In Depth Feasibility Studies
Aquifer Thermal Energy Storage (ATES)
VA Hospitals in Columbus and Chillicothe, OH

30 June 2015

Presented to

by

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Project Team

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Outline

- Why seasonal thermal storage?
- How seasonal storage works
- Methodology for assessing seasonal storage opportunities
- Seasonal storage findings for two sites in Ohio
  - Project History
  - Hydrogeology
  - Engineering
  - ATES Benefits
  - Project Finances
  - Conclusions and Recommendations
- Broader implications for reducing GHG emissions

Why seasonal storage?

- Steep reductions in GHG are not achievable without utilizing waste heat and low temperature renewable energy resources.

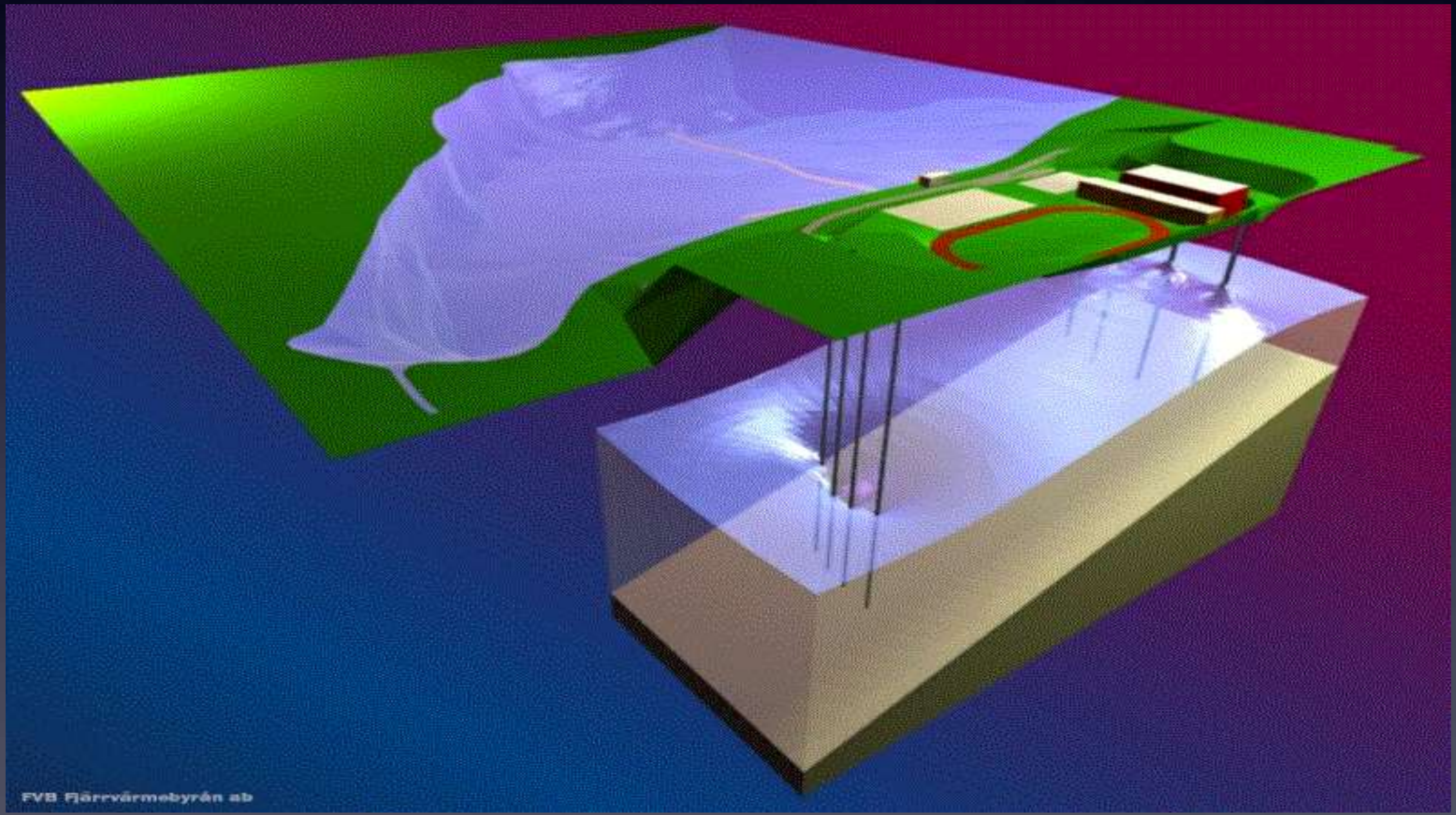
- Availability of zero-carbon heating resources is greater in summer, when heat demand is low:
  - Solar
  - Reject heat from chiller systems.

- Availability of zero-carbon cooling resources is greatest when cooling demand is low:
  - Cold winter air
  - Cold surface water

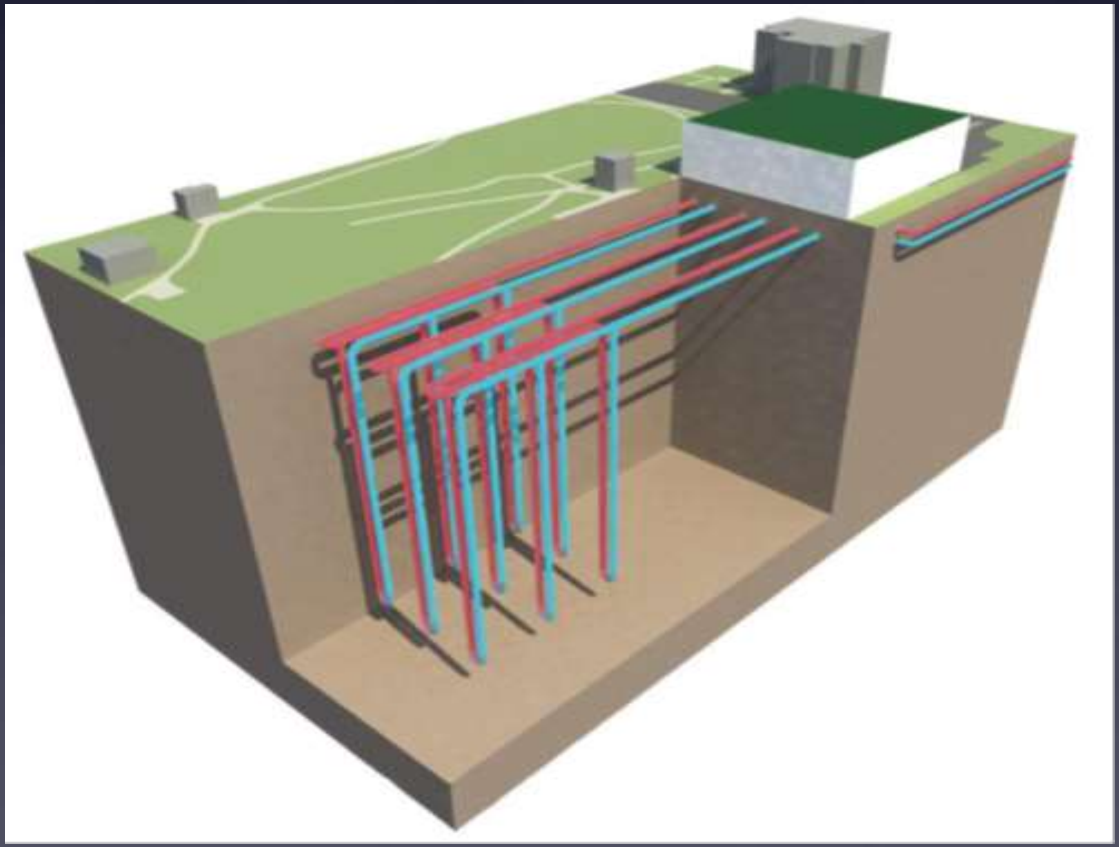
- Other no- or low-carbon heat resources may not correlate well with heating demand:
  - Industrial waste heat is tied to operating hours of the industrial facility, and may be subject to interruptions
  - Power production is generally more valuable during summer, leading to sub-optimized CHP design and operations.

Why seasonal storage?

- Air conditioning using naturally cold water can be optimized with seasonal thermal energy storage
- For example, integration of Deep Water Cooling and Seasonal Aquifer Storage in Sollentuna, Sweden



How seasonal storage?



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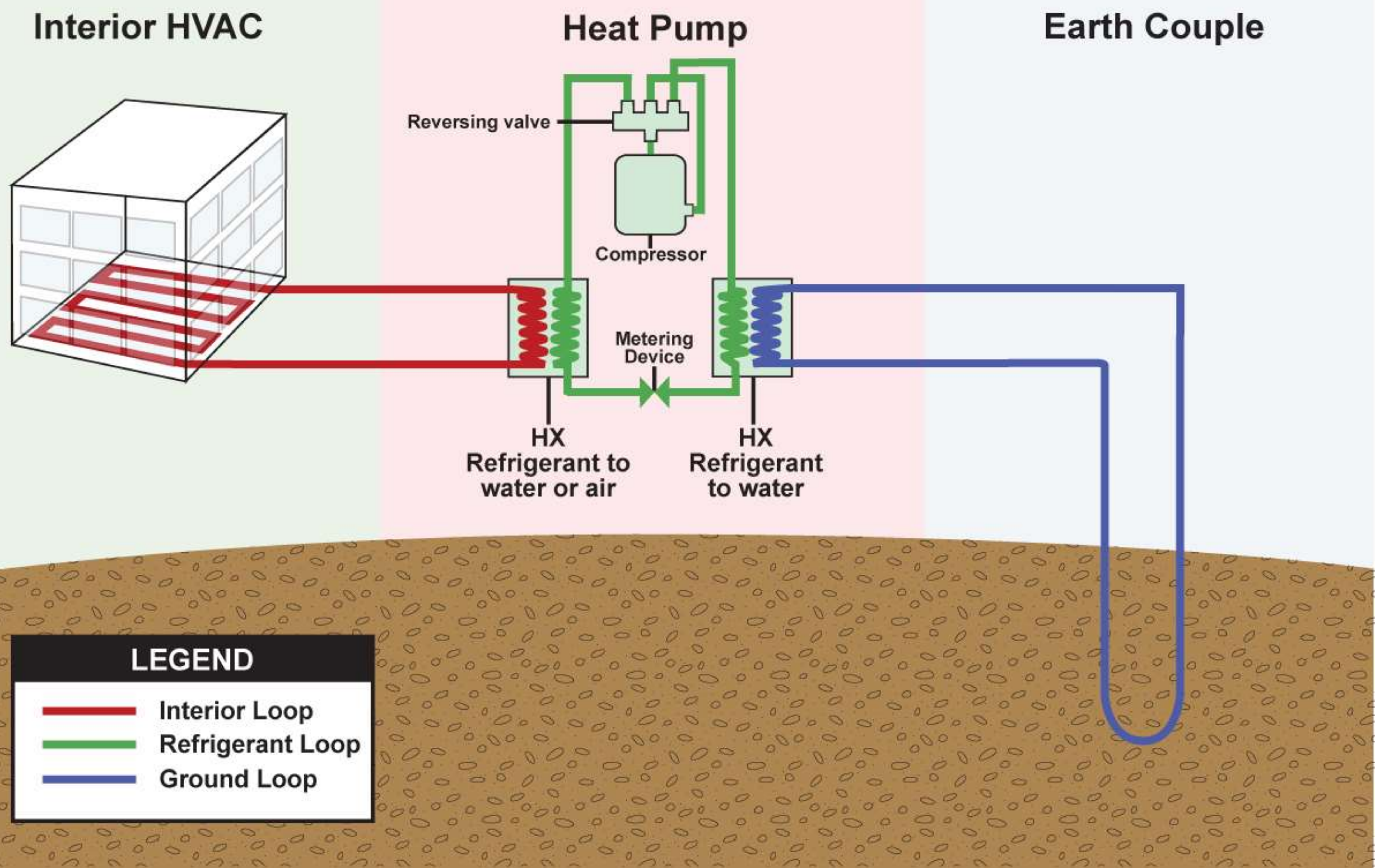
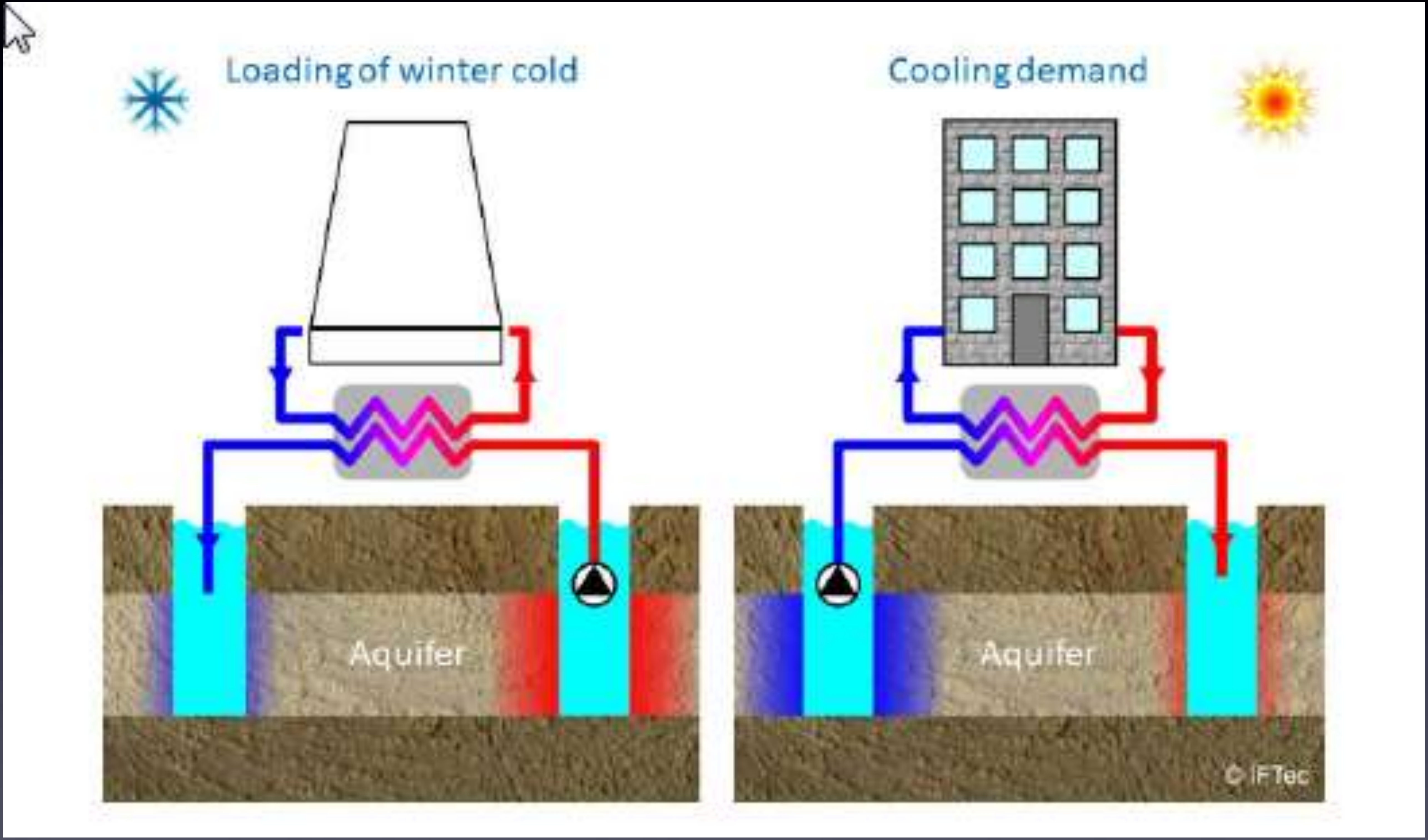
Schematic of an Earth-Coupled Heating and Cooling System



ATES for Cooling



ATES Growth in The Netherlands

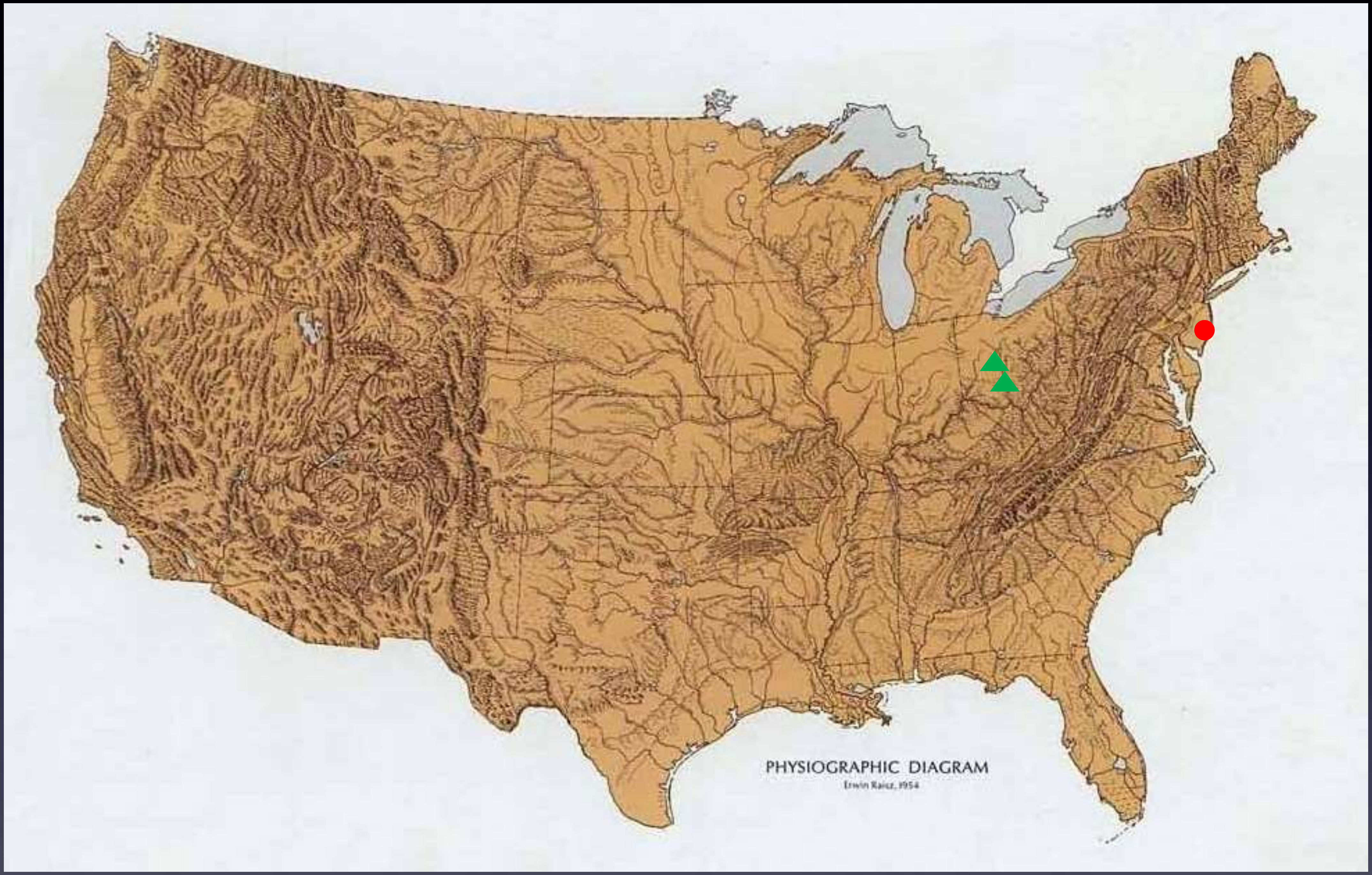
1990

2000

2010

Source: www.iftechnology.nl/

ATES Based District Heating & Cooling Systems in The United States



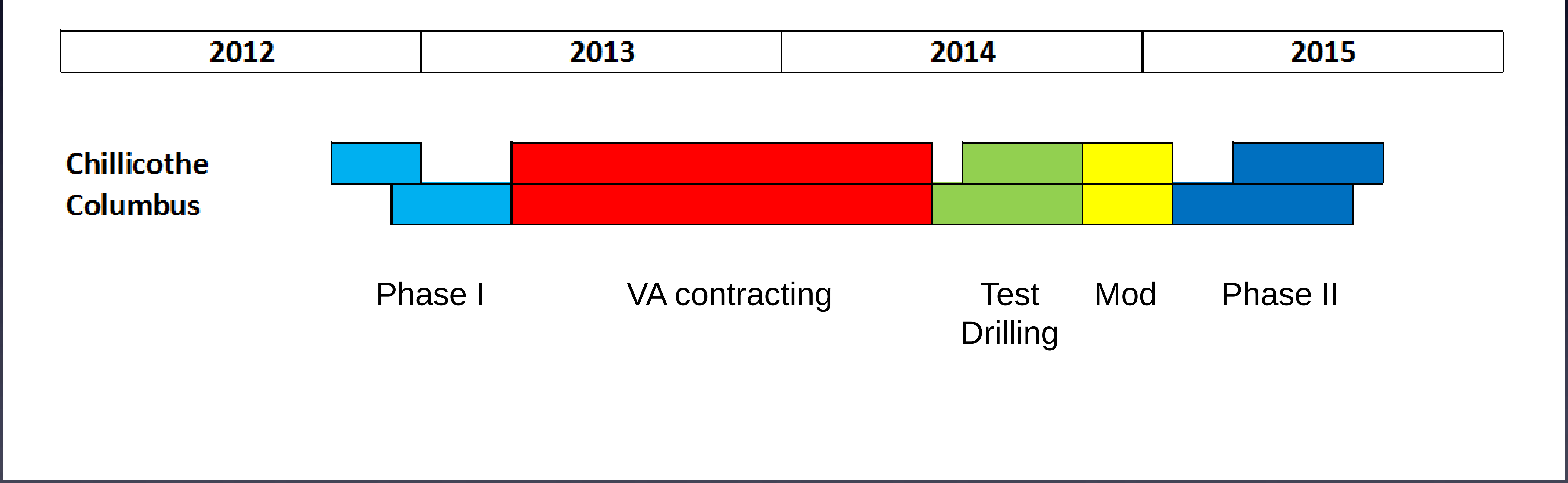
Richard Stockton College, Pamona, NJ (2 MW)

Seasonal Thermal Energy Storage Feasibility Study Components

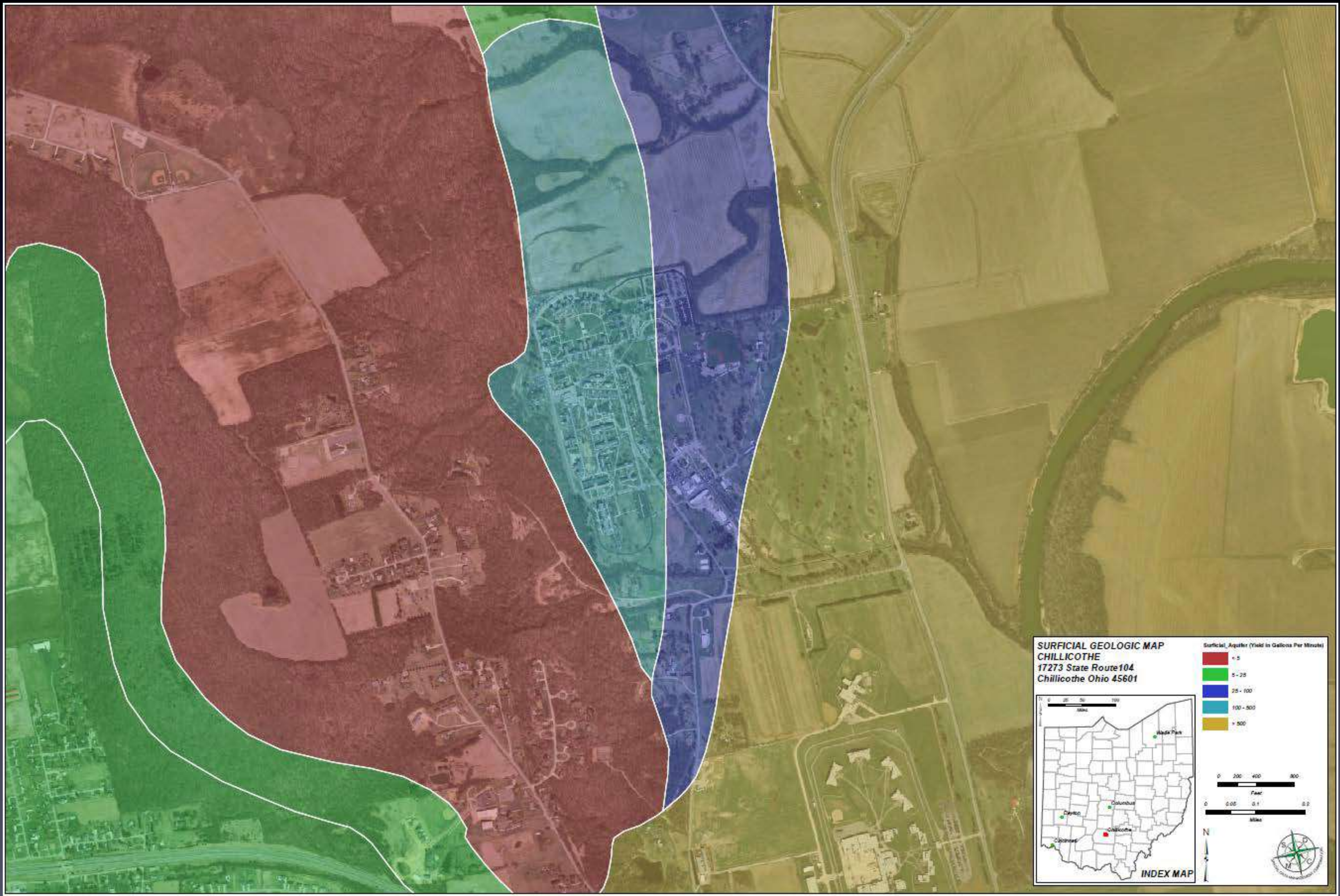
- Hydrogeologic Evaluation
  - Aquifer physical and hydraulic properties
  - Aquifer geochemical properties
- Engineering Evaluation
  - Cooling/Heating configuration evaluated
  - Conceptual design
  - Calculate OPEX and emissions reductions
- Financial Evaluation
  - Estimate CAPEX
  - Life-Cycle Cost Analyses
  - Identify incentives and financing mechanisms
- Regulatory Evaluation
  - Identify permits required

Veterans Administration Case Study
ATES Feasibility Studies

Project Timeline

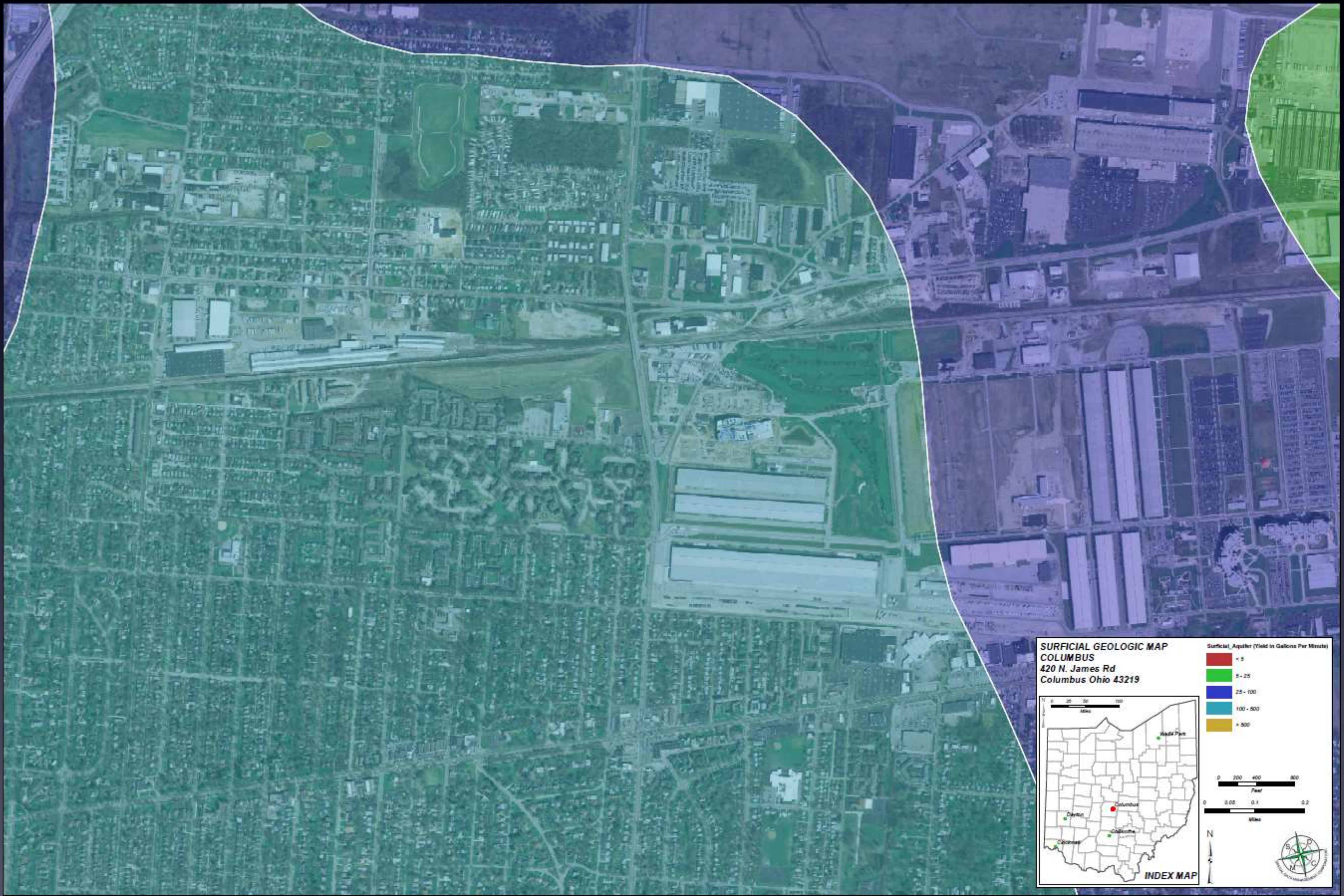


ATES Hydrogeologic Evaluation
Chillicothe, OH



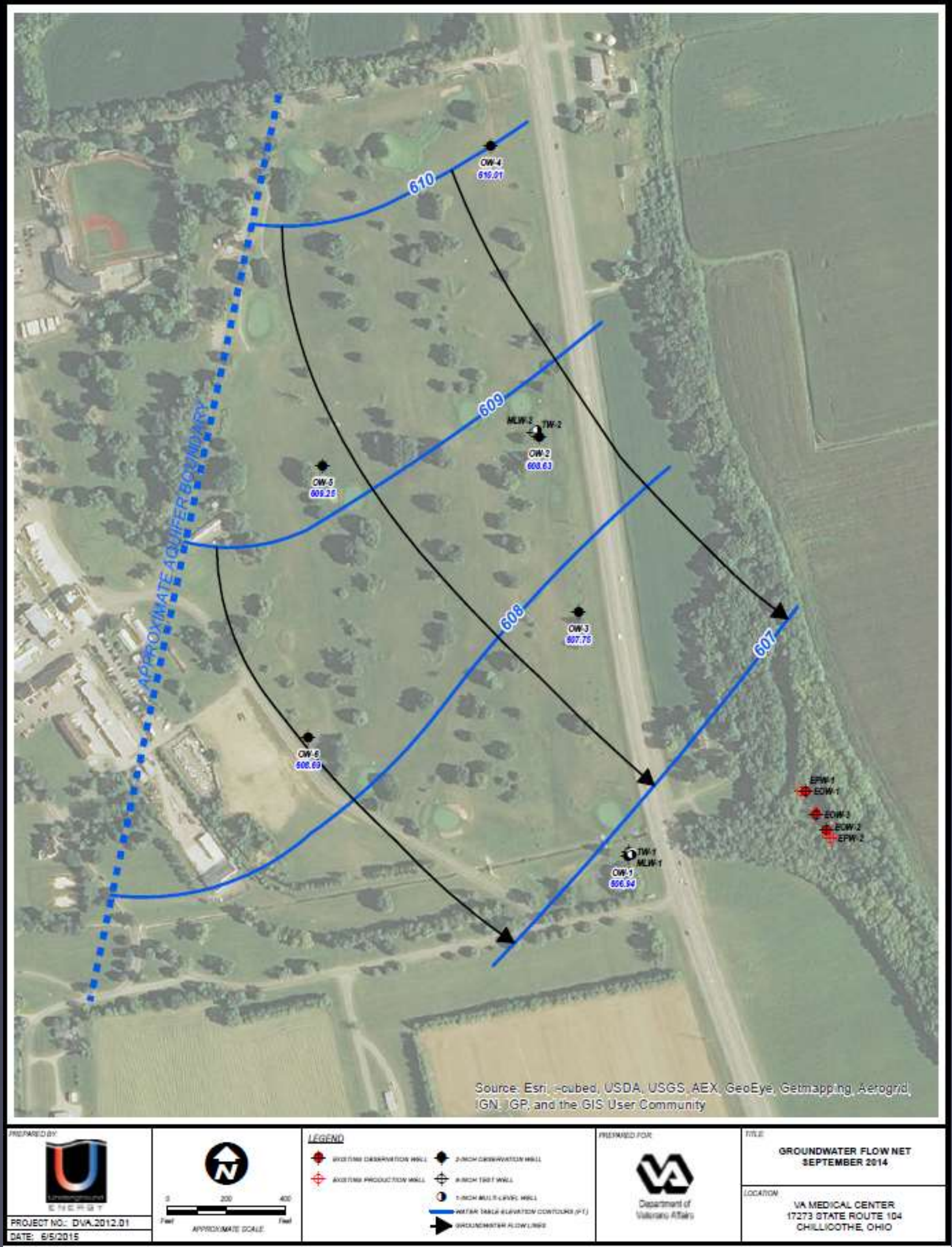
ATES Hydrogeologic Evaluation

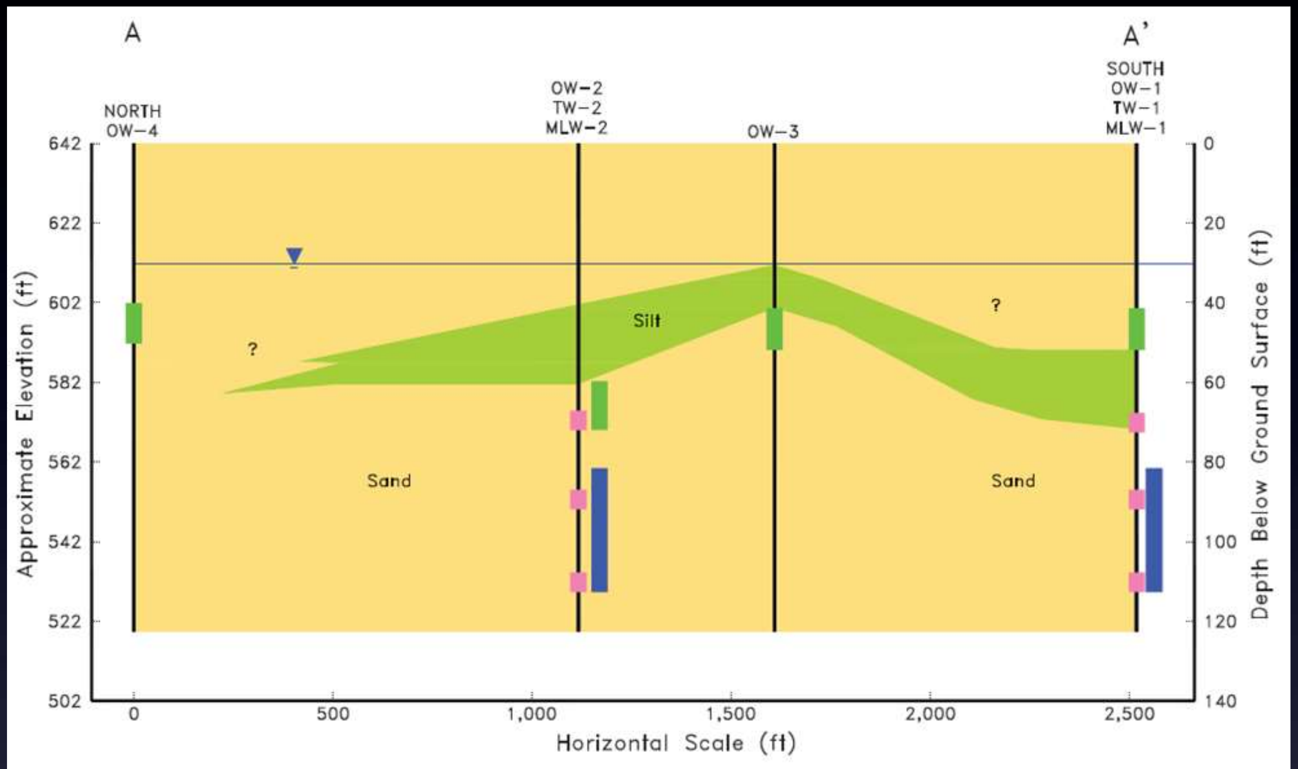
Columbus, OH

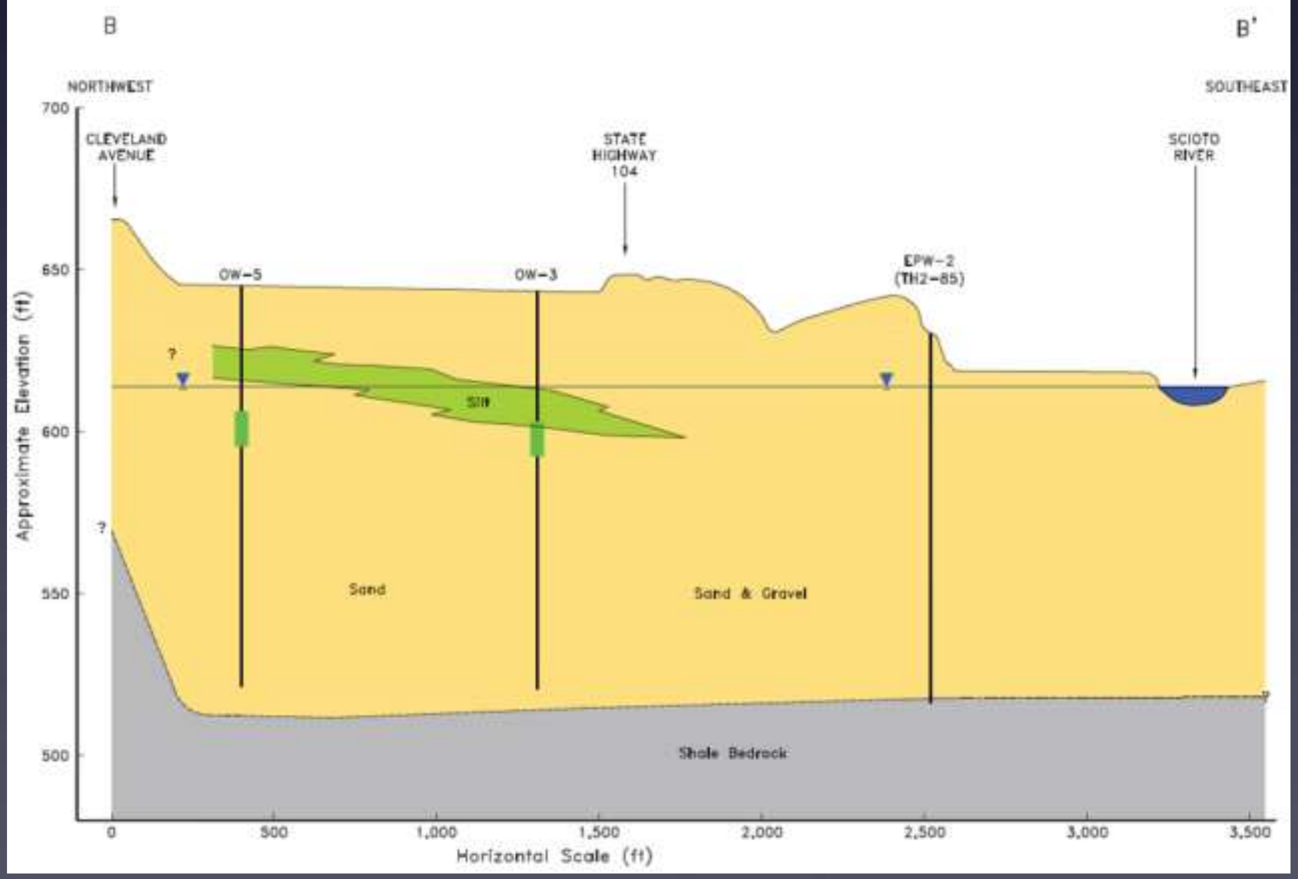


ATES Test Drilling Program

Chillicothe, OH







ATES Test Drilling Program

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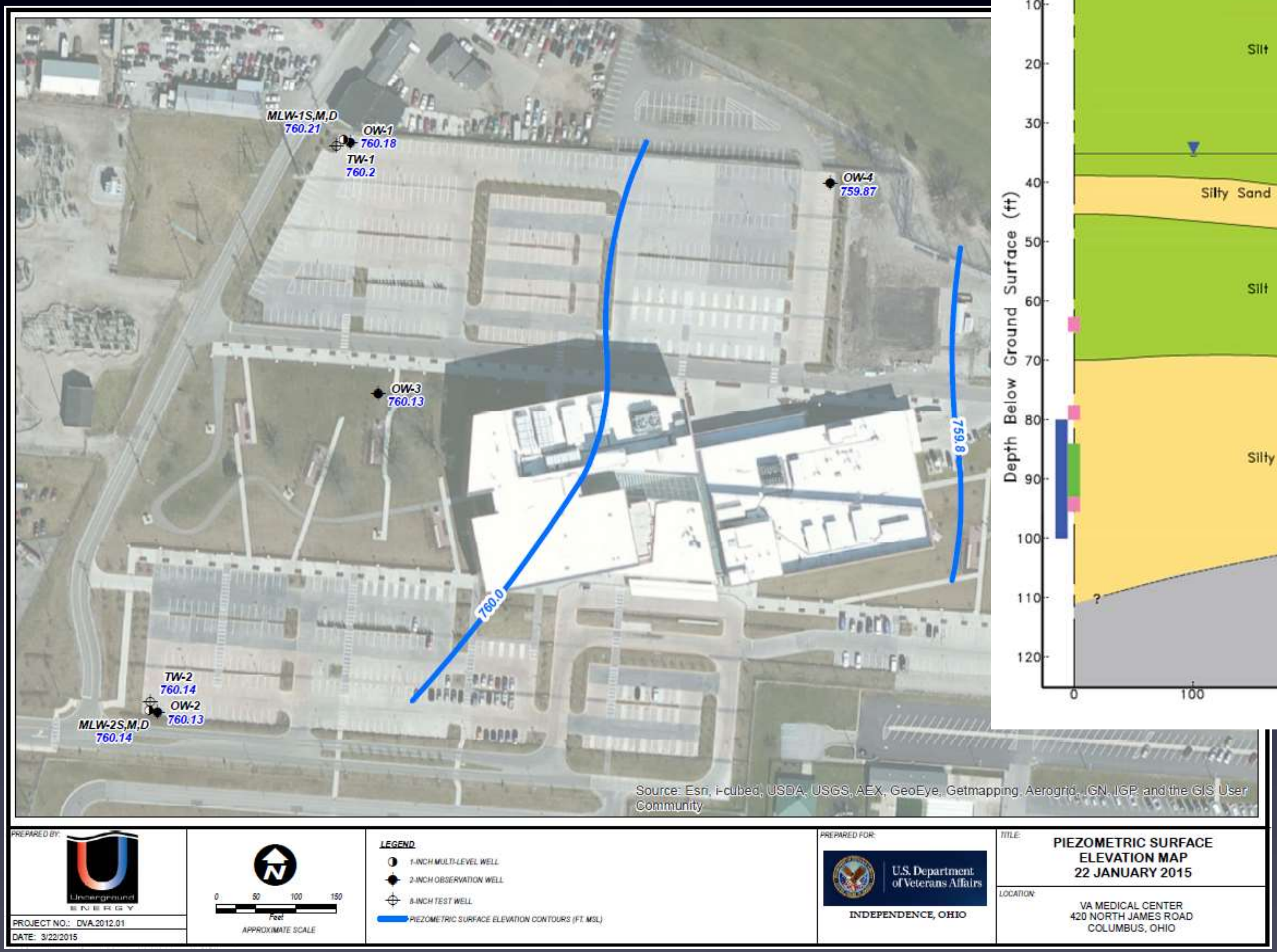
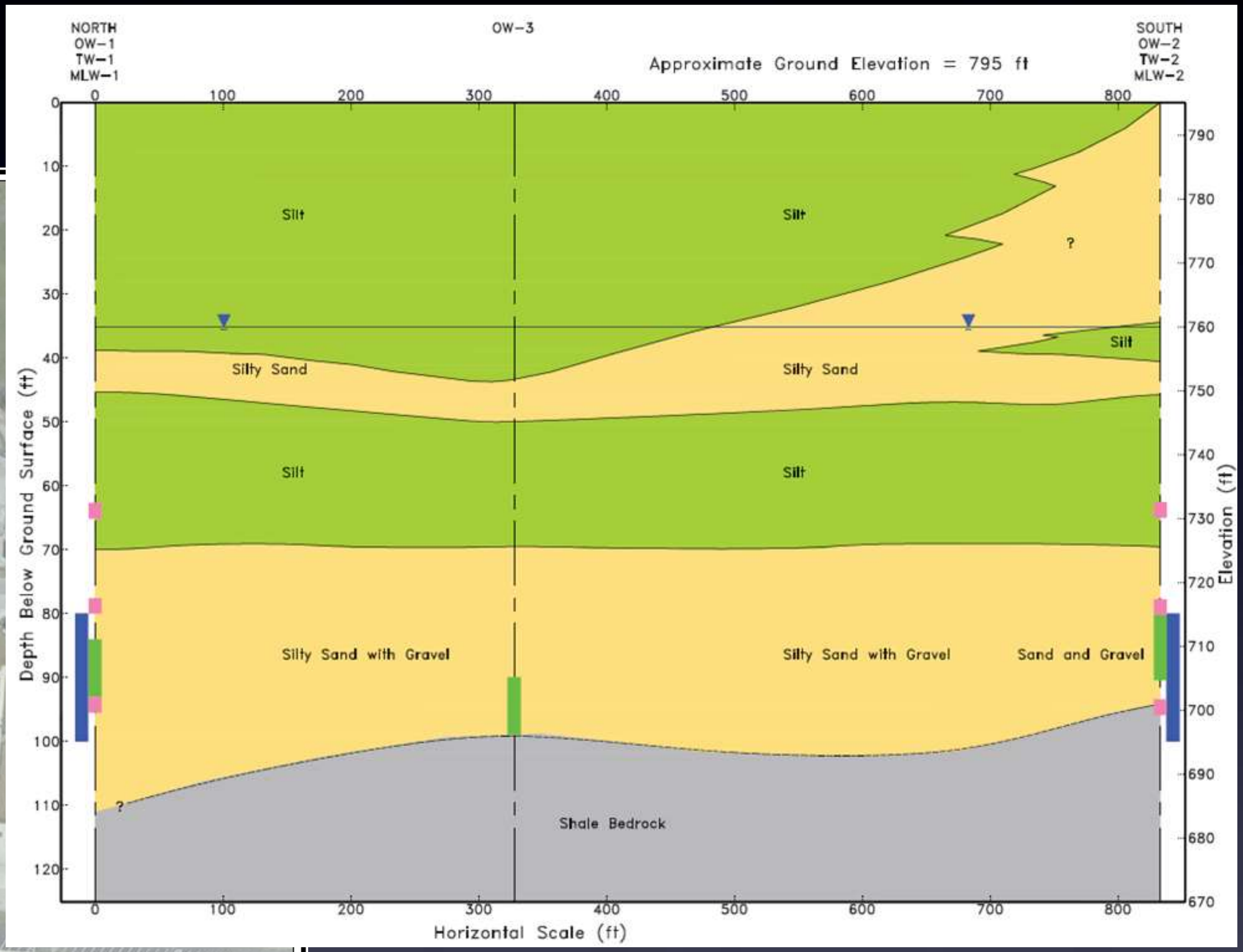




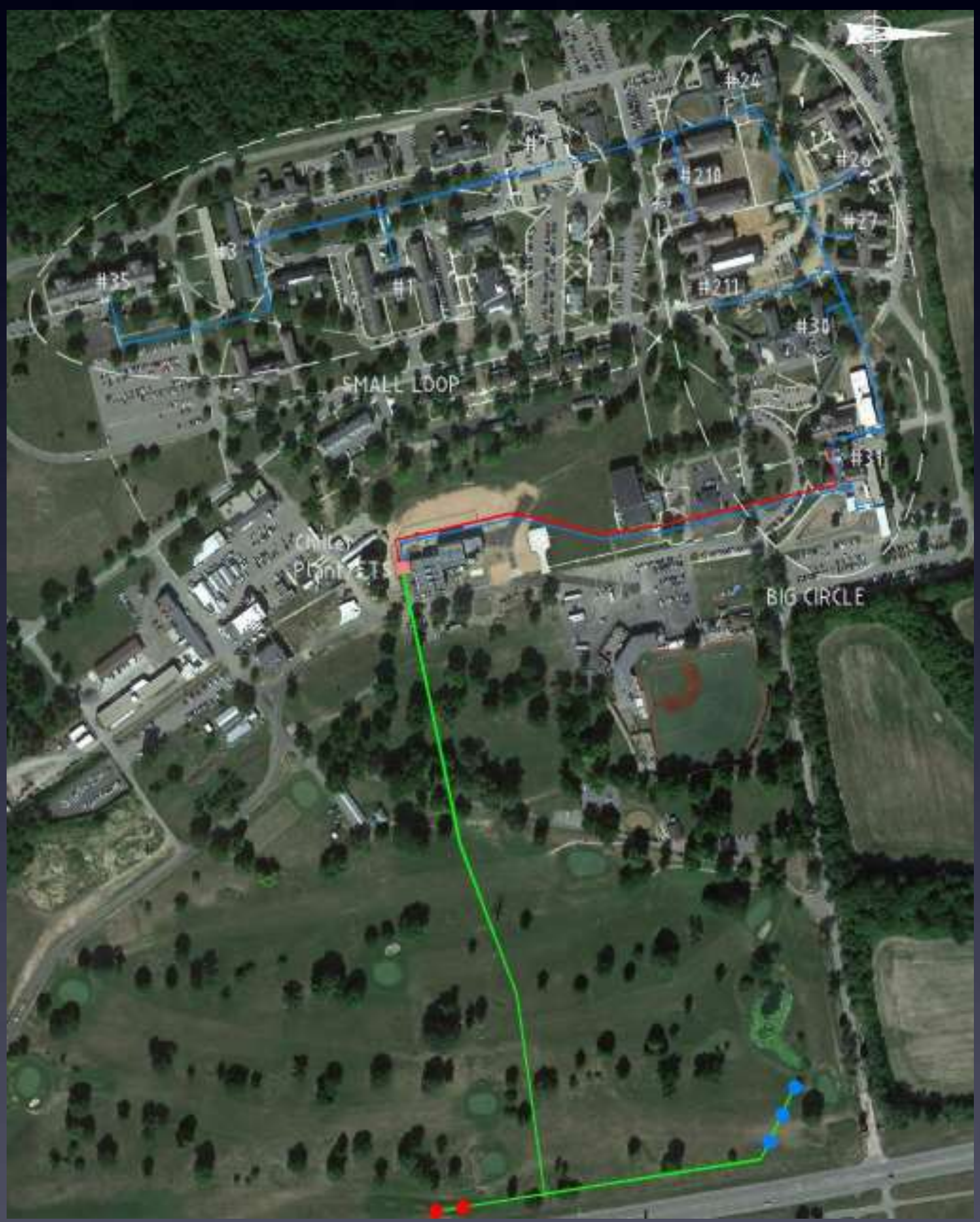
ATES Hydrogeologic Evaluation

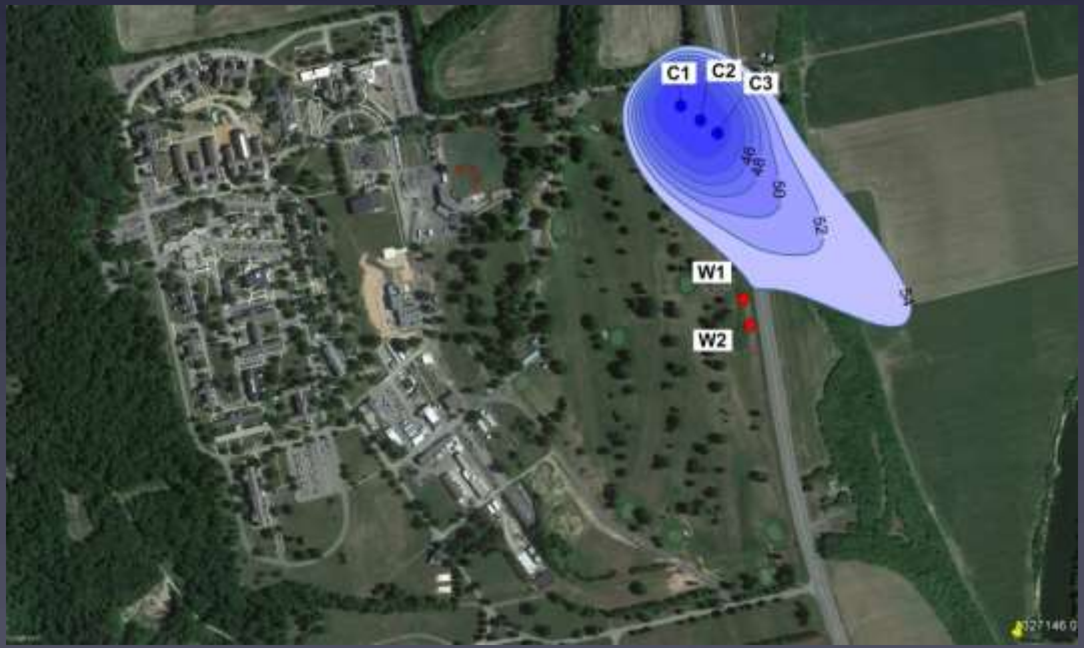
Aquifer Hydraulic Properties

Parameter	Chillicothe	Columbus
Aquifer Saturated Thickness	95 ft (29m)	30 ft (6-21m)
Aquifer depth	120+ ft (37+m) bgs	100 ft (34m) bgs
Aquifer hydraulic conductivity	0.13 - 0.16 cm/s	0.2 – 0.5 cm/s
Aquifer transmissivity	36,000 ft^2/day (3,300 m^2/day)	17,000 – 43,000 ft^2/day (53 – 1,800 m^2/day)
Hydraulic Gradient	1.3 x 10^{-3}	5 x 10^{-4}
Aquifer storativity	0.001	0.001
Aquifer Porosity	0.38	0.38
Ambient Groundwater Temperature (est)	56 °F (12.8° C)	56 °F (12.8° C)
Groundwater depth	32 - 38 ft (~10 m) bgs	32-34 ft (~10m) bgs
Groundwater elevation in aquifer	607 ft MSL	760 ft MSL
Groundwater flow velocity	1.3–1.6 ft /day (0.4-0.5 m/day)	1.1 ft /day (0.3 m/day)

ATES Conceptual Design

Chillicothe, OH





ATES Conceptual Design

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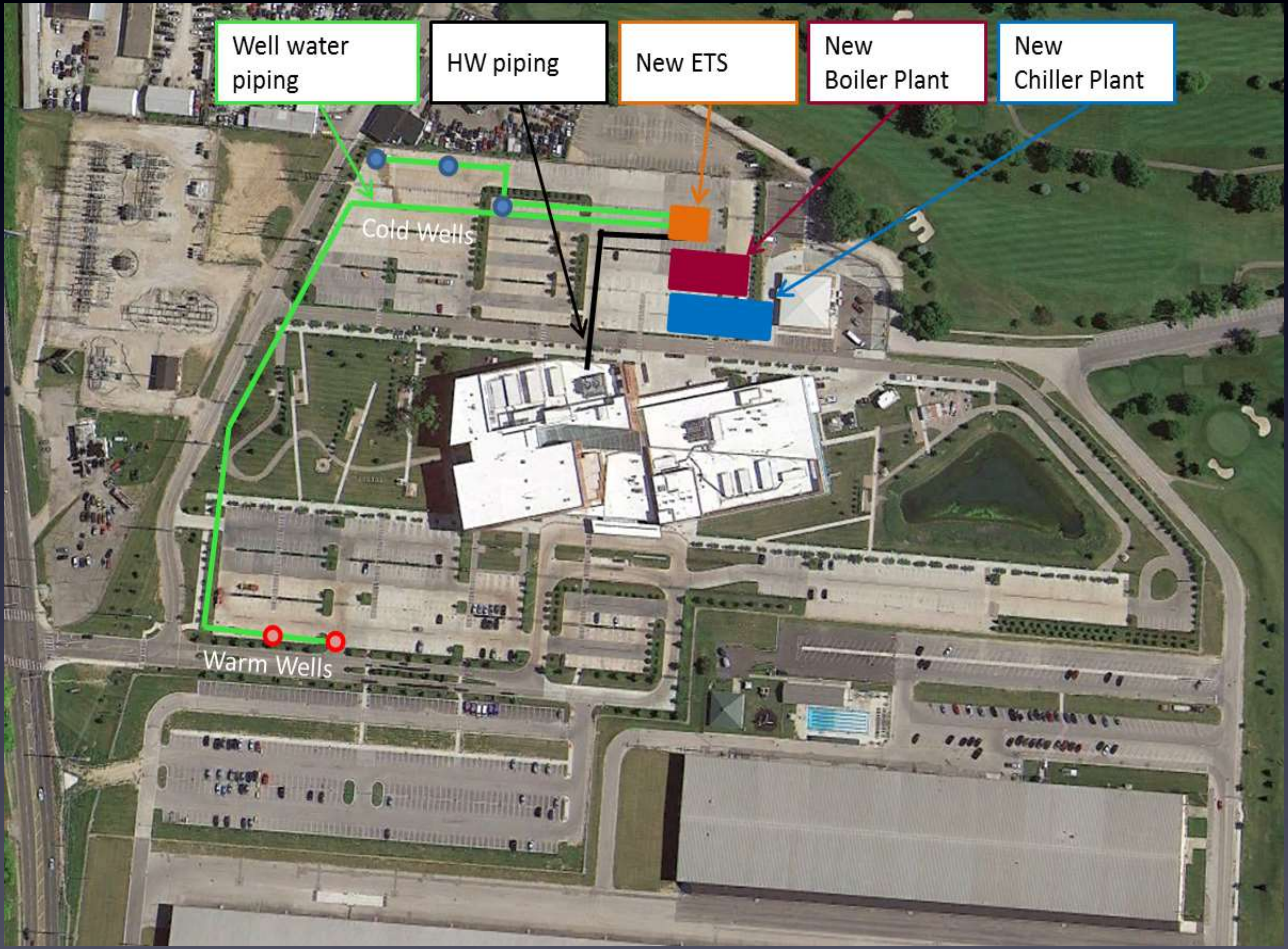


ATES Engineering Evaluation

Status Quo and Implementation Scenarios

VA Chillicothe

Status quo:

- Biomass plant with steam and electricity generation as per current
- New chiller plant with cooling towers for Bldg. 31
- Air cooled chillers at all other buildings as per current

ATES Implementation Scenarios

- Cooling only, Big Circle, winter charging with dry cooler
- As above, but adding Small Loop
- Cooling Big Circle and Heating Bldg. 31, gas engine heat pump (plus supplemental winter charging with dry cooler)

VA Columbus (focus of remainder of presentation)

Status quo:

- #1 New Chiller Plant and Heating Plant
- #2 New Chiller Plant and CHP Plant

ATES Implementation Scenarios

- Cooling only, winter charging with dry cooler
- Cooling & Heating, gas engine heat pump

ATES Engineering Evaluation

CHP Integration

VA Chillicothe has biomass CHP

VA Columbus has completed CHP design

- Existing design wastes most low-grade heat from CHP.
- ATES system would supply low heat while CHP would reject about the same amount!

ATES Engineering Evaluation

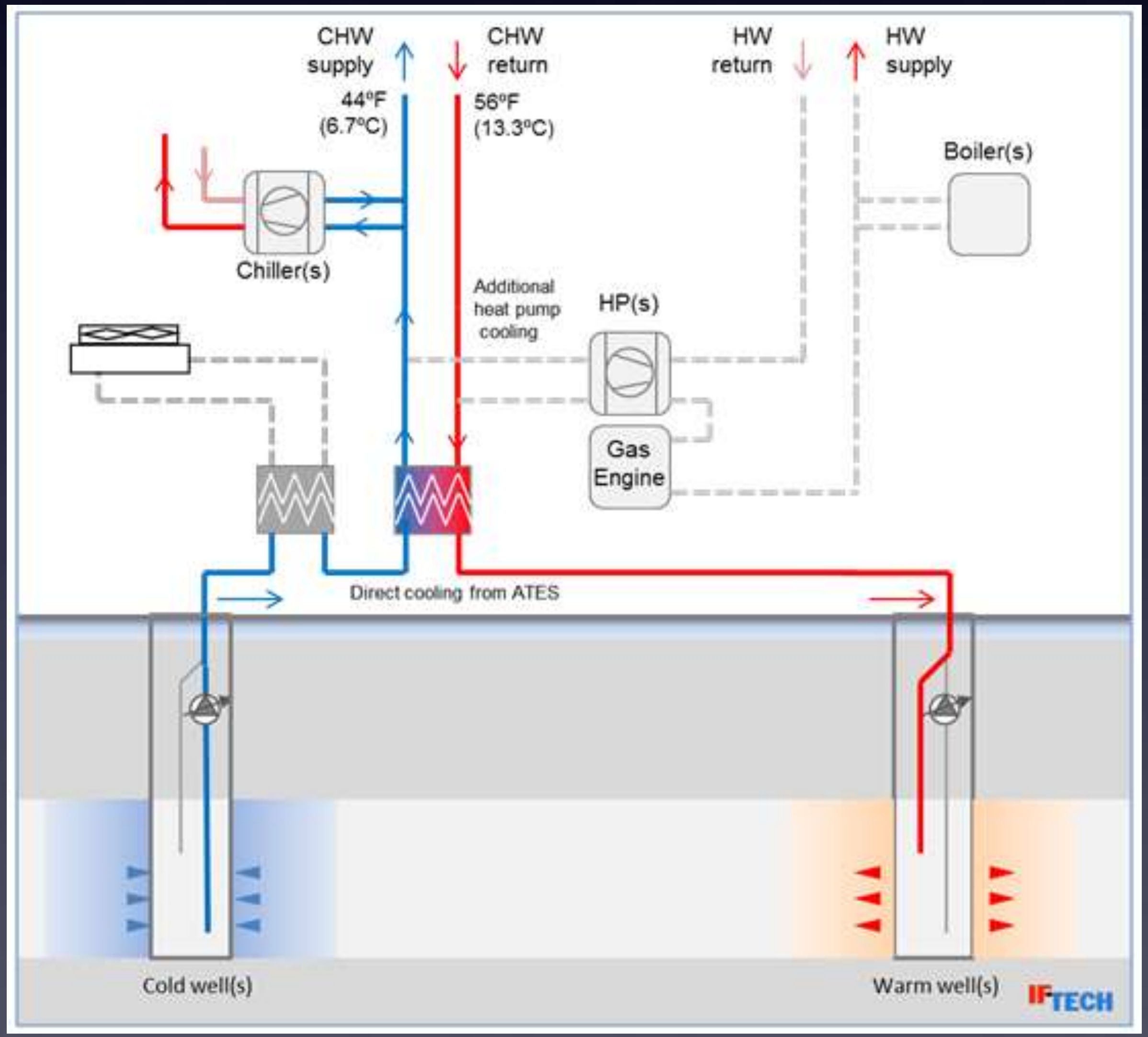
Groundwater System Design Assumptions
VAMC Columbus, OH

Cooling and Heating Options	Value
Well Depth	110 feet
Max yield (per well)	440 gpm
Number of Warm Wells	2
Number of Cold Wells	3
Maximum Yield Well Water System	880 gpm
Cold well groundwater charging temperature	41°F
Cold well groundwater abstraction temperature	41 °F ⇨ 48 °F

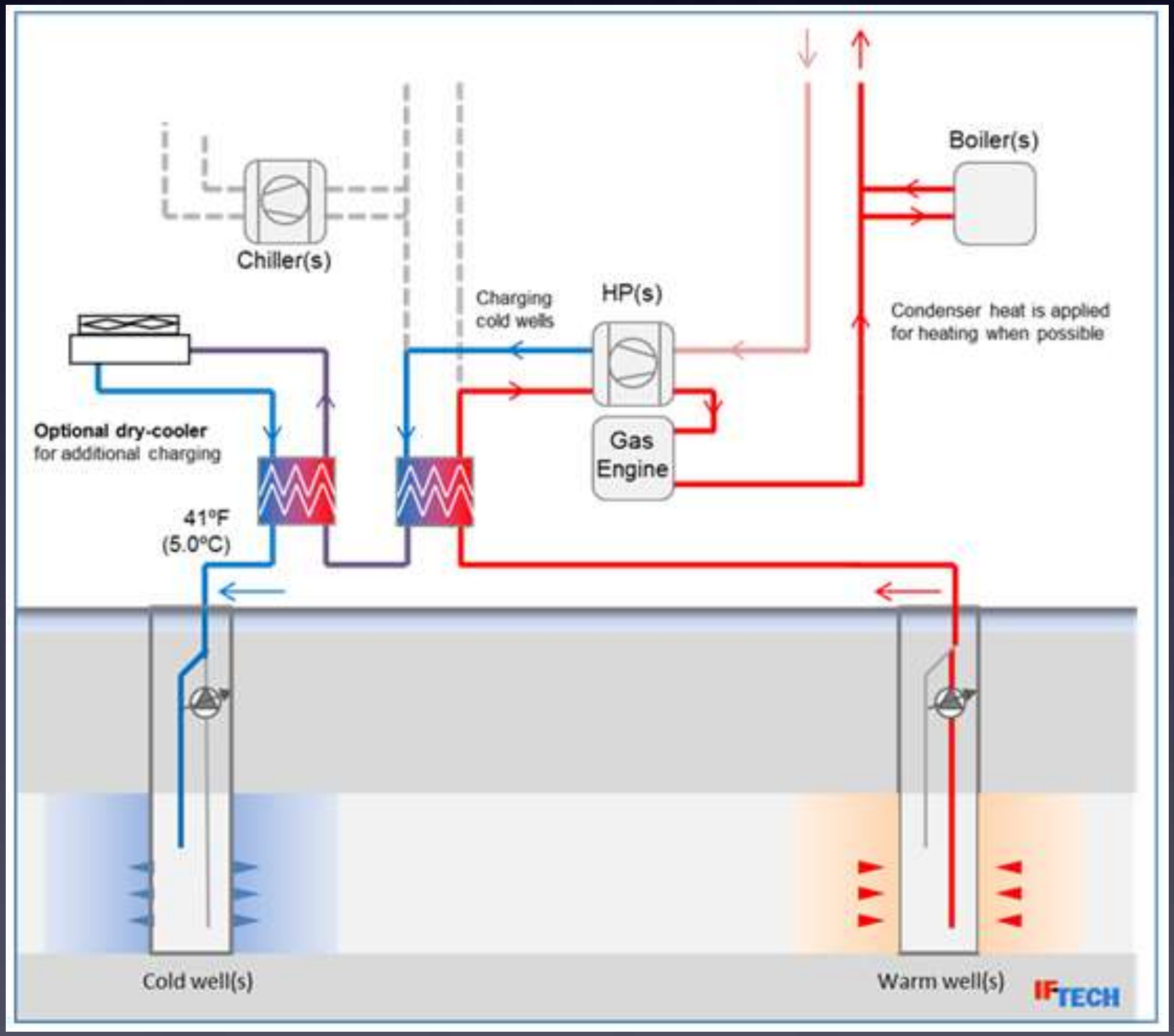
ATES Heating & Cooling Conceptual Design

Columbus, OH

Summer



Winter

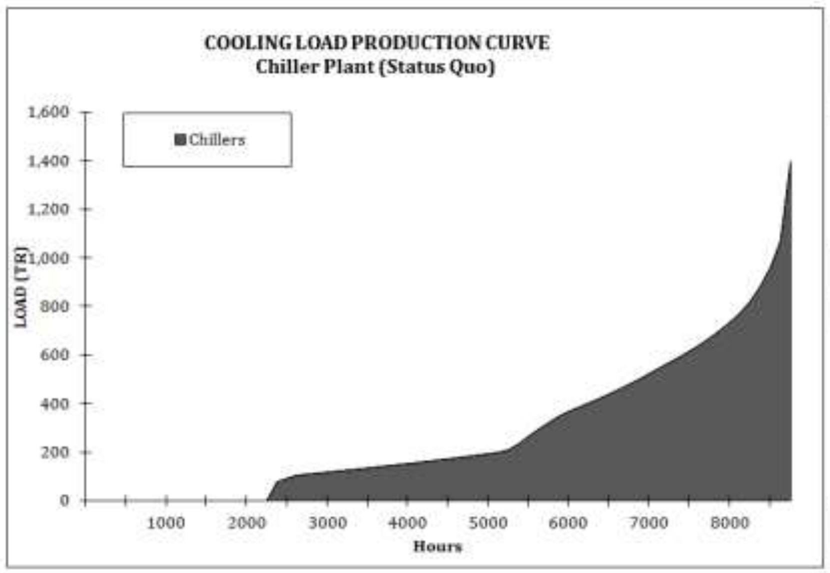


ATES Engineering Evaluation

Cooling and Heating Load Duration Curves (Columbus, OH)

Status quo vs. ATES Heating/Cooling With CHP

Cooling LDC



COOLING DEMAND

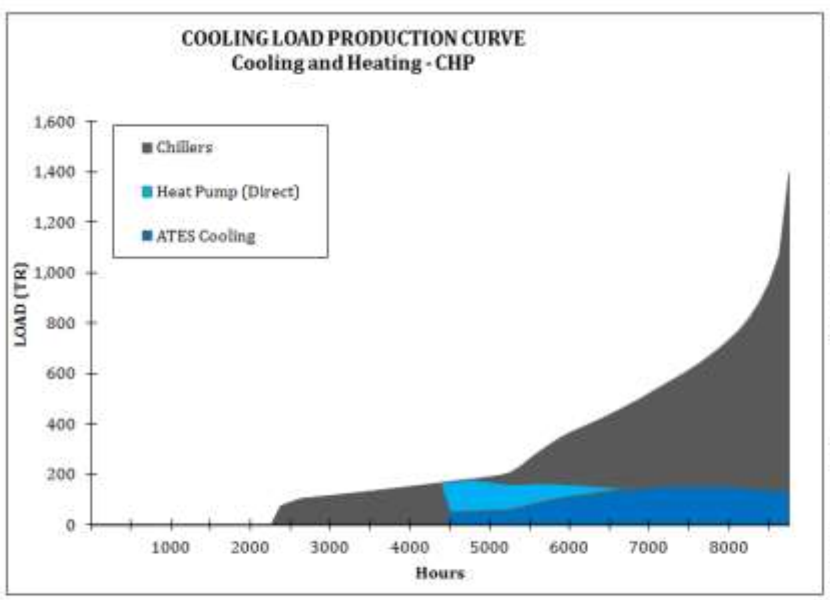
Chillers	2,500 kTR-hrs	100%
Sum	**2,500 kTR-hrs**	**100%**

HEAT DISPERSAL FROM COOLING PRODUCTION

Cooling Towers	34,546 MMBtu	100%
Sum	**34,546 MMBtu**	**100%**

ELECTRICITY DEMAND

Chillers & Towers	1,692 MWh	100%
Sum (From Grid)	**1,692 MWh**	**100%**



COOLING DEMAND

ATES Cooling	523 kTR-hrs	21%
Heat Pump (Direct)	170 kTR-hrs	7%
Chillers	1,806 kTR-hrs	72%
Sum	**2,500 kTR-hrs**	**100%**

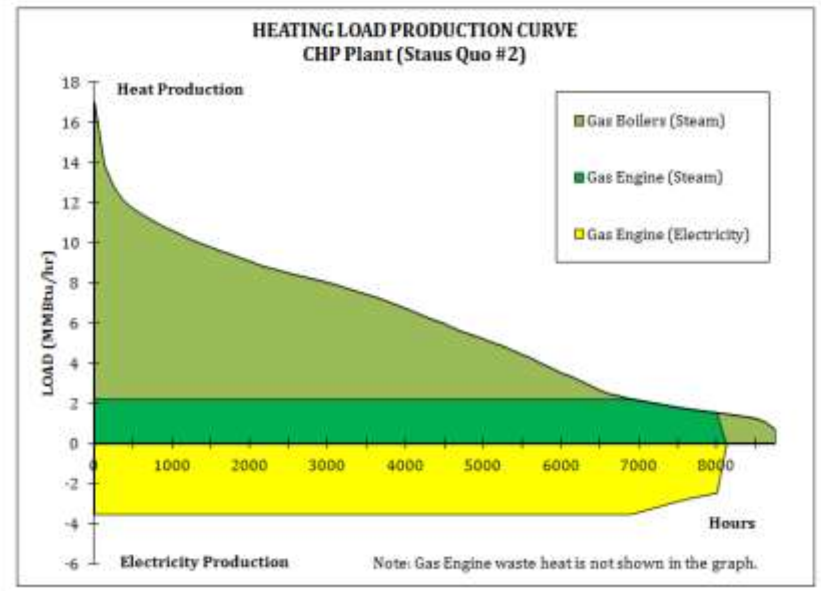
HEAT DISPERSAL FROM COOLING PRODUCTION

ATES Cooling	6,282 MMBtu	18%
Heat Pump (Direct)	2,876 MMBtu	8%
Cooling Towers	24,959 MMBtu	73%
Sum	**34,117 MMBtu**	**100%**

ELECTRICITY DEMAND

ATES Cooling (Summer)	90 MWh	7%
Heat Pump (Direct)	6 MWh	0%
Chillers & Towers	1,222 MWh	93%
Sum (From Grid)	**1,319 MWh**	**100%**

Heating LDC



HEAT DEMAND

Gas Engine (Steam)	17,731 MMBtu	32%
Gas Boilers (Steam)	37,269 MMBtu	68%
Sum	**55,000 MMBtu**	**100%**

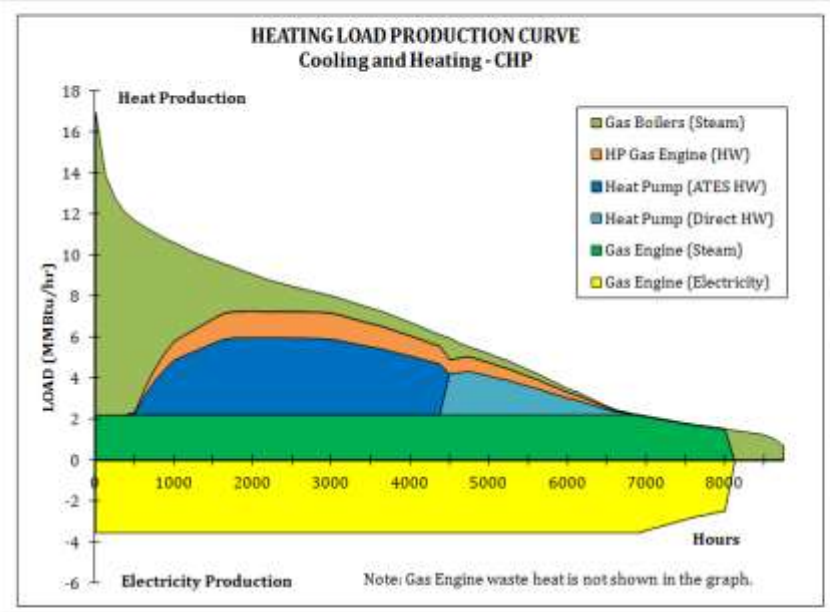
Gas Engine (Waste Heat)	14,911 MMBtu	27%

FUEL DEMAND

		Eff.	
Gas Engine	78,477	58%	63%
Gas Boilers	46,586	80%	37%
Sum	**125,063 MMBtu**		**100%**

ELECTRICITY DEMAND

Facility	14,000 MWh	100%
Gas Engine (Electricity)	-8,143 MWh	-58%
Sum (From Grid)	**5,857 MWh**	**42%**



HEAT DEMAND

Heat Pump (Direct HW)	2,876 MMBtu	5%
Heat Pump (ATES HW)	12,449 MMBtu	23%
HP Gas Engine (HW)	5,197 MMBtu	9%
Gas Engine (Steam)	17,731 MMBtu	32%
Gas Boilers (Steam)	16,747 MMBtu	30%
Sum	**55,000 MMBtu**	**100%**

Gas Engine (Waste Heat)	14,911 MMBtu	27%

HEAT FROM WELLS

ATES Well Discharge	8,847 MMBtu	100%

FUEL DEMAND

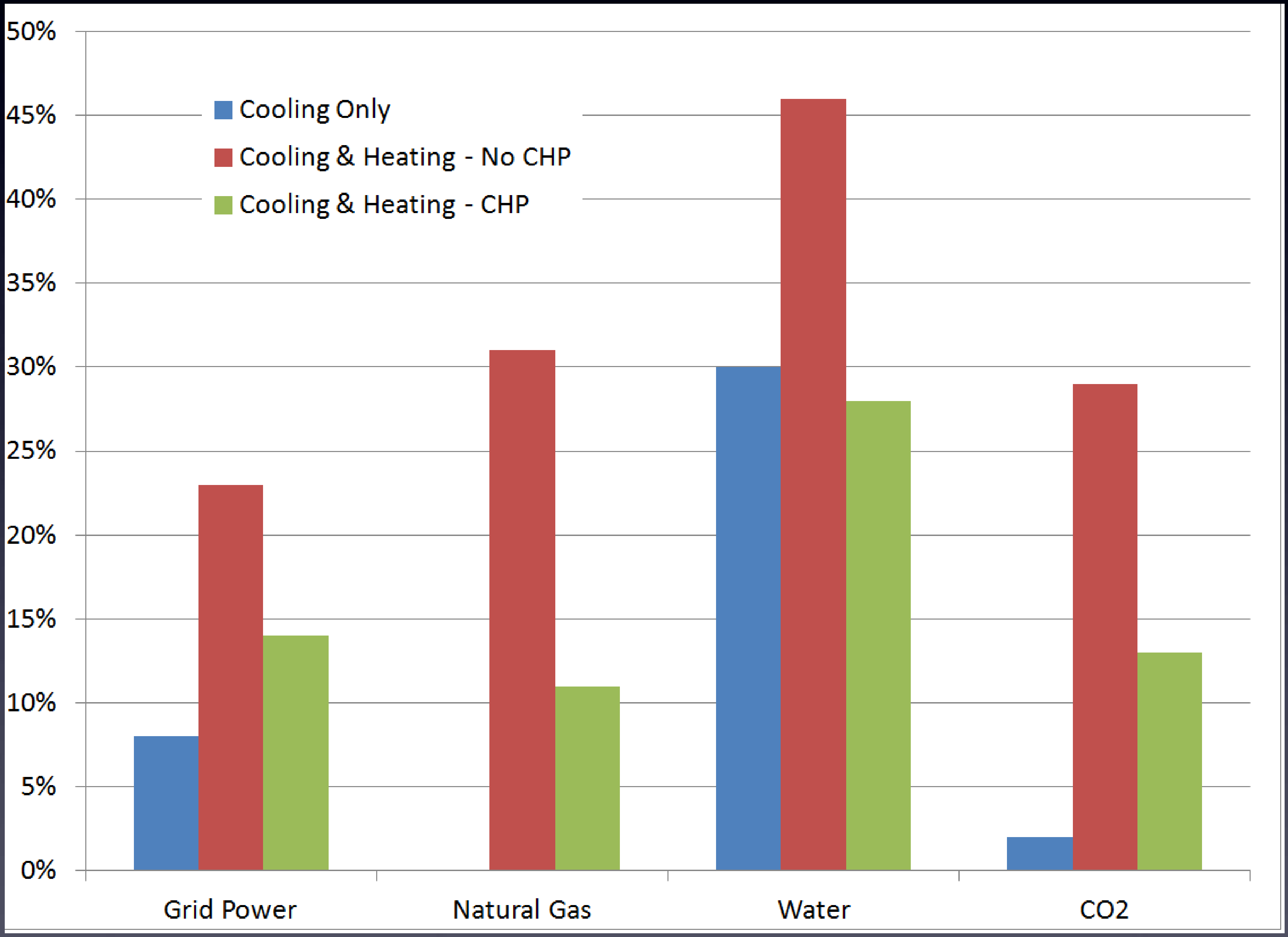
		Eff.	
HP Gas Engine	12,507	77%	11%
Gas Engine	78,477	58%	70%
Gas Boilers	20,934	80%	19%
Sum	**111,918 MMBtu**		**100%**

ELECTRICITY DEMAND

Heat Pump (Direct HW)	6 MWh	0%
Heat Pump (ATES HW)	127 MWh	1%
Facility	14,000 MWh	99%
Gas Engine (Electricity)	-8,143 MWh	-58%
Sum (From Grid)	**5,990 MWh**	**42%**

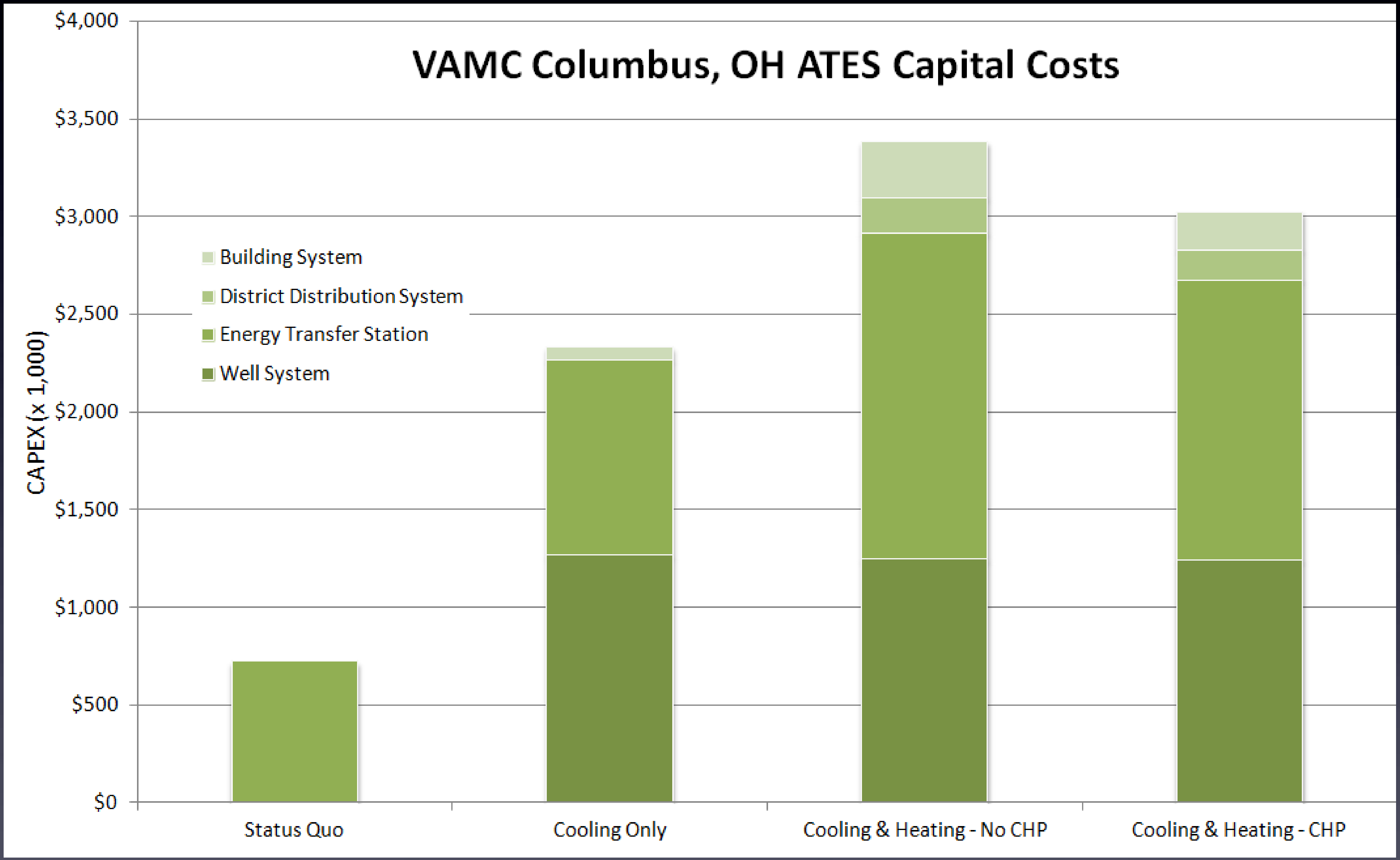
ATES Engineering Evaluation

Average Annual Plant Savings



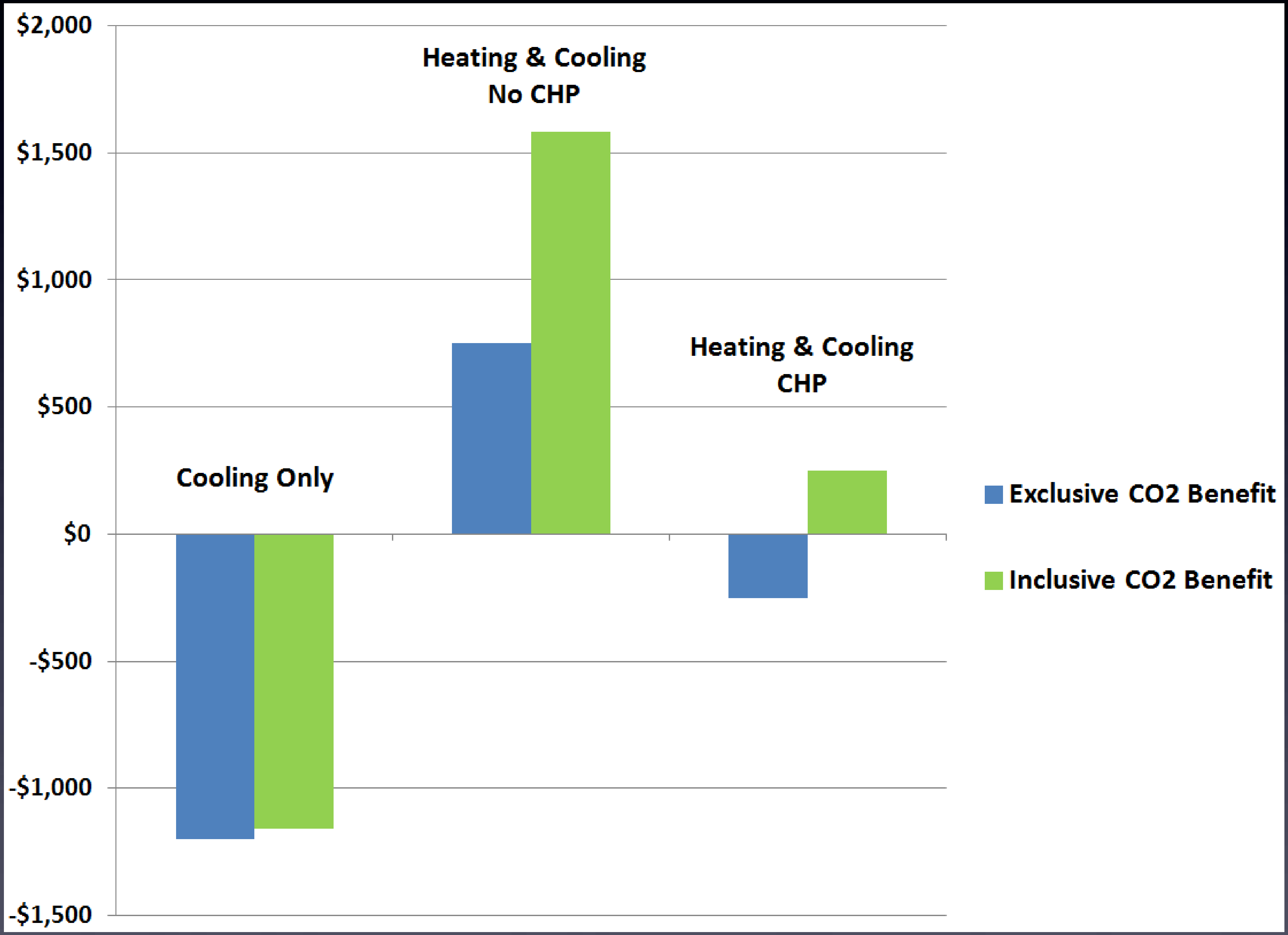
ATES Financial Evaluation

Columbus CAPEX Summary



ATES Financial Evaluation

Present Value of Financial Benefit (25 yrs)
VAMC Columbus, OH



ATES Regulatory Evaluation

- Underground Injection Control (UIC) program administered by the Ohio EPA. ATES wells are Class V wells requiring permits for construction and operation per OAC Rule 3745-34-12 and OAC Rule 3745-34-16.

- Any open-loop system with the capacity to withdraw 0.1 MGD or greater must register with the ODNR-DSWR's Water Withdrawal Facilities Registration Program as required by Section 1521.16 of the Ohio Revised Code.

- No significant problems or barriers to ATES project development have been identified by the regulatory evaluation.

ATES FS Conclusions

- ATES is technically feasible at both VA hospital facilities in Ohio from the perspectives of climate, hydrogeology, geochemistry, regulatory and facilities integration.

- The financial result was most favorable for ATES heating & cooling without CHP.

- Gas-engine heat pumps in ATES system man be a competitive alternative to CHP.

- The electricity cost inflation rate used in our Life-Cycle Cost Analysis (<1%) is far below the rate calculated from actual 2012-2015 cost data (6%). The financial picture improves significantly when realistic escalation rates are used.

- The financial feasibility of ATES at other US locations will be improved where site-specific conditions differ from the VA Hospitals in Ohio:
  - Low energy prices in Ohio reduce OPEX savings;
  - We are comparing ATES OPEX savings to new, efficient CHP and chiller plants under the status quo scenarios; and
  - The Chillicothe ATES system cost is burdened by the long pipe runs required to connect the well fields to the new ETS, and from there to a new CHW district cooling system.

- ATES will be most cost effective in new construction where building systems retrofit costs are not incurred.

- Other than localized thermal impacts in the aquifer and temporary construction impacts, the ATES projects will have minimal adverse environmental impact.

Recommendations

- Evaluate ATES for cooling and/or heating modes where:
  - Large heating and cooling loads, and
  - Seasonably variable climate, and
  - An aquifer exists!
  - Consider BTES if no aquifer exists

Thank You!

Knowing is not enough; we must apply.
Willing is not enough; we must do.