 stages are used in the deeper wells. The original pumps were basically irrigation well water pumps with direct-coupled motors, open lineshaft with rubber bear-

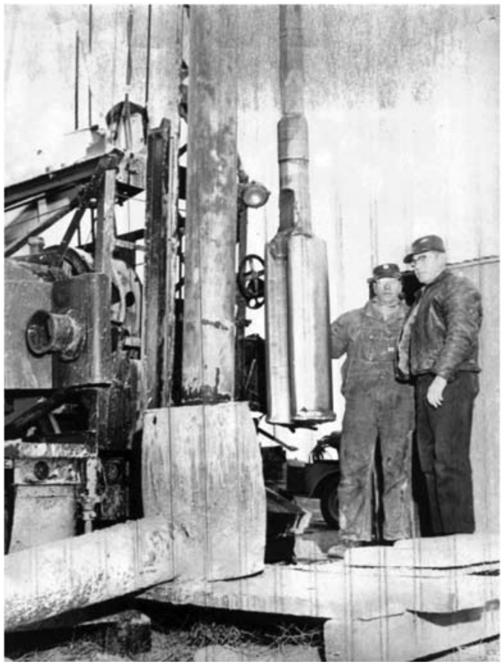

Figure 1: 1963 photograph of Storey Drilling, completing one of the deep geothermal wells with a cable tool.

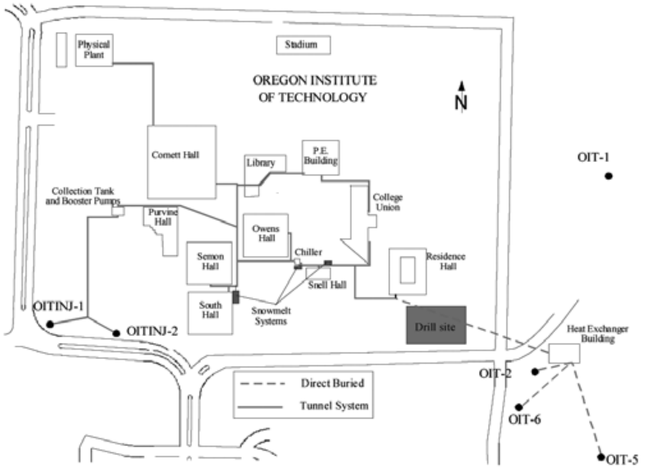

Figure 2: OIT campus map showing the location of wells and distribution pipelines.

ings and standard lateral pumps with bronze bearings and impellers. Problems were experienced with broken lineshafts, motors overheating, pump impellers loosened on the shaft due to differential expansion and bronze bearings corrosion (Culver, 1994). Since hot water does not lubricate the bearings well, an oil drip system had to be installed within an enclosed lineshaft, and allowance had to be made for the difference in thermal expansion between the line shaft and the impellers – which can be as much as 5.5 inches (14 cm) as the system is heated during the initial startup (Rafferty and Keiffer, 2002). The wells are pumped with 75 hp (56 kW) pumps, and a variable speed fluid drive to regulate the amount of water needed was added in 1970. These were later replaced with variable frequency drives. The water is then piped into a heat/water collection building where it enters a settling tank for removal of sand and to meet peak demands. From here the water is then gravity fed into the various buildings on campus. Initially the geothermal water was used directly in the heating systems, but due to 2 ppm (2 mg/L) of hydrogen sulfide which attacked the copper and solder in the radiators, isolation plate heat exchangers had to be installed in each building (Fig. 4) at a later date. In the beginning, the waste water was disposed into a drainage ditch and eventually ended up in Upper Klamath Lake, about one mile (1.6 km) to the west. However, based on a 1990 ordinance passed by the City of Klamath Falls, all geothermal water produced has to be returned to the reservoir. As a result, two injection wells (INJ #1 and INJ #2) were drilled in 1990 to 2,005 and 1,675 feet (611 m and 510 m) on the southwest side of campus, approximately 2,000 feet (610 m) from the production wells. These two well can handle up to 2,500 gpm (158 L/s).

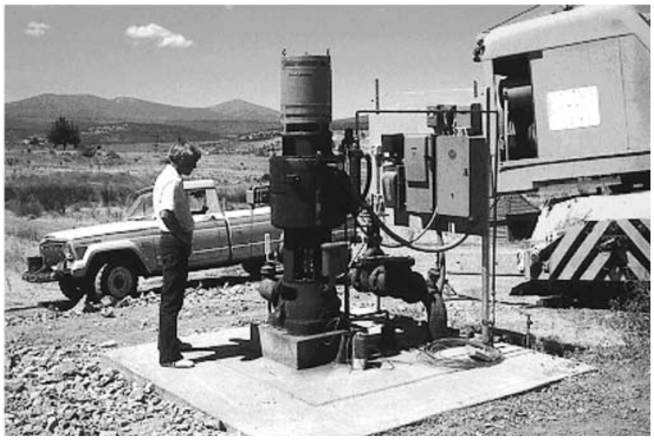

Figure 3: Gene Culver at well #6 showing the 75 hp (56 kW) motor and fluid coupling drive. The well house is moved for maintenance.

The distribution pipeline around campus initially consisted of steel pipe covered by a rigid foam glass insulation buried directly in the ground between buildings. Unfortunately, the metal pipe would expand and contract depending upon flow rate which changed with the supply temperature of the geothermal water, however, the insulation did not. Thus, ground water leaked into the cracks in the insulation and corroded the steel pipe. Oxygen was introduced into the water from a vent in the storage tank causing some minor internal corrosion of the pipes as well. Also, since the pipe was direct buried, it was often dug up by accident, since the exact location was not well documented. Thus, in 1980 a utility tunnel at 6 feet (1.8 m) on a side was constructed to house most of the pipeline, as well as other utilities on campus being added later (Fig. 5) (Lund and Lienau, 1980). Where possible, the tunnel was located under sidewalks, so any residual heat would melt the snow and ice above. The cost at that time was about $160/ft. ($525/m). A 312 ton (1,095 kW) lithium-bromide/water absorption cycle chiller was installed on campus in 1980 using the 192˚F (89˚C) geothermal water to provide cooling in the summer for about half of campus (Lund and Lienau, 1980). Chilled fluid at 44˚F (7˚C) was delivered to the space cooling system in several of the buildings. Unfortunately, the unit at that time required 240˚F (116˚C) geothermal water to operate at 100% efficiency, thus the machine only produced half of the normal output. For this reason, and the

Figure 4: Plate heat exchanger in the College Union building.

required high geothermal flows (600 gpm – 38 L/s), high discharge temperature and corrosion of the copper pipes in the generator section, the unit was replaced with an electric chiller in 1998 (Lienau, 1996).

In the beginning the geothermal water, which could be pumped up to 750 gpm (47 L/s) using two wells, heated 440,000 ft2 (40,900 m2) of floor space in six buildings using either forced air for interior rooms or base-board hot water for exterior building walls. An average of 2.8 million Btu/hr (3.0 GJ/hr) with a maximum of 24.8 million Btu/hr (26.1 GJ/hr) was used on campus, costing about $12,000 to $14,000 per year compared with $94,000 to $100,000 per year on the old campus with conventional fuel. A standby oil fired boiler from the old campus was installed in the Heat Exchange building, however, it was never used and was eventually removed in the 1990s. Today, only one well is normally used, with two being required during extreme cold weather (below 0˚F or -18˚C). The third well is used for standby, and allows maintenance to be performed without interrupting the usage.

PRESENT CAMPUS OPERATION (BOYD, 1999)

Today, geothermal water is produced from three wells at a temperature of 192˚F (89˚C), which are located in the southeast corner of the campus (Fig. 2). Well water temperature can vary between 192˚ and 196˚F (89˚ and 91˚C), depending on the pumping rate and location of the well. The water is pumped individually from each well, with a maximum total flow of all the wells at 980 gpm (62 L/s). The water is then collected in a 4,000-gallon (15 m3) settling tank in the Heat Exchange building before it is delivered to each building via gravity through the distribution system according to the demand on the system. The settling tank provides the necessary head for the gravity flow system and allows the fines from pumping to settle out of the water. Due to pipe failures from the direct buried distribution system, a concrete utility tunnel was constructed in 1980. When new extensions to the tunnel are added, corrugated galvanized steel culvert are used instead of concrete, costing about 25% of the tunnel cost.

Figure 5: OIT utility tunnel with geothermal pipe and other utilities.

In the original design, the geothermal water was used directly in each of the building mechanical systems. This "once through" approach eliminated the need for circulation pumps in the buildings. The direct use of the geothermal fluids caused problems due to the corrosive nature of the water. The original chemical analysis of the water failed to consider the effect of hydrogen sulfide and ammonia on the copper alloys used in the mechanical system. There were a number of different types of failures identified that occurred as a result of using the water directly. The more important ones were:

- Failure of the 50/50 tin/lead solder connections,
- Rapid failure of 1% silver solder,
- Wall thinning and perforation of copper tubing was a common occurrence,
- Control valve failure where plug (brass) was crimped to the stem (stainless steel). The threaded ones experienced no problems, and
- Control valve problems associated with packing leakage.

To address these problems, the geothermal water was isolated from the building heating systems using plate heat exchangers. The type selected consists of 316 stainless steel plates and Buna-N gaskets. The heat exchanger for the campus swimming pool failed due to the chlorine in the pool water, and thus, had to be replaced with titanium plates, which was eventually replaced with a brazed plate heat exchanger due to the cost of the titanium plates.

The original discharge temperature of the waste effluent was initially quite high (135˚F - 57˚C in winter and 170˚F 77˚C in summer) when it was delivered to a drainage ditch. This method presented a safety hazard and was stopped when the City Ordinance was put into effect in 1990, as mentioned earlier. Two injection wells were drilled, that can now handle up to 2,500 gpm (158 L/s). To reduce the effluent temperature, when Purvine Hall was constructed, it was designed to use the effluent from the rest of campus. The temperature of the effluent as it enters the building is around 155˚F (68˚C) and leaves at a temperature of around 130˚F (54˚C). The main components of this building's heating system are a 4,000-gallon (15-m3) storage tank, circulating pumps and heat exchangers. On the building heating side, space heating is accomplished by 54 variable air volume terminals equipped with hot water coils.

The newest additions to the OIT geothermal system are sections of sidewalks, stairs and handicap ramps equipped with geothermal snow melting system. In 2009 approximately 37,000 ft2 (3,400 m2) of sidewalk and driveway systems were installed in front of the administration building (Snell Hall) (Fig. 6). The pipes in the concrete are 5/8- to 3/4-inch (1.6- to 1.9-cm) diameter cross-linked polyethylene tubing (PEX), placed 8 to 10 inches (20 to 25 cm) apart. The system should be able to maintain a slab surface temperature of 38˚F (3˚C) at -5˚F (-21˚C) air temperature and 10 mph (16 km/h) wind when the entering 50/50 propylene glycol/water temperature is 144˚F (62˚C). Each major area has a separate plate heat exchanger and the system will activate when the outside air is 30˚F (-1˚C). The total amount installed on campus to date covers around 40,400 ft2 (3,750 m2).

Figure 6: Installation of PEX pipe for the campus entrance snow melting system in 2008.

At present twelve buildings are heated totaling 732,000 ft2 (68,000 m2). At peak use, the system provides 16 million Btu/hr (16.9 GJ/h) or a capacity of 4.7 MWt. The annual use is approximately 64.4 billion Btu (67.9 TJ), saving around $1,000,000 annually in heating costs as compared to natural gas.

FUTURE CAMPUS PROJECTS

Five new geothermal projects are being planned and some are already underway for the campus. These include: (1) a low-temperature, 280 kWe (gross) binary power plant using the existing well water, (2) completing a deep well on campus producing 196˚F (91˚C) geothermal water, (3) a 1.0 to 1.2 MWe (gross) binary power plant to use the energy from the deep well, (4) an incubator greenhouse facility, and (5) an incubator aquaculture facility. Each of these projects is described in detail below.

Low Temperature Power Plant

A contract was signed with United Technology Corporation of Connecticut (now Pratt and Whitney, Co.) for a 280 kWe (gross) binary power plant that can use the 192˚F (89˚C) geothermal from the existing wells on campus. We are taking approximately 15˚F (8˚C) off the top, and then the remaining 177˚F (81˚C) is still adequate to supply the heating needs of campus. Maximum flow would be 600 gpm (38 L/s). In summer and warmer periods, the reject temperature can be reduced to as low as 150˚F (66˚C), when the campus heating demand is less. This unit purchased uses a single-cell wet cooling tower with 70˚F (21˚C) cooling water and produce an average net output of 85 to 140 kWe depending on the outside temperature and humidity. This will provide approximately 10% of the campus electrical energy demand and save $100,000 annually. In addition, the project will serve as a demonstration site and student laboratory, mainly for students in the new Renewable Energy Engineering Program. Real time monitoring would be available for students on our campus and at other universities.

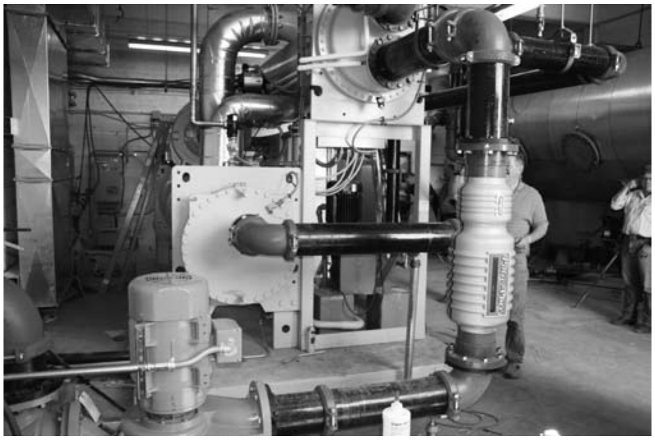

Figure 9. The low-temperature power plant inside the building.

Figure 10. Building housing the low-temperature power plant and the associated cooling tower.

Deep Well Drilling Project

To produce additional electrical energy for campus, we drilled a deep (5,308 feet – 1,618 m) geothermal well that intersected the high angle normal fault on the east side of campus. The geothermally heated fluid upwelling along the fault is already tapped by our existing geothermal wells. Geochemistry predicted that up to 300˚F (150˚C) geothermal fluids might be found at depth – however, the depth and amount could not be predicted. Unfortunately, the highest temperature found in the well was just under 200˚F (93˚C). We have tested the well at 1,500 gpm (95 L/s) and proposed to test it at 2,500 gpm (158 L/s) which can supply a 1.0 MWe to 1.2 MWe (gross) power plant, depending upon the final temperature and flow rate of the fluid. The surface water level is at 320 feet (97.5 m) below the surface, which is typical of the other wells in the area. The drawdown at 1,500 gpm (95 L/s) was only 23 feet (7.0 m) and predicted to be 75 feet (23 m) at 2,500 gpm (158 L/s). Funding was provided by the US Department of Energy and the Oregon University System in a matching grant.

The following projects were completed prior to drilling the well to better define the resource and drilling target. In 2008, we contracted for and completed a reflection seismic survey of campus to better locate the fault and thus located the drilling site. Approximately 64 2.2 lb (1 kg) dynamite charges at 18 feet (6 m) depth were set off on campus and surrounding property to bounce energy waves off subsurface structures. The seismic survey can be viewed at http://geoheat.oit.edu/oit/Sesimic_Final _Report.pdf. This investigation determined the optimum drilling target at about the 3,000 to 4,000 foot (900 to 1,040 m) depth (Fig. 7). The drill site was located in the southeast corner of the upper parking lot.

As a part of the USDOE grant requirements, we completed an environmental assessment (EA) under the NEPA requirements. The final EA can be viewed at http://geoheat.oit.edu/oit/OIT-Deep-Geothermal-Well-andPower-Plant-Project-FEA_0908.pdf.

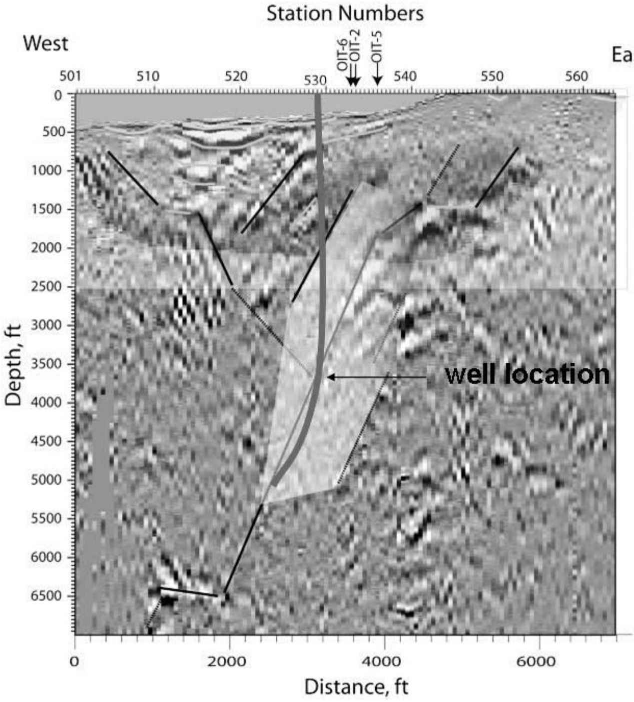

Figure 7: East-west seismic profile showing the fault and fracture zone with the deep well location

A Request for Proposal (RFP) for drilling the deep well was prepared and a contract was awarded to ThermaSource, Inc. of Santa Rosa in December 2008. Drilling of the 30foot (9-m) deep surface casing (conductor pipe) of 30 inch (76 cm) was completed in early January by a local contractor. ThermaSource had their drilling rig on site and started their drilling by the 2nd week of January 2009 (Fig. 8). They then drilled to 300 feet (91 m) and set and cemented a 20-inch (51-cm) diameter casing. This was followed by a 2,500-ft (760 m) hole for a 13-3/8-inch (34cm) casing cemented back to the surface. The well was finished with a 9-5/8-inch (24-cm) diameter production liner that was slotted at selected intervals. Deviated drilling was used to better intersect and tap the fractured fault zone from 3,200 ft (975 m) to bottom. The only problem that we experience on campus was complaints by student due to lack of parking, as the drill site had temporally taken out about 75 parking spaces. Noise was not a problem with the residence hall or the adjacent hospital that are located only 500 ft (150 m) on either side of the project site.

Figure 8: ThermaSource drilling rig on the OIT campus.

Moderate Temperature Power Plant

A 1.0 to 1.2 MWe power plant (gross) would be design to use the fluids from the deep well. It will be a binary type (organic Rankine cycle using a secondary low boiling point hydrocarbon) supplying around 0.8 MWe to 1.0 MWe (net) to campus, enough to cover approximately half of the electric energy requirements. This would save the campus round $300,000 per year.

The cost of the well and the 1.0 to 1.2 MWe (gross) power plant would be around $11.7 million, however, the "waste water" from the power plant at around 175˚F (80˚C), could then be sold to adjacent property owners or used to supplement the existing and new OIT heating demands, generating additional income or savings. The site would also become a demonstration site and student laboratory with real time monitoring available. Funding for the projects will come from a US Department of Energy grant, and from Oregon State bonds and grants. Additional support will be provided from the Energy Trust of Oregon and the Climate Trust.

Incubator Greenhouse Facility

We are proposing to construct two geothermally heated greenhouses on campus. The greenhouses would be 100 by 60 feet (31 by 18 m) covering 6,000 ft2 (560 m2) and designed to grow a variety of cut flowers, potted plants and vegetables. Different heating and cooling systems would be provided to each greenhouse as a research and demonstration project. All heating and cooling in the greenhouse would be monitored and controlled by a computer system. The greenhouses would be an incubator facility for interested investors/developers to test the feasibility of growing their crop in a controlled environment utilizing geothermal energy. The facility would also provide research projects for students on campus and for the local agricultural programs at the community college and rural high school. The facility would require around 140˚F (60˚C) and 60 gpm (4 L/s), that could easily be met from our existing geothermal wells, mainly by cascading the effluent water from the campus heating system.

Incubator Aquaculture Facility

We are also proposing to construct two geothermally heated outdoor aquaculture ponds and a covered nursery tank facility on campus. The outdoor ponds would be 100 by 30 feet (31 by 9 m) of 3,000 ft2 (280 m2) and the indoor covered facility would be of greenhouse construction 100 by 60 feet (31 by 19 m) covering 6,000 ft2 (560 m2). Different heating systems would be provided to each pond as a research and demonstration project. The covered facility would consist of a series of fiberglass tanks, heated by the geothermal water. All heating systems would be monitored and controlled by computer. Various fish species, hard-shell aquatic species and even various algae could be tested. Effluent water from the campus geothermal heating system at around 140˚F (60˚C) and 150 gpm (9 L/s) would be required, that could easily be met by cascading. The facility would provide an incubator facility for potential developer/investors and also be used as a laboratory for campus students.

CONCLUSIONS

The campus was built on its present location mainly to take advantage of the geothermal energy that is provided by water moving up along the high-angle normal fault on the east side of campus. Using three geothermal wells that tap a 192˚F (89˚C) fluid and are pumped up to 600 gpm (39 L/s), provides an installed capacity of 3.8 MWt and annual supply of 64.4 billion Btu (67.9 TJ), saving an estimate $1,000,000/yr in heating costs.

A 280 kWe (gross) binary power plant has been installed and is operating providing between 80 and 140 kWe of net energy to campus, which satisfies about 10% of the campus electric needs and saves approximately $100,000 annually. This is the first combined geothermal heat and power plant installed and operating in Oregon, and also the first on a university campus.

With the deep well completed and when the 1.0 to 1.2 MWe (gross) power plant is up and running on campus, Oregon Institute of Technology will be the first campus in the world to supply all its heating and a majority of its electrical energy from a geothermal resource directly under campus. We will be a showplace for all forms of geothermal utilization. Along with our Renewable Energy Engineering Program and technical assistance provided by the Geo-Heat Center (http://geoheat.oit.edu), we will be a leader for renewable geothermal energy utilization.

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