Lake coil fabrication (left) and placement (right).

Resource Center Surface Water Heat Pump System

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The ideal combination of a client with water source heat pump (WSHP) experience, an architect with an interest in surface water heat pumps (SWHPs), a quality mechanical contractor, and an engineering firm with SWHP expertise resulted in a successful installation in a 20,000 ft^2 (1860 m^2) community college resource center. The close proximity of a small nearby lake presented both an opportunity and a challenge. Guidance for minimum lake size and depth is not well established,[1] and there were concerns given the cooling load was 70 tons (250 kW) on the 13 acre (5.3 ha/52 700 m^2) lake and only 6 acres (2.4 ha/24 300 m^2) with depths between 10 and 15 ft (3.0 and 4.5 m).

A secondary issue was the initial assumption in the project planning stage that there would be an added premium of an SWHP system compared to other campus WSHP systems connected to fluid coolers and boilers. The college decided to pursue, even with the understanding that it may be a cost premium. The A/E team communicated the benefits of anticipated lower life-cycle cost, lower energy bills, and other potential benefits such as less maintenance and aesthetics of no outdoor equipment. When the engineers were brought on board, they estimated the first cost to be comparable to, or possibly lower than a traditional fluid cooler/boiler system, which made the system that much more attractive to the college. The total annual energy use

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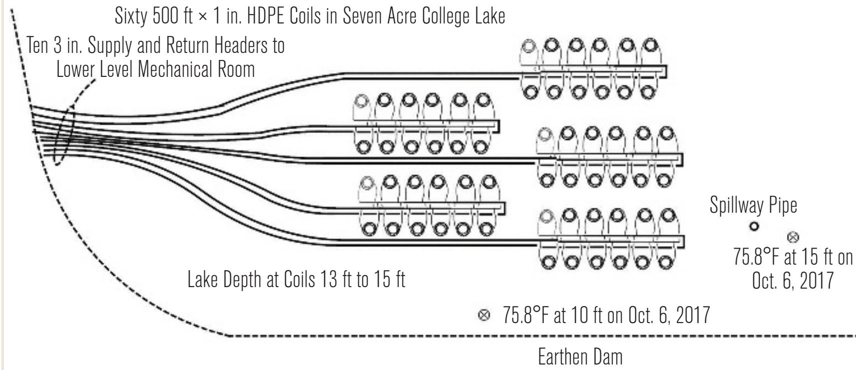
of the all-electric building was 8.1 kWh/ft^2 (0.75 kWh/m^2) after the first year of occupancy, and the occupant satisfaction ratings were higher than any of the ground source heat pump (GSHP) systems assessed in a previous survey.

FIGURE 1 SUSCC lake heat exchanger and nearby temperatures.



System Description

The Resource Center of the Southern Union State Community College (SUSCC) in Wadley, Ala., was completed in 2016. The upper two levels consist of a library, offices, a computer learning center and study rooms. The lower level is a conference center consisting of a main multipurpose room, two smaller conference rooms, an office, and a serving kitchen. The upper floors are open 110 hours per week with an average occupancy of 80 students and staff.

Cooling and heating are provided by 20 water-to-air heat pumps (WAHPs) totaling 47 tons (165 kW) and three outdoor air WAHPs totaling 23 tons (81 kW) for a total of 70 tons (246 kW) connected to the lake coil. Liquid flow through the units and the lake heat exchanger is provided by a variable-speed 5 hp (3.7 kW) vertical shaft pump in a lead-lag arrangement with an auxiliary pump. Two 2 ton (7 kW) ductless mini-split units provide cooling for the equipment room and the data center.

The lake heat exchanger consists of sixty 500 ft (150 m) 1 in. (32 mm) nominal high density polyethylene (HDPE) coils. The total tubing length of 30,000 ft (9150 m) equates to 430 ft/ton (37 m/kW). As shown in *Figure 1* the coils are arranged in five parallel circuits with 12 coils each connected to nominal 3 in. (90 mm) reverse-return headers that are routed under a parking lot and through the building slab to the lower level mechanical room. The original design called for short transitions to 2 in. (51 mm) HDPE to accommodate long radii 90° bends without thermal fusion joints beneath the slab. However, the smaller diameter pipe was extended under the parking lot and the added head loss resulting in a required increase from a 3 hp (2.2 kW) to a 5 hp (3.7 kW) pump.

As shown in the photos on the facing page, the heat exchanger coils with weights were fabricated on the earthen dam, lifted into the lake with a crane and pulled into place with a boat. The coils are located where the lake depth is 13 to 15 ft (4 to 4.5 m). The client reported that the lake level has remained relatively constant even during drought periods.

The coils are filled with a 10% methanol-water mixture. Lakes in this climate typically fall below 45°F (7°C) in the late winter.[2] Small amounts of antifreeze are required since liquids leaving the coils to the heat pumps are near 40°F (4°C). The liquid temperature leaving the heat pumps and returning to the coils would be 6°F to 8°F (3.3°C to 4.4°C) lower and near the freeze point of water. Under these conditions, frost would begin forming on the heat pump liquid-to-refrigerant heat exchangers.

Design Challenges

The largest challenge during design was obtaining the information needed on the lake to properly size the system and locate it within the lake. No water temperature data was available and had to be obtained by the engineer. The engineer measured the temperatures and depths of the lake at various locations across the lake to create a temperature and depth profile. The owner was able to provide other useful information to the design team during the design process, aiding in the sizing and location of the lake coils, such as stability in lake levels throughout the year, and the fact that the lake was continuously fed from a tributary of a nearby river. Even during drought years, the school had not seen a noticeable lake level drop or change in the behavior of the source that fed the lake. Since the lake was privately owned by the school, no additional permissions had to be sought to use the lake for a SWHP application.

FIGURE 2 Monthly energy consumption and billed demand.

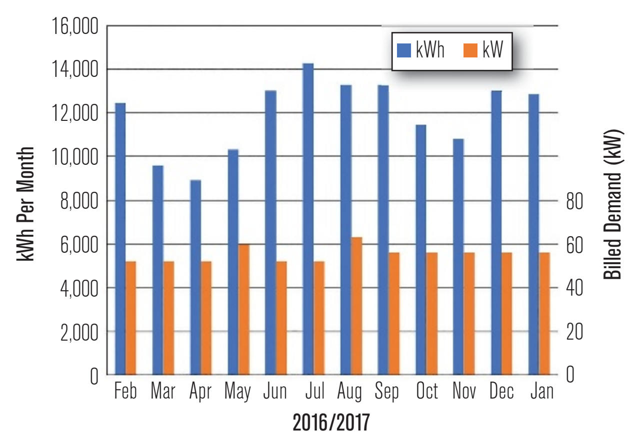
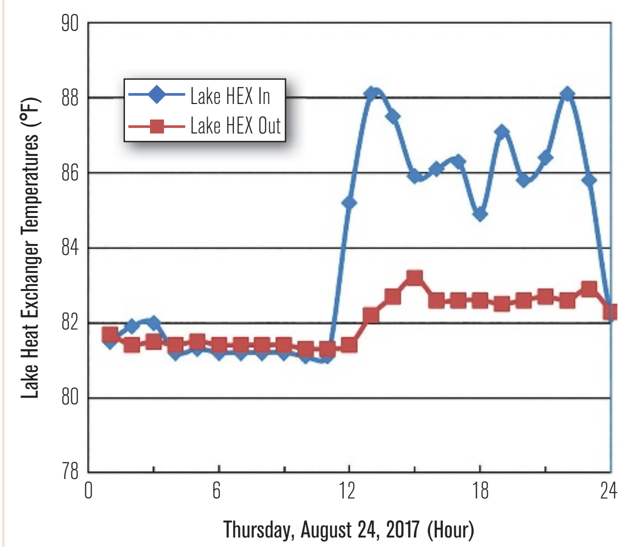


FIGURE 3 Summer lake loop liquid temperatures.



Performance and Occupant Satisfaction

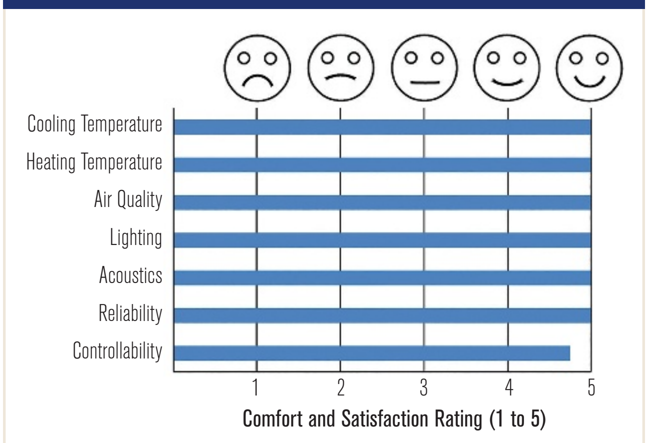
Figure 2 demonstrates the monthly energy use and billed demand for the 20,000 ft^2 (1860 m^2) all-electric building of which 17,720 ft^2 (1650 m^2) is heated and cooled.

Figure 3 is a plot of the inlet and outlet temperatures of the lake heat exchanger (HEX) near the end of a work week when local outdoor air temperatures were near the average for late August. These results tend to alleviate some of the concern regarding the performance of a 15 ft (4.5 m) deep lake with a cooling load of approximately 10 tons per acre (87 kW/ha). This area is measured at the 10 ft (3 m) depth since this value is expected to be a better indicator than the surface area of the lake.[3] Caution is advised since local summer temperatures of 2017 were relatively mild compared to previous years and the area had a 34% higher than average rainfall during May through August.[4]

Additionally, interaction between the central DDC system, internal controls of the heat pumps, and the VS water pump (three different manufacturers) proved to be challenging, as evidenced in the low differential temperatures in the loop. It is unclear why this was occurring; however, it appears the VS drive was 100% for the entire 2017 summer data collection period. Thus, it is difficult to determine if the building heat pumps were experiencing full-load conditions.

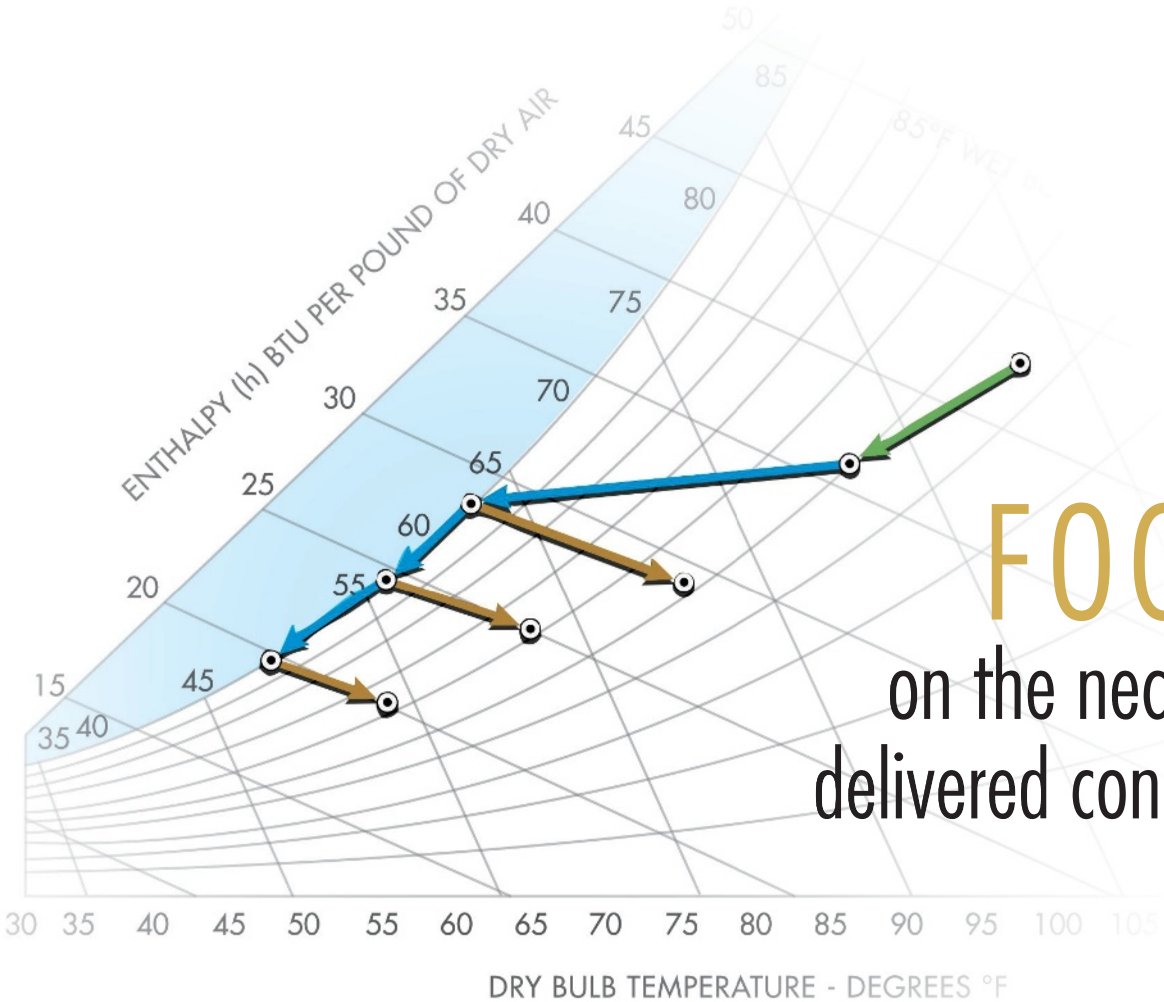
In spite of the issue with the interactions between the various equipment and central controls, the occupants experienced an abnormally high satisfaction level as indicated by the survey results shown in *Figure 4*. Staff members completed surveys on the seven items shown in the figure with a value of 1 assigned for very dissatisfied, 2 = dissatisfied, 3 = acceptable, 4 = satisfied and 5 = very satisfied. The results were substantially above all of those reported for buildings in a previous comprehensive survey of GSHPs.[5]

FIGURE 4 Occupant satisfaction survey results (four surveys).



Installation Cost and Issues

The mechanical cost as shown in *Table 1* for the installation was $609,000 ($30.45/ft² [$328/m²]). Included in this cost was $90,000 ($1,286/ton [$366/kW]) or 14.8% of total for the lake heat exchanger. The installation and equipment cost for the 20 water-to-air heat pumps, three water-to-air outdoor air units, and two ductless mini-splits was $151,000, or 24.8% of the total. Other significant costs were $110,000 (18.0%) for ductwork, $81,000 (13.3%) for controls, and $76,000 (12.5%) for interior piping.[6]



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The cost of the lake coil alone was $1,286/ton ($366/kW), which was considerably less than the cost for ground heat exchangers in previous surveys of $2,000 to $4,000/ton ($570 to $1,140/kW). However, total system cost for the entire system was in the same range at $8,700/ton ($2,470/kW).[7]

Since this SWHP system is not a commonly used HVAC system in Alabama, one consideration during the design of the project was to make sure that an experienced ground loop subcontractor was selected to fabricate and install the loop piping in the lake and underground to the building. This was accomplished by identifying regional geothermal contractors with experience in installing large (at least the tonnage of this project) ground loop systems, as well as experience in SWHP systems, and listing them as prequalified subcontractors in the project specifications. The project was a traditional design-bid-build, therefore, the lake loop installation was competitively bid. As a result of the pre-qualification requirements, the subcontractor that was selected to perform the SWHP installation was experienced largely with ground loops, but was able to translate this experience without any issues to a quality SWHP system installation.

A third-party commissioning agent was hired by the owner to provide design and construction commissioning services for the project, to provide additional quality control. This provided an extra set of eyes on the project to help identify potential issues, as well as make sure that the owner's goals and requirements for the building were met by the A/E team and the contractor.

One issue and lesson learned for the project is regarding the underground piping headers from the lake to the building. The piping headers were routed underneath the main parking lot for the building. It is recommended by the Plastics Pipe Institute, for buried HDPE thermal pipe to be back-filled with a loose material, such as sand or pea gravel, to allow for thermal expansion.[8] However, due to a discrepancy between the architect's and engineer's specifications on the backfill material, the HDPE headers between the lake and the building were back-filled with a flowable fill mortar. The intent of the flowable fill was to limit damage to piping if the contractor failed to compact the soil properly. The flowable fill is a soft, light-weight concrete that is brittle to the touch.

During construction, an electrician installing an underground conduit accidently cut into one of the buried HDPE pipe headers, causing a leak. When the loop contractor came on-site to repair the pipe, it was discovered that a hard concrete had been poured over the HDPE headers instead of the softer flowable fill mortar that was specified. This was a major cause for concern by the A/E team, as it was unknown if the hard concrete would allow for thermal expansion in the pipe or if it could potentially cause damage to the pipe. After much research and discussion between the A/E team, owner, and the contractor, it was ultimately decided to leave the piping in place as installed. After two years of operation, there have been no leaks or known damage in the HDPE piping headers between the lake and the building.

TABLE 1 SWHP system installation costs.

ITEM	COST	PERCENT OF TOTAL
Lake Loop	$90,000	14.8
WAHPs (20), OA Units (3), Mini-Splits (2)	$151,000	24.8
Pumps (2) and Accessories	$20,500	3.4
Ventilation Accessories	$29,500	4.8
Hydronic (Interior) Piping	$76,000	12.5
Ductwork Spaces Fabrication and Installation	$75,000	12.3
Ductwork Mechanical Room Fabrication and Installation	$35,000	5.7
Insulation	$40,000	6.6
Controls	$81,000	13.3
Miscellaneous and Equipment	$11,000	1.8
Total	**$609,000**	**100.0**
Cost Per Unit Floor Total Area ($/ft^2)	$30.45	
Cost Per Unit Floor Conditioned Area ($/ft^2)	$35.41	
Cost Per Unit Cooling Capacity ($/ft^2)	$8,700	
Lake Coil Cost Per Unit Cooling Capacity ($/ft^2)	$1,286	

Summary

Successful SWHP systems are demonstrated to be affordable, efficient, and provide a high level of occupant and owner satisfaction.

While the performance results using 430 ft of HDPE tubing per ton (37 m/kW) and 10 acres (87 kW/ha) of lake (at a 10 ft [3 m] depth) per ton was successful, additional results from other SWHP installations are necessary to establish guidelines for other climates and building types.

Properly backfilled underground HDPE thermal piping per industry standards is necessary to accommodate expansion and contraction and prevent potential leaks. HDPE piping expansion and contraction is much greater than that of metallic piping.[8]

Unlike ground temperature data, data on the seasonal water temperatures for the desired lake are likely to be unknown, and must be obtained for a successful design. In addition, a thorough understanding of the lake levels and other outside factors that affect the lake is crucial for success.

Even with a commissioning agent on this project working to ensure that HVAC equipment and controls were operating properly and as designed, the challenge of proper interoperability between the on-board controls for equipment (WAHPs, pumps, and fans) and the $81,000 building automation system (BAS) made using simple thermostat controls an attractive and lower cost option.

This installation has demonstrated cost-effective design and quality installation can be realized without federal tax credits. Recommendations to achieve this success and improve future installation are:

- Identify and employ experienced, proficient and high quality engineer firms;
- Identify and employ experienced, proficient and high quality mechanical contractors and ground loop contractors; and
- Simplify equipment controls so that connection to conventional room thermostats or a simple non-proprietary BAS does not consume an inordinate amount of effort by the engineers and mechanical contractors.

SUSCC Resource Center in Wadley, Ala.

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