MURRAY HIGH SCHOOL
SALT LAKE CITY, UTAH

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LOCATION & BACKGROUND

The Murray High School is located in Murray, UT, which is part of the Salt Lake City metropolitan area. It is a two-story building with 267,256 ft^2 (24,829m^2) of floor space, and construction was completed in 2003.

Average high temperatures in the region in July are about 91^{o}F (32.8^{o}C) and average low temperatures in January are about 21^{o}F (-6.1^{o}C). There are approximately 5600 heating degree days (3110^{o}C-day) and 1100 cooling degree days (610^{o}C-day) per year [65 ^{o}F (18^{o}C) base].

SYSTEM DESCRIPTION

Ground Source System

The ground source system (Figure 1) is a "hybrid system", consisting of vertical, closed-loop ground heat exchangers and a supplementary fluid cooler to balance the annual ground loads (since summer occupancy of the school was expected). The ground loop is comprised of 316 vertical boreholes, each 300 ft (91.4 m) deep, for a total length of 94,800 ft (28,895 m). It is installed under the north parking lot of the school, and the boreholes are placed in a grid-like pattern consisting of 5 sub-fields for easier flushing and purging. A single u-tube heat exchanger is installed in each borehole, and the borehole sub-fields are piped in a reverse-return arrangement. A photograph of the supplementary fluid cooler is shown in Figure 2. The fluid cooler capacity is 125 tons (440 kW).

The mean annual ground temperature in this location is approximately 53^{o}F (11.7^{o}C). An in-situ thermal conductivity test revealed that the average thermal conductivity of the soil to a depth of 300 ft (91.4 m) is 1.13 Btu/(hr-ft-^{o}F)(1.95 W/m-^{o}C). The loop field was installed in basin-fill type sediments, consisting of clay, sand, and gravel with cobble stringers.

Interior System

The total installed heat pump capacity at the Murray High School is approximately 650 tons (2286 kW). Space conditioning is accomplished by over 100 water-air heat pumps, which are installed in ceiling spaces to serve individual classrooms and other zones. Outdoor air is introduced through heat recovery ventilator (HRV) units. The original design called for total energy recovery (ERV) units, but HRV's were installed due their to lower cost. There is little use of domestic hot water in the school, and thus it is generated partially by water-water heat pumps and natural-gas water heaters. The fluid distribution system consists of a central pumping system with a variable frequency drive. Figure 3 is a photograph of the ground-loop headers in the main mechanical room.

PROJECT COSTS

The Murray High School is an example of a building where a ground-source heat pump system was cheaper to install than a conventional boiler chiller system. The project costs are summarized as follows:

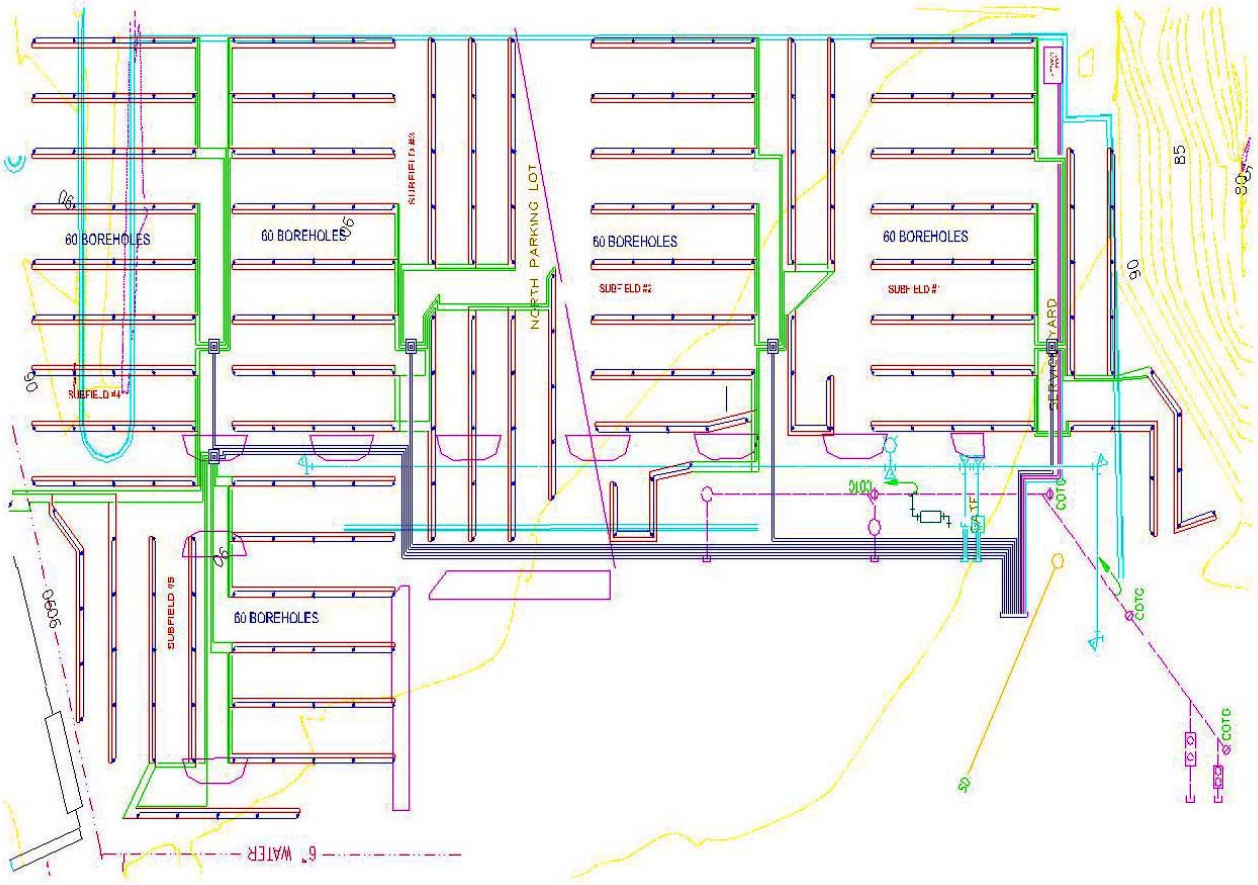

Figure 1. Murray High School ground loop field.

• Conventional Mechanical System Bid:
$19.00/ft^2 ($204.50/m^2)
• Murray High School Ground Source System Bid:

Mechanical/Plumbing bid:	$3,065,161
Loop Field bid:	$930,784
Total Ground Source bid:	$3,995,945
Mechanical Cost/ft^2 (m^2):	**$14.95/ft^2 ($160.92/m^2)**
Cost Savings: 4.05/ ft^2 ($43.59/m^2) =	**$1,082,387**

Additional cost savings may be realized if one considers architectural savings in the mechanical room floor space in the ground-source system over the conventional system. For the Murray High School, the mechanical room for the ground-source system is 2,160 ft^2 (200.7 m^2), or 0.8% of the total floor space. Comparing this value to 3.80% of mechanical room floor space to total floor space for average schools, and assuming $50/ft^2 ($538.20/m^2) cost of new construction, an additional savings of $405,000 may be realized

SYSTEM PERFORMANCE AND OPERATING COST

Maximum ground loop temperatures observed in the summer are about 92°F (33.3°C), and minimum loop temperatures in the winter are 40-42°F (4.4-5.5°C). According to the designers of the system, to their knowledge, the fluid cooler has not yet been needed. Annual utility costs for 2003-2004 are summarized as follows:

Figure 2. Photograph of the fluid cooler at the Murray High School.

• Annual Utility Costs for Canyon View High School:

Electricity:	$156,505	(96%)
Natural Gas:	$6,521	(4%)
Total:	$163,026	
Cost/ft^2 (m^2):	$0.61/ft^2 ($6.57/m^2)	

• Utility Costs for a Comparable School:

Cost/ft^2 (m^2): $0.86/ft^2 ($9.26/m^2)
(77% electrical, 23% gas)

• Operating Cost Savings:

$0.25/ ft^2 ($2.69/m^2) = **$58,300 (or 29%)/year**

Figure 3. Photograph of the main mechanical room at the Murray High School, showing the ground loop field supply and return headers.

OPERATING EXPERIENCES

Thus far, the system has operated well, with the only difficulties being those typical at start-up, such as trapped air and some mud in the ground loop.

ACKNOWLEDGEMENTS

The Geo-Heat Center wishes to thank Cary Smith of Sound Geothermal for providing the data and information for this case study.

OVERALL SUMMARY

Building Description:

Location: Salt Lake City, Utah
Occupancy: School
Gross Floor Area: 267,256 ft^2 (24,829 m^2)
Number of Floors: 2
Type of Construction: New
Completion Date: 2003
July Avg. High Temp.: 91^{o}F (32.8^{o}C)
Jan Avg. Low Temp.: 21^{o}F (-6.1^{o}C)
Annual Heating Degree Days: 5600^{o}F-day (3110^{o}C-day)
Annual Cooling Degree Days: 1100^{o}F-day (610^{o}C-day)

Interior System:

Total Installed Heat Pump Capacity: 650 tons (2,286 kW)
No. of Heat Pump Units: 100+
Pumping System: Central with VFD

Ground-Source System:

Geologic Materials: Basin-fill sediments
Mean Ann. Ground Temp.: 53^{o}F (11.7^{o}C)
Type: Hybrid, vertical closed loop, single U-tube
Configuration: 316 boreholes (grid-like pattern in 5 sub-fields),
300 ft (91.4 m) deep + fluid cooler
Borehole per ton: 146 ft/ton (12.6 m/kW)

Economic Analysis:

Installed Geothermal HVAC Capital Cost:
$3,995,945 ($14.95/ft^2)($160.92/m^2)
Conventional HVAC Capital Cost Bid:
$5,077,864 ($19.00/ft^2)($204.50/m^2)
Annual HVAC Energy Cost (2003-2004):
$163,026 ($0.61/ft^2)
Annual HVAC Energy Cost of Comparable Conventional School: $229,840 ($0.86/ft^2) ($9.26/m^2)
Annual HVAC Energy Savings:
29%
Estimated Simple Payback Period:
Immediate