GEOTHERMAL POTENTIAL OF ABANDONED UNDERGROUND MINES IN OHIO

Benefits of Geothermal Heat Pumps

- Reduce energy consumption and emissions conserving fossil fuels.
- Greater than 40% more efficient than air-source heat pumps; greater than 70% more efficient than electric resistance heating with standard air conditioning.
- The 1,000,000 geothermal installations in the U.S. have eliminated 5.8 million metric tons of CO_2 annually, with an annual savings of 8 million kWh.
- Various geothermal configurations can be installed nearly everywhere.

Disadvantages of Geothermal Heat Pumps

- Higher initial cost of installation
- Some site limitations due to existing land-use or geologic conditions
- Lack of experienced installers and a reluctance by architects and engineers to recommend the systems.

Ground-source heat pumps in Ohio

- First residential geothermal heat pump in the U.S. installed in Columbus, Ohio by Carl Neilsen, professor at OSU in 1948.
- Battelle Memorial Institute, Columbus, installed one of the first commercial geothermal heat pump systems in the U.S. in 1958.
- In 2009, Ohio led the nation in tons of rated capacity of geothermal heat pump shipments by destination; 23,348 tons (EIA). The states of OH, PA, IL, IN, KY, & MI accounted for 31.5% of U.S. GSHP by destination in 2009.

Northside Lofts

- Downtown Akron condominiums
- 40, 500 foot boreholes under parking lot (2006)

Barberton High School geothermal

- Installed one of largest geothermal HVAC systems (264,000 sq ft school building) in the state during 2000. By 2012, more than 140 Ohio schools will have installed geothermal systems.

HOCKING COLLEGE ENERGY INSTITUTE: $1.6 M, U.S. Dept. of Commerce

BUILDING INTEGRATED SUSTAINABLE FEATURES

1. NORTH-SOUTH ORIENTATION 2. GREEN ROOF 3. DAYLIGHT HARVESTING 4. GROUND SOURCE HEAT PUMPS 5. SOLAR THERMAL UNIT
6. BUILDING INTEGRATED PHOTOVOLTAICS 8. BIOSWALE 9. HIGH-ALBEDO ROOF 10. ALTERNATIVE TRANSPORTATION

Flooded Underground Coal Mines: A Significant Source of Inexpensive Geothermal Energy

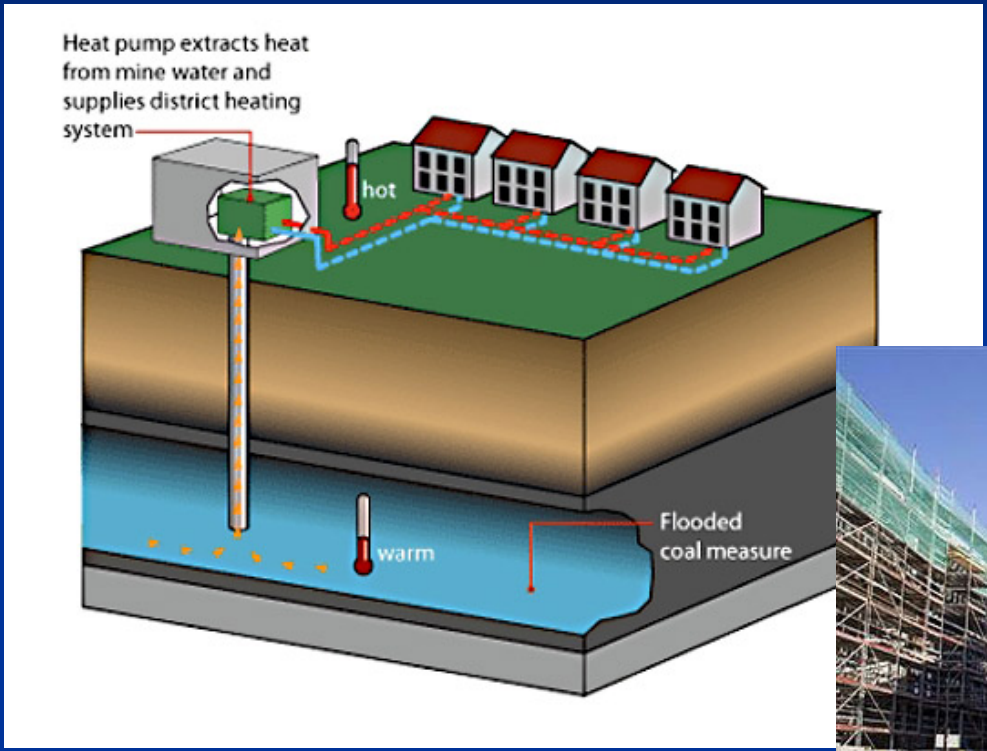
By George R. Watzlaf and Terry E. Ackman
U.S. Department of Energy, Pittsburgh, Pennsylvania

An estimated 2,000 square miles of underground mines in the Pittsburgh No. 8 coal seam in the Appalachian Basin are flooded. The calculated geothermal resources from the estimated 4% of total storage capacity discharged annually could heat and cool 20,000 homes.

THERMAL PROPERTIES OF SELECT MATERIALS

Material	Thermal conductivity (W/mk)	Specific Heat Capacity (J/g°C)
Air	0.025	1.02
Water	0.6	4.18
Sandy soil	0.3	0.8
Clay soil	0.25	0.92
Peat soil	0.06	1.92
Sandstone	2.4	0.92
Limestone	1.3	0.84
Coal	0.33	1.38
Clay (saturated)	0.6-2.5	0.92
Gypsum	0.17	1.09
Concrete	1.7	0.88
Aluminum	237	0.9
Copper	370	0.39
Lithium	85	3.58

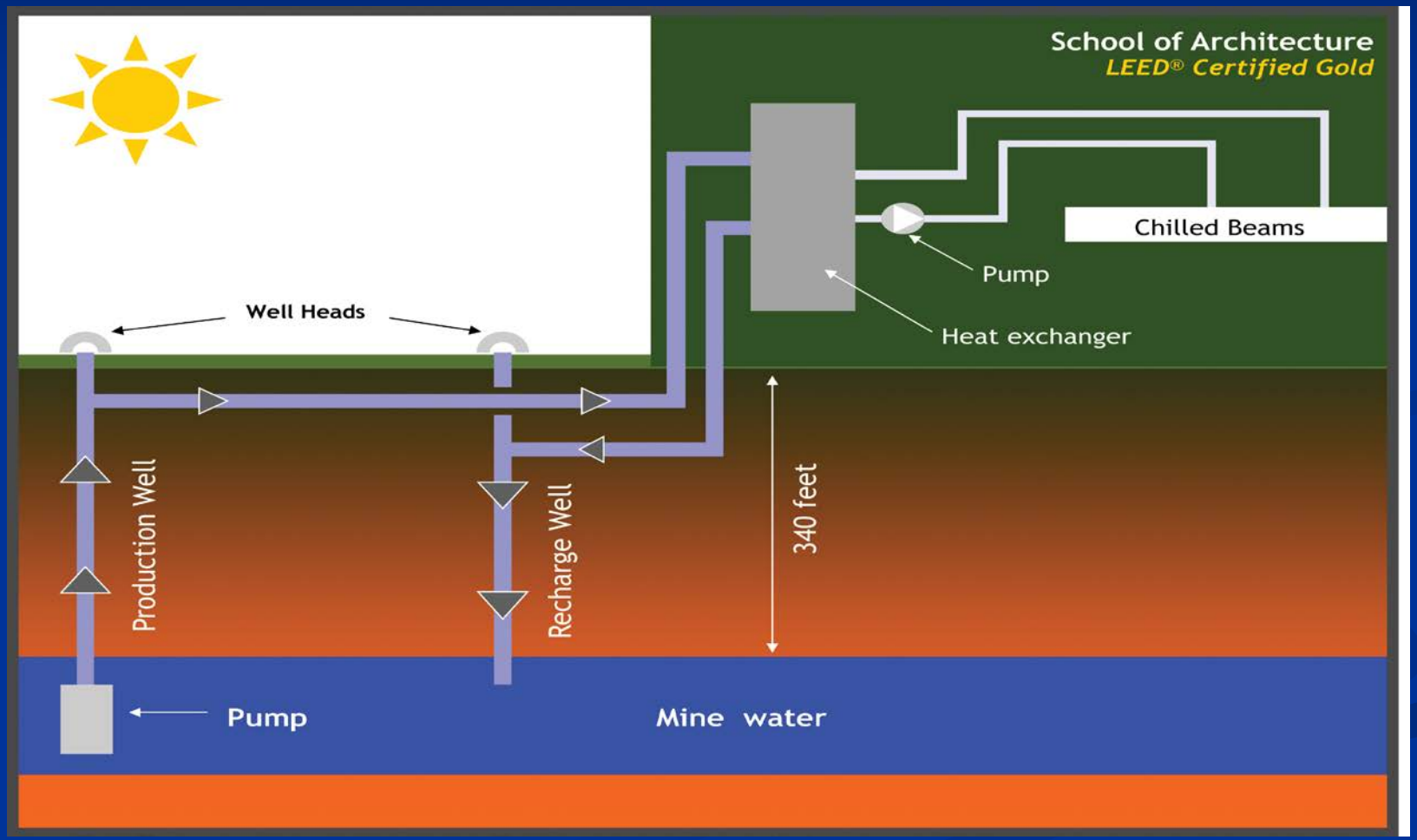
Heerlen in the Netherlands



Park Hills, Missouri

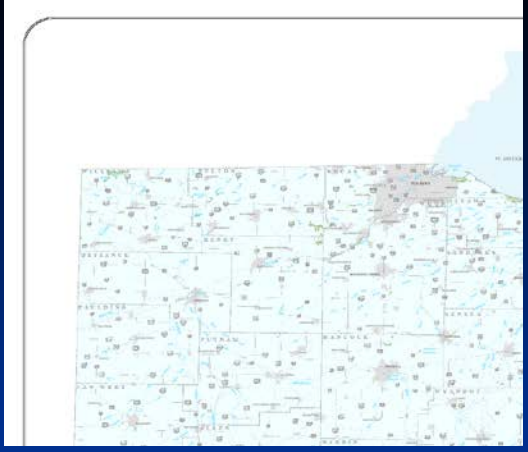
- Open loop; 2 wells, 400 foot deep, 75 gpm from abandoned lead mine. Cost $132,400 for 8,100 sq ft building (1995). Payback period: 4.6 years

Marywood University, Pennsylvania



John Wesley AME Zion Church, Pittsburgh

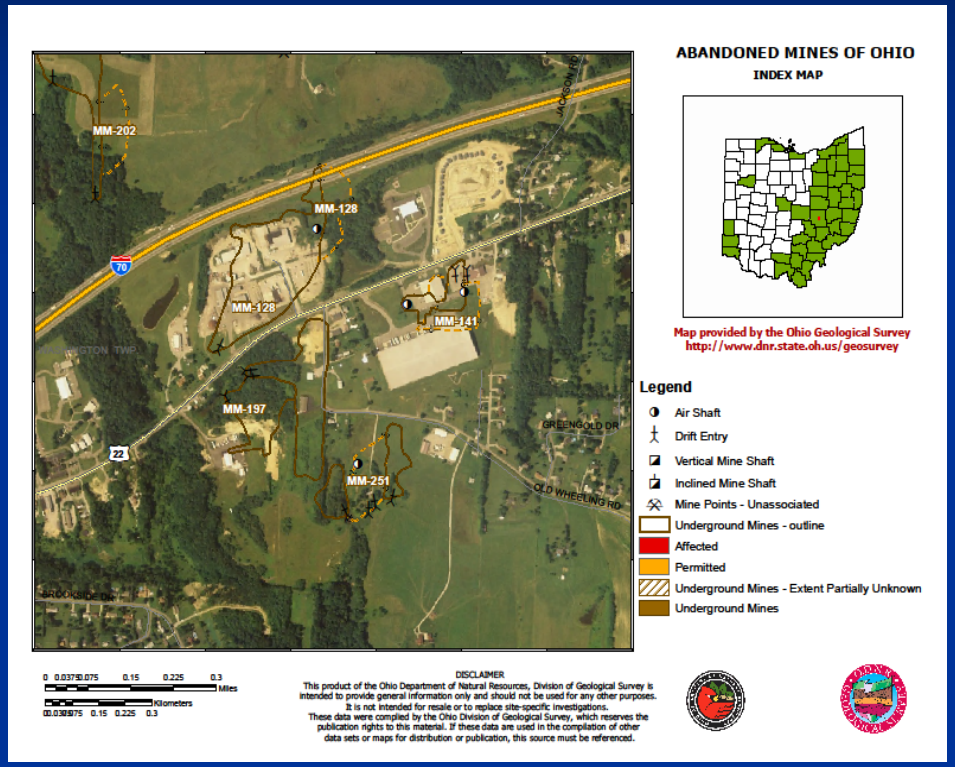
- $80,000 project; reduce heat by 80% & cooling by 50%
- PA EPA had spent $106,000 in 2004 to control water seepage



GEOTHERMAL ENERGY POTENTIAL OF FLOODED ABANDONED UNDERGROUND MINES IN OHIO: *FUN WITH NUMBERS*

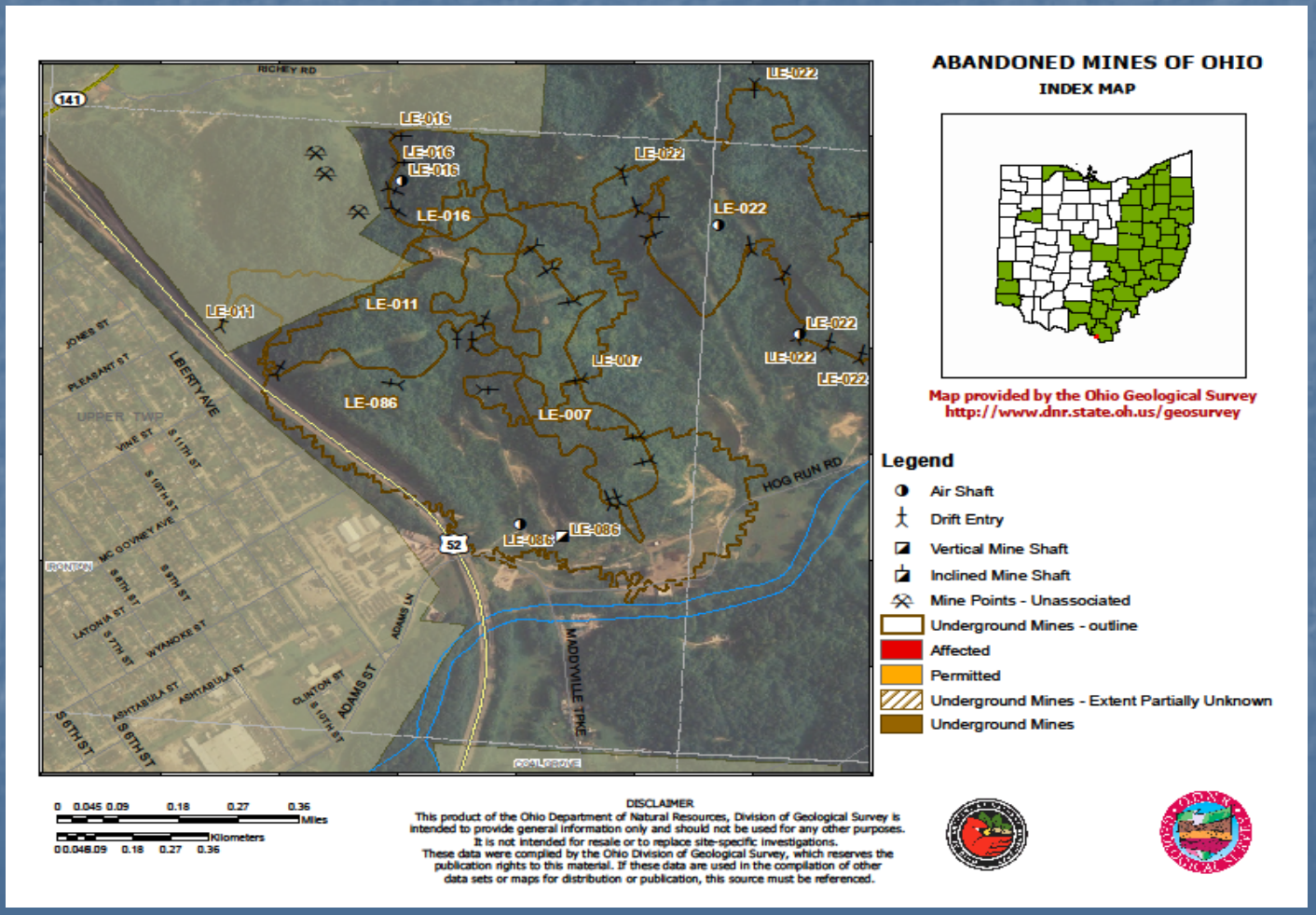
- Area of known abandoned underground mines (AUM) in Ohio: **777.39** sq. mi. or **497,332** acres.
- 1 acre = 43,560 square feet; therefore Ohio AUM area = **21,663,782,000** square feet.
- Assume approximately 50% of Ohio AUMs are flooded and a typical underground mine void is 5 feet, therefore there is approximately **54** billion cubic feet of water stored in Ohio AUMs.
- The specific heat capacity of water is 62.42 Btu/ft3 and 1 Btu = 0.002928 kilowatt-hours (KWh) ; **Viola!** There is approximately **98,694,000** megawatt-hours (MWh) of potential energy in Ohio AUMs.
- Comparisons: the largest coal-fired power plant in Ohio is the **2,600** MWh Gavin plant; a large wind farm is approximately **350** MWh (160 turbines spread over hundreds of acres); the largest solar array in Ohio is **12.6** Mwh on 77 acres.
- Ohio consumed **160,176,000** MWh of electricity in 2005; assume 20% was for HVAC (32,000,000 MWh). Also assume that 10% of the HVAC (3,200,000 MWh) use was in areas with AUM geothermal potential, a **3.5 percent** utilization of the potential geothermal energy in Ohio AUMs would replace 100% of the electricity for HVAC use.

Abandoned Underground Mines (AUM) in Ohio



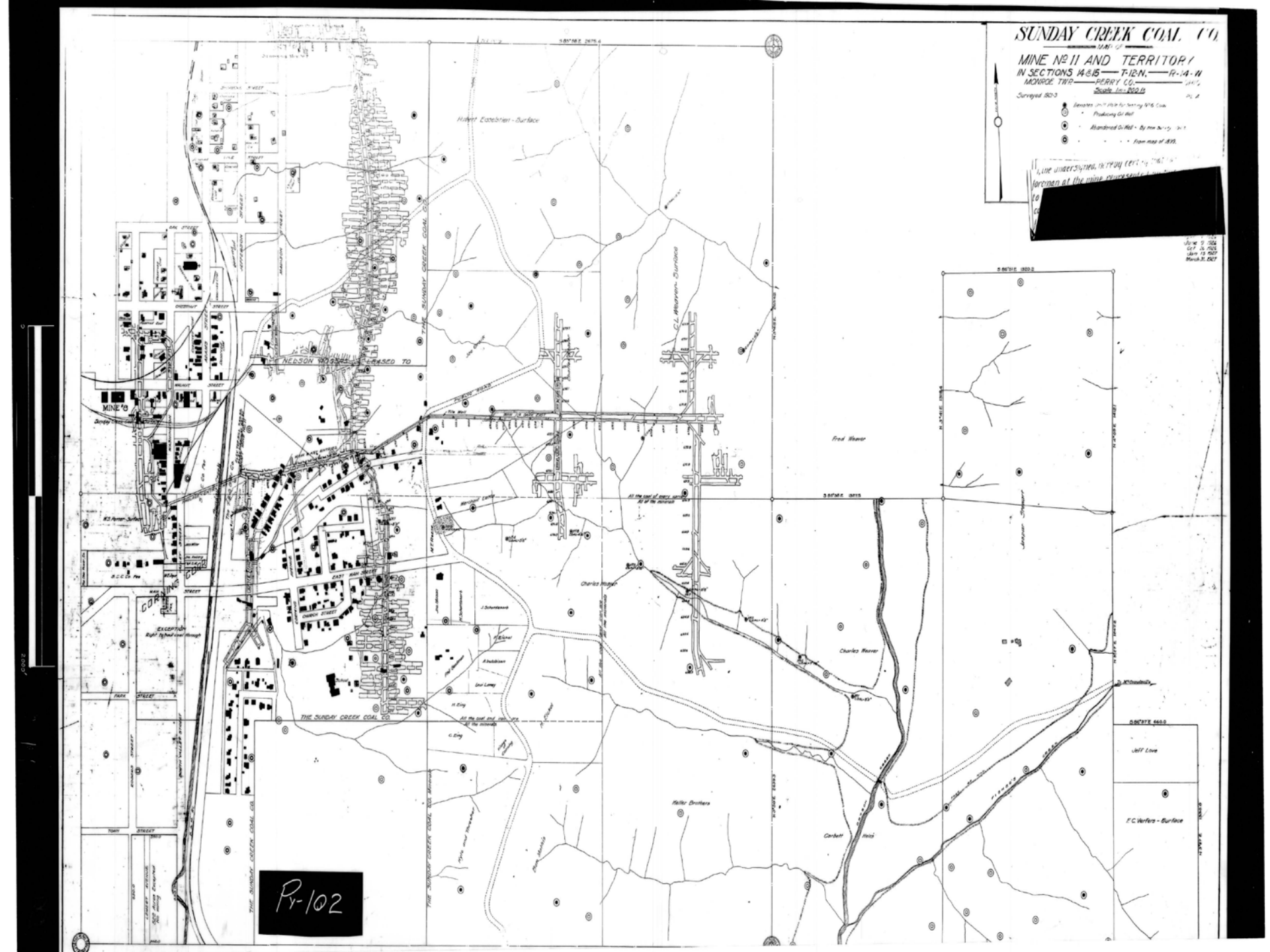
- The Ohio Geological Survey AUM interactive map can be used to delineate areas of potential for geothermal energy from abandoned underground mines. This area east of Zanesville along I-70 is one such example.

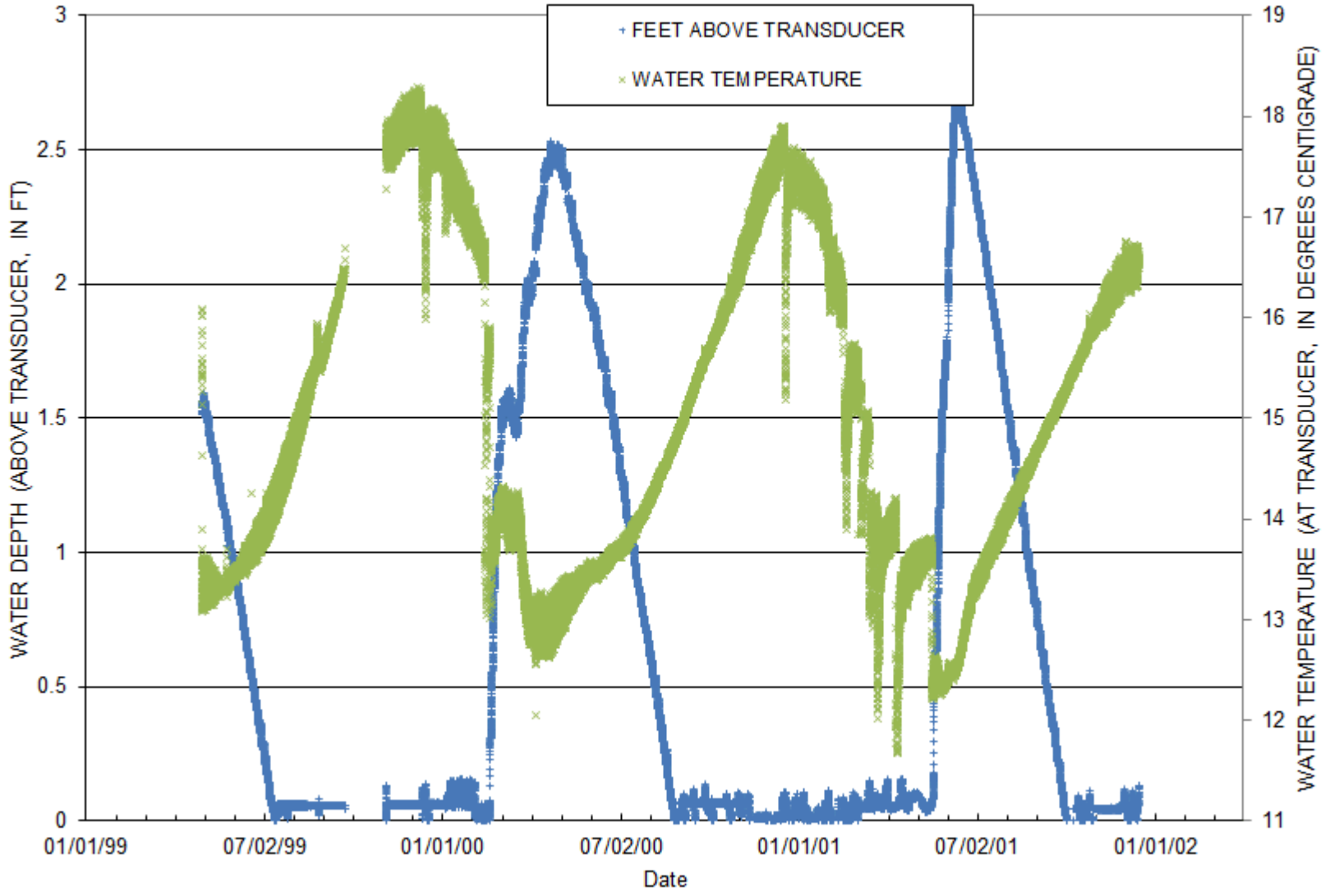
Alpha Portland Cement site in Lawrence County



Alpha Portland Cement AUM Water Analysis

- Water sample collected 4/28/11; Depth: ~ 400 feet
- pH : 6.86
- Specific Conductivity: 49,500 uS/cm
- TDS: 30,820 mg/L
- Hardness (Calcium Carbonate): 3845
- Cl: 18,318 mg/L
- Na: 8830 mg/L
- Sulfate: 16 mg/L
- Fe: 3.01 mg/L
- Mn: 0.28 mg/L
- Al: 0.76 mg/L

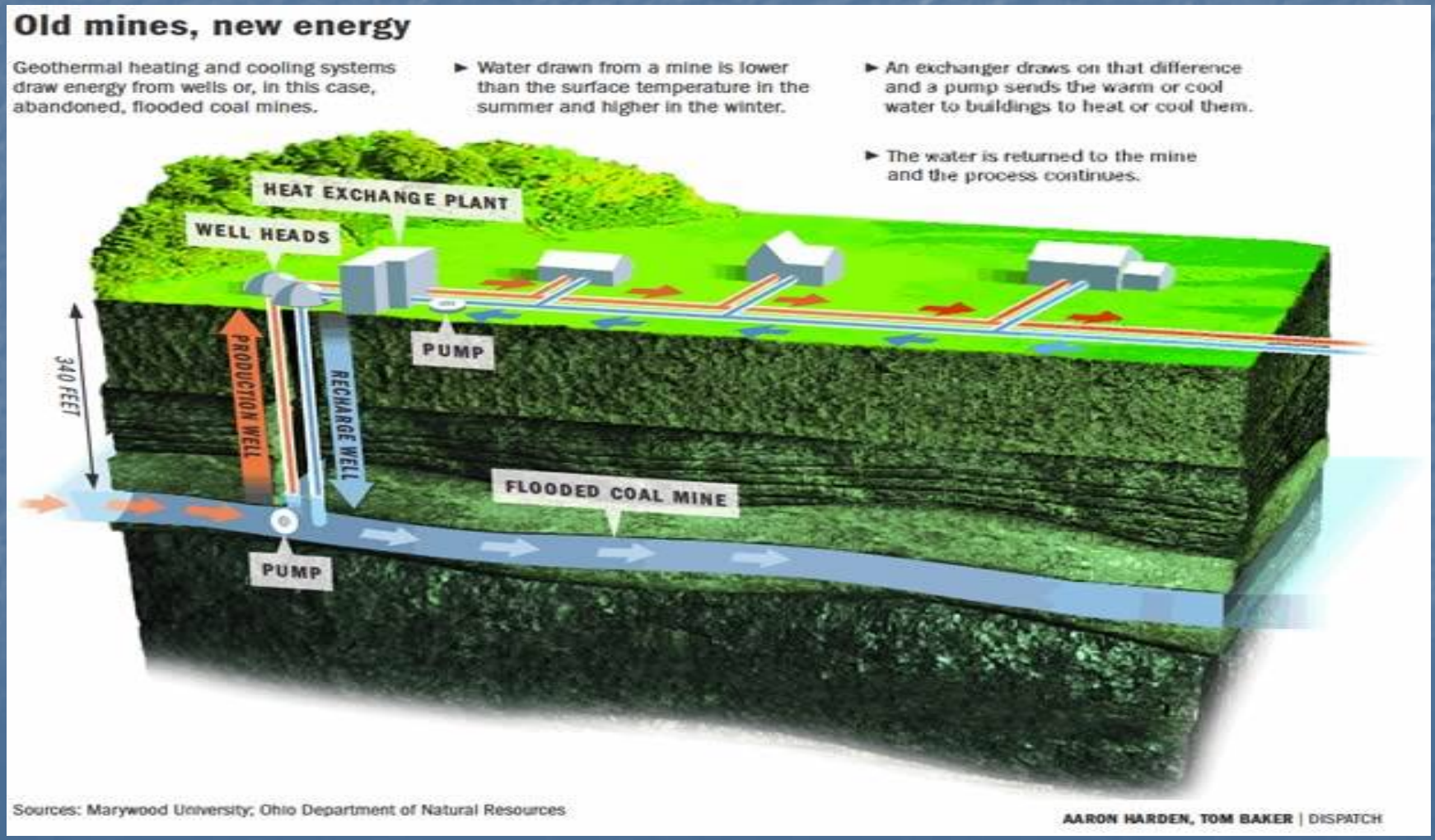

SUNDAY CREEK COAL CO.
MAP OF
MINE № 11 AND TERRITORY
IN SECTIONS 14 & 15 — T-12 N. — R-14-W
MONROE TWP. — PERRY CO. — OHIO
Scale 1in.=200 ft.
Surveyed 1903
Hubert Eastman - Surface
C.L. Maurer - Surface
Fred Weaver
Charles Hedges
Charles Reaver
Jeff Love
F.C. Vertes - Surface
Heller Brothers
Corbett Heirs
THE SUNDAY CREEK COAL CO.
MINE № 11
CORNING
EAST MAIN STREET
CHURCH STREET
MAIN STREET
PARK STREET
TOWN STREET
Py-102


FEET ABOVE TRANSDUCER
WATER TEMPERATURE
WATER DEPTH (ABOVE TRANSDUCER, IN FT)
WATER TEMPERATURE (AT TRANSDUCER, IN DEGREES CENTIGRADE)
Date
0
0.5
1
1.5
2
2.5
3
11
12
13
14
15
16
17
18
19
01/01/99
07/02/99
01/01/00
07/02/00
01/01/01
07/02/01
01/01/02

Buckingham Coal, Glouster

East Fairfield Limestone mine, Mahoning County

Columbus Dispatch article, 8/29/11



RECENT DOE GRANT AWARDS FOR GEOTHERMAL ENERGY FROM ABANDONED UNDERGROUND MINES

- **A demonstration system for capturing geothermal energy from mine waters beneath Butte, MT.** New Natural Resources building at Montana Tech.

  DOE: $1.1M; Total cost: $2.2M.
- **Geothermal retrofit of Illinois National Guard State Headquarters building.** DOE: $1.2 M; Total cost: $1.6 M

Geothermal Retrofit of Illinois National Guard State Headquarters Building

Principal Investigator: Mark Lee, Department of Military Affairs

- Retrofit 74,000 sq ft building using abandoned 2,000 acre Panther Creek #2 coal mine at depth of 200 feet

•Potentially reduces cost of installation by reducing well field requirements from hundreds of wells to as few as two.

•Scalable

•"Green" use of former coal mine

•Payback periods of less than 10 years for implementation to meet National Guard Bureau standards

– Project Design complete December 1, 2010

Project update (Fall, 2011) Test boreholes drilled in Spring, 2011 encountered gas-filled voids at a depth of approximately 170 feet. Measured water depths were only 12-18 inches. After due consideration, it was determined the mine did not have sufficient water to sustain the planned geothermal load. A conventional vertical loop geothermal system is currently being constructed as an alternative.

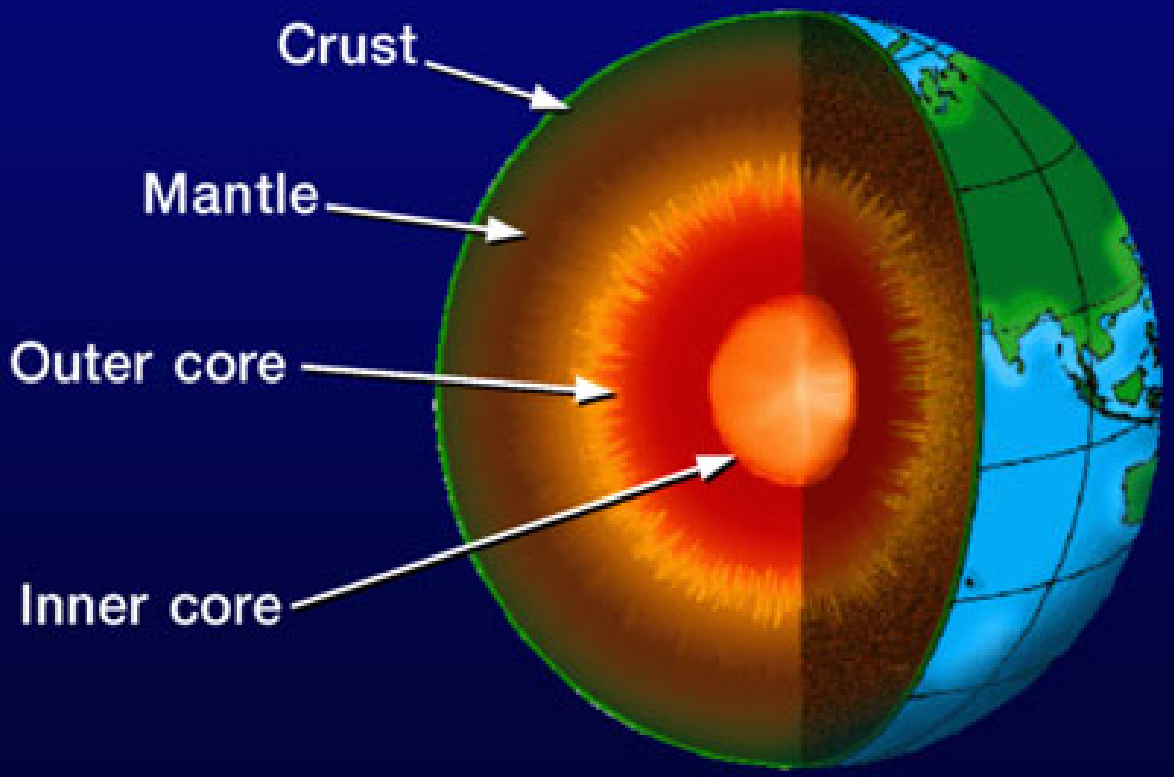
Geothermal Retrofit of Illinois National Guard State Headquarters Building

- Develop methodology for determining mine water quality and quantity;
- Determine legal issues related to ownership, liability and permitting requirements;
- Determine the best energy recovery systems that balance cost with environmental or other concerns;
- Estimate scalability for campus use;
- Develop alternative plans and emergency planning for potential changes in mine water availability and temperature
- Publish a methodology for exploiting this resource across the state of Illinois.

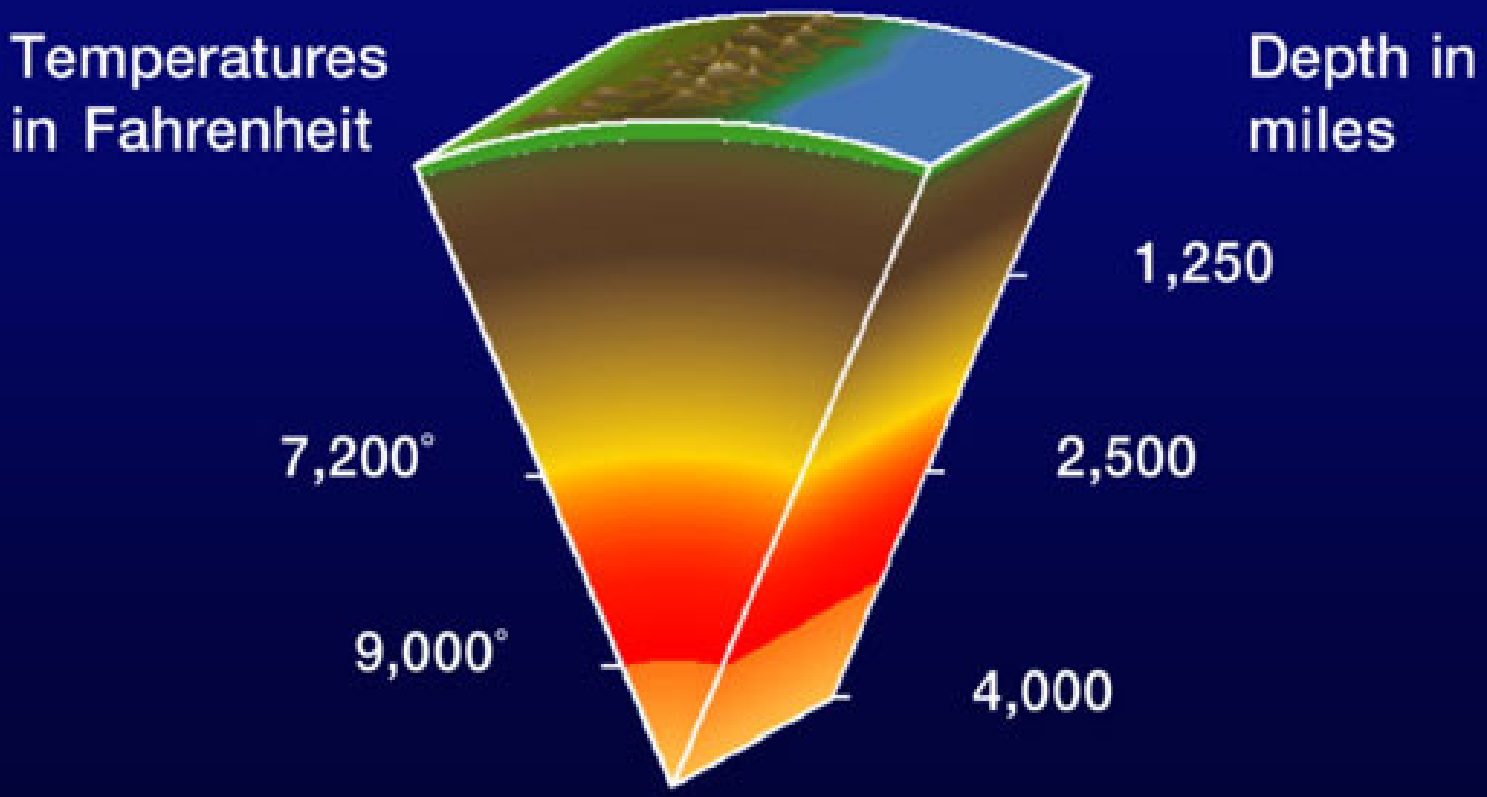
Even though project was not successful as envisioned, methodology can be modified to improve future results at other sites.

NOT THE END, BUT THE BEGINNING!

The Earth

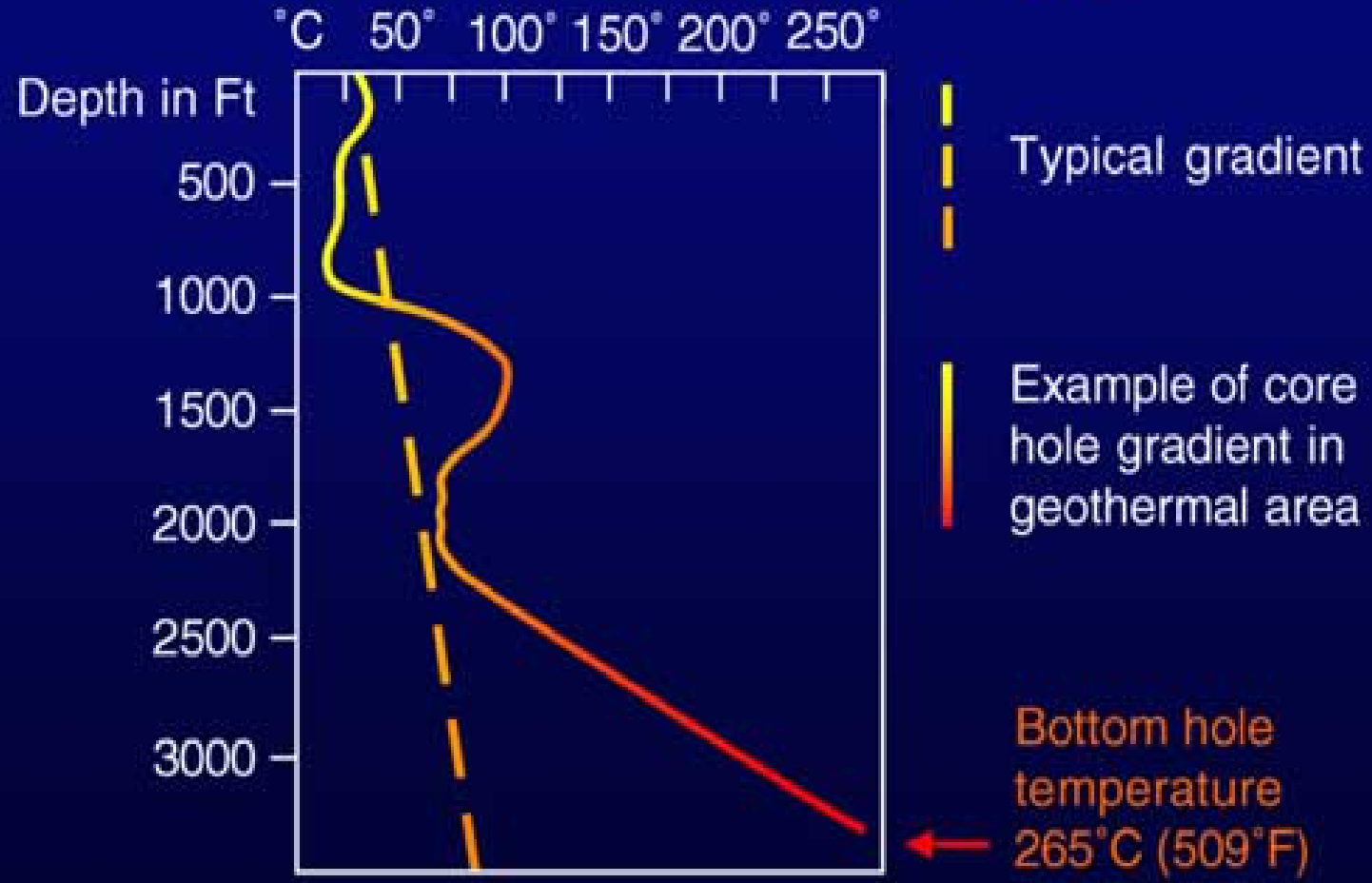


Temperatures in the Earth

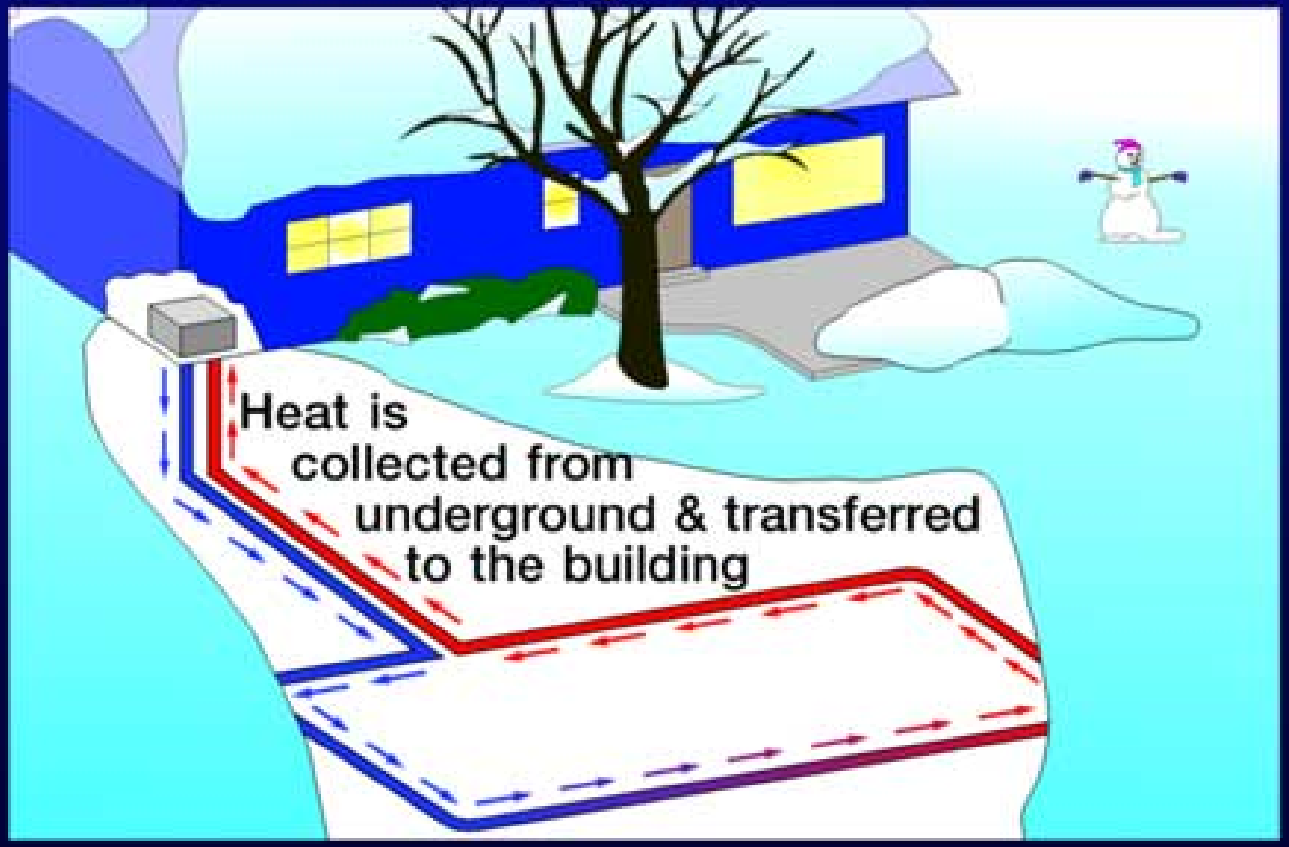


Drilling to assess geothermal resources

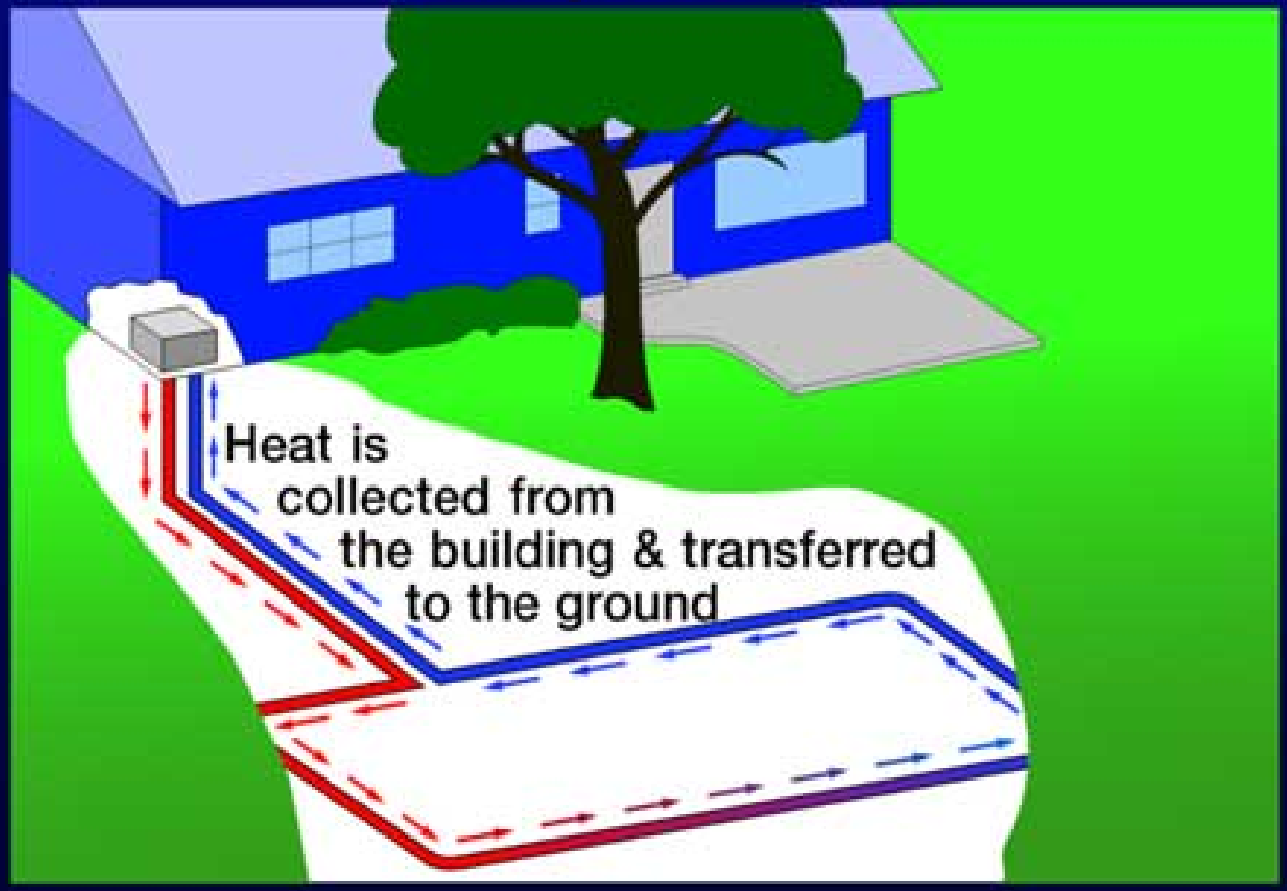
Temperature Gradient Data



Heat Pump in Winter



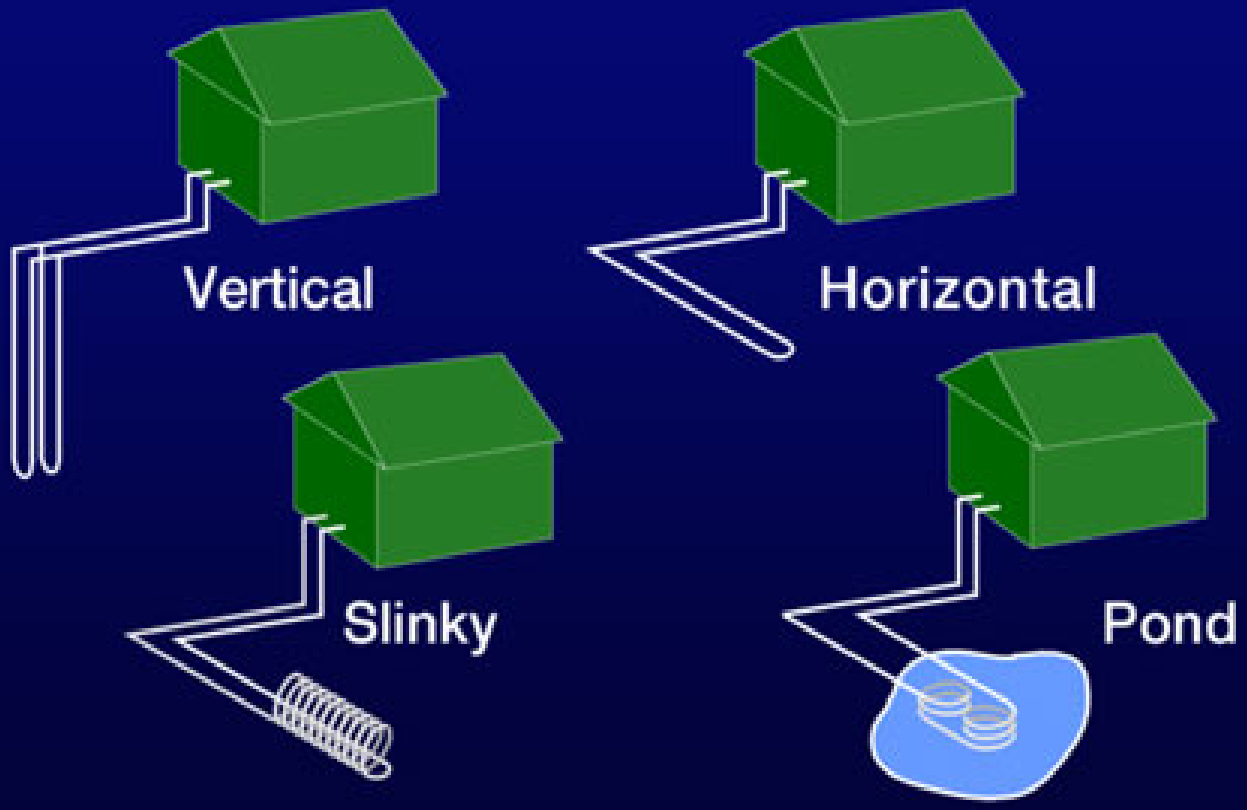
Heat Pump in Summer



Geo means **Earth**

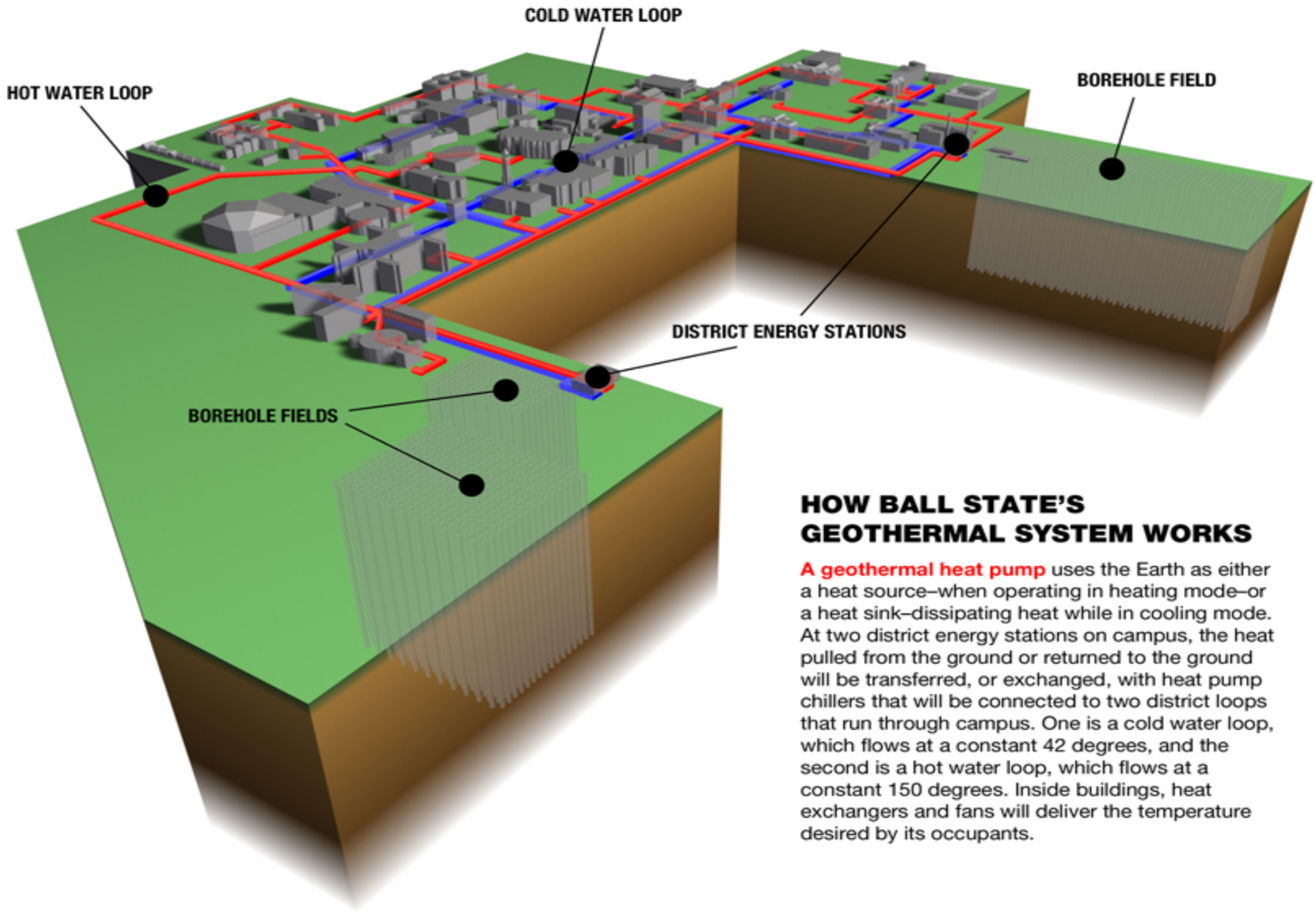
Thermal means **Heat**

Heat Pump Ground Loops



Geothermal used for deicing

3,600 boreholes; 45 buildings on 731 acre campus
Save $2 million annually in heating/cooling costs

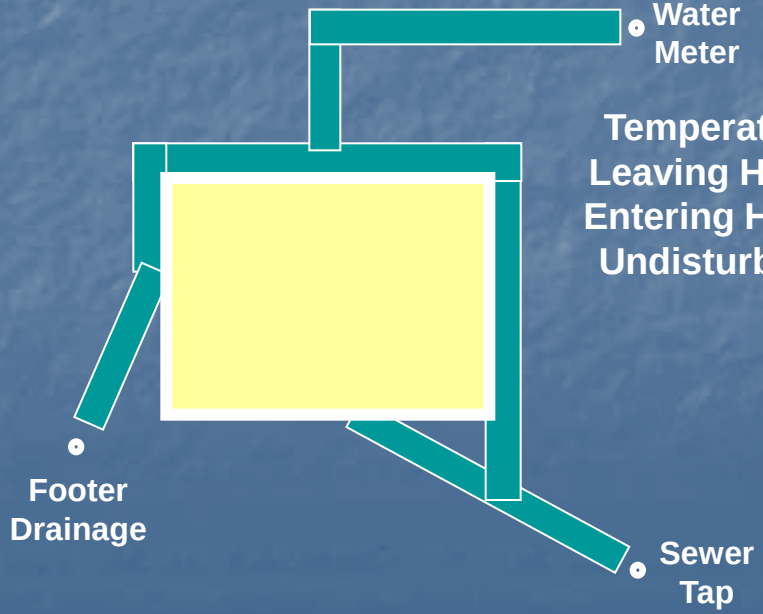


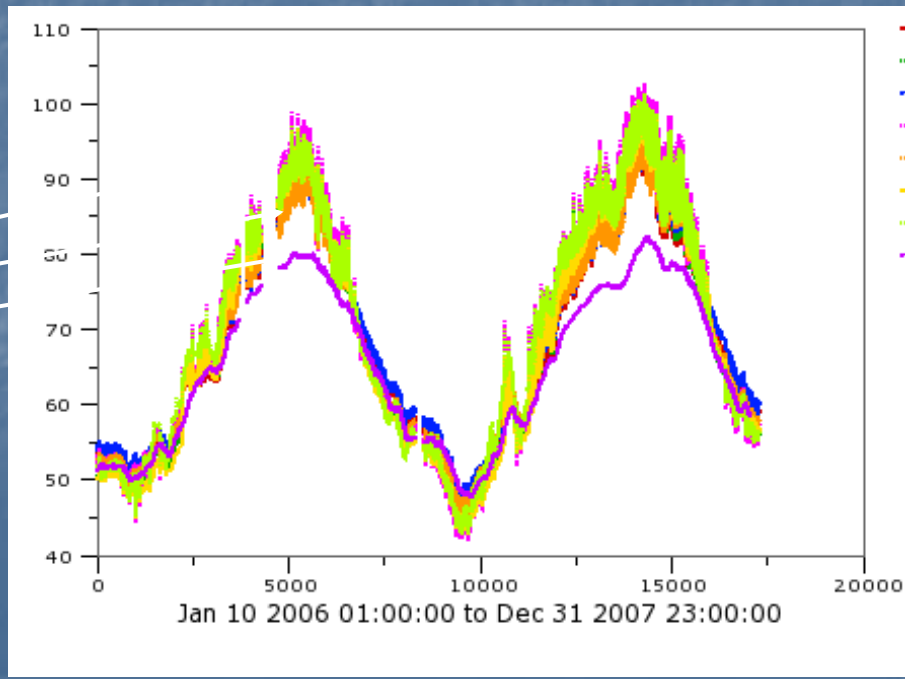
HOW BALL STATE'S GEOTHERMAL SYSTEM WORKS

A geothermal heat pump uses the Earth as either a heat source–when operating in heating mode–or a heat sink–dissipating heat while in cooling mode. At two district energy stations on campus, the heat pulled from the ground or returned to the ground will be transferred, or exchanged, with heat pump chillers that will be connected to two district loops that run through campus. One is a cold water loop, which flows at a constant 42 degrees, and the second is a hot water loop, which flows at a constant 150 degrees. Inside buildings, heat exchangers and fans will deliver the temperature desired by its occupants.

Foundation Heat Exchanger (FHX)

- **Saves energy & reduces peak demand**
  - **Enables use of geothermal (ground-source) heat pump**
- **Reduces cost**
  - **Uses excavations needed anyway to build the house**
  - **No extra digging or drilling**
- **Retrofit? (normal loops not FHX)**



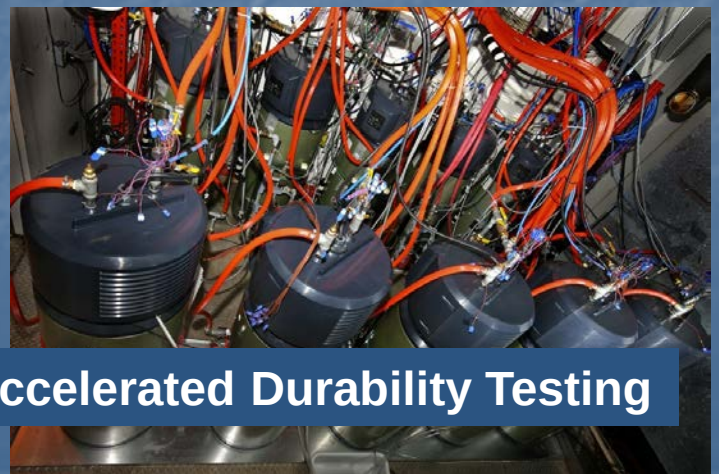


Ground-Source Integrated Heat Pumps are Coming

- A single unit in lieu of separate ones for heating and cooling, water heating, dehumidification
- Same amenities, 50-60% less energy
- Enables shorter loop (in areas where loop is sized on cooling)
- For sale in 2011
- New & retrofit

Major Brand Name Firms are Bringing Heat Pump Water Heaters to Market in 2009

- DOE announced new ENERGY STAR water heater criteria April 2008
  - Compared to electric storage WH
- Same amenities 50% less energy
- Other major brands hinting they may do the same
- GE units are currently under test in lab and in houses
- New & retrofit



Accelerated Durability Testing