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

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by

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Project Team

DEPARTMENT OF VETERANS AFFAIRS
UNITED STATES OF AMERICA

IF TECH

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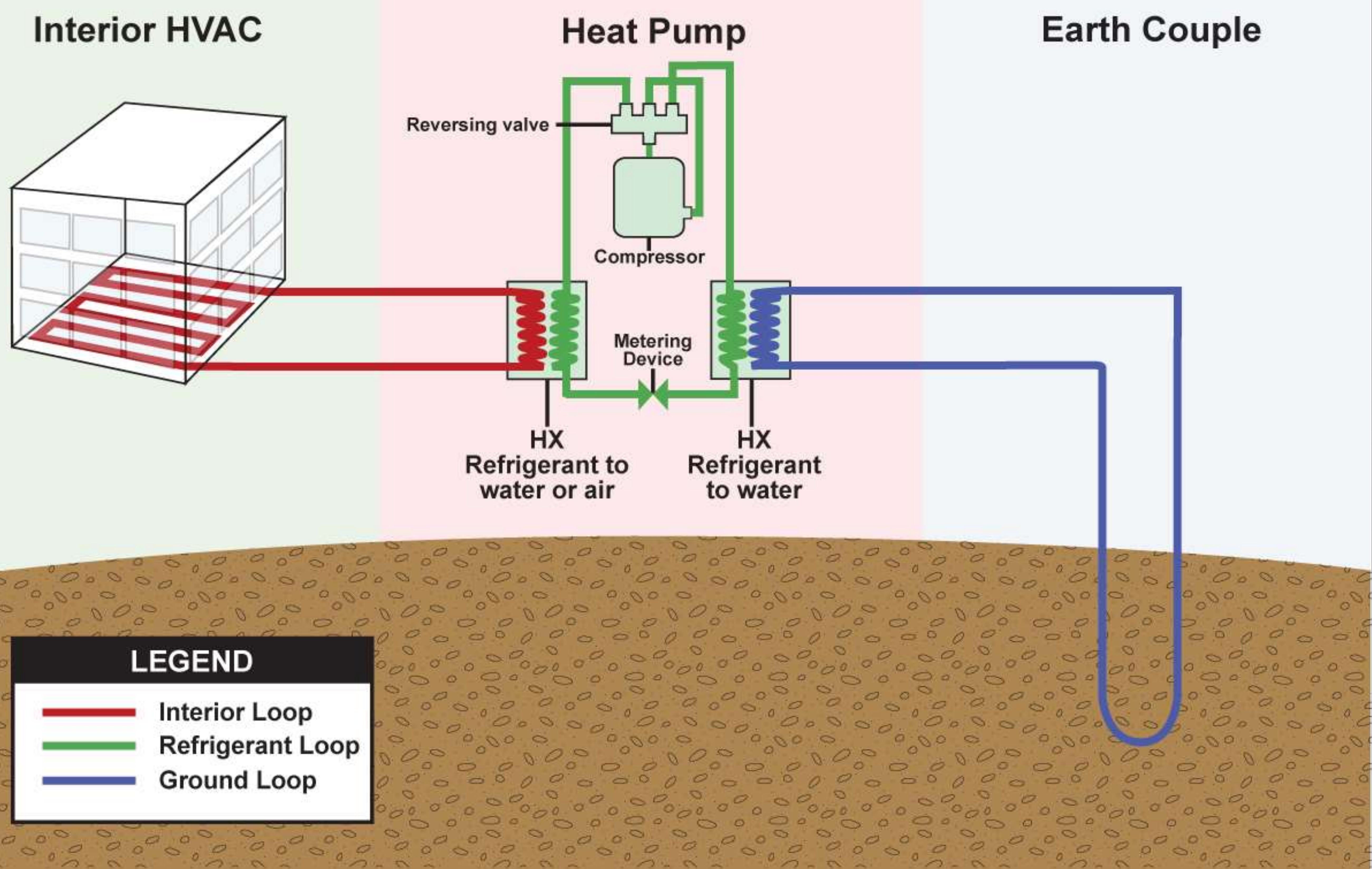
Outline

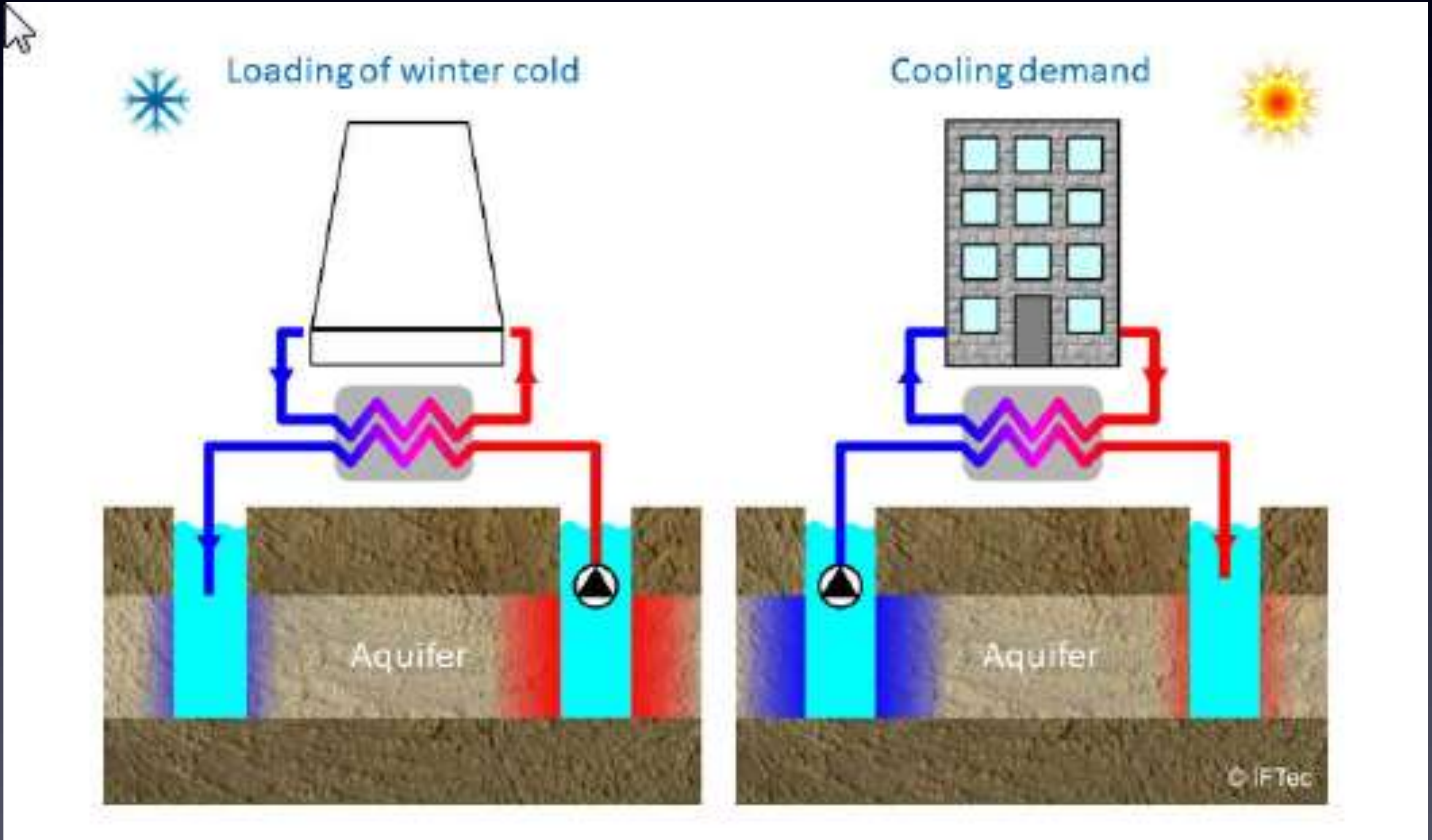
- Purposes of this presentation:
  - Understand ATES applications for district energy systems
  - Understand ATES feasibility study methodology
  - Review ATES FS findingsfor two sites in Ohio

- Project History
- Review ATES FS Results
  - Hydrogeology
  - Loads
  - ATES Conceptual Design
  - Electricity and Emissions Reductions
  - Project Finances
- Current Project Status

Schematic of an Earth-Coupled Heating and Cooling System



ATES for Cooling



ATES Growth in The Netherlands

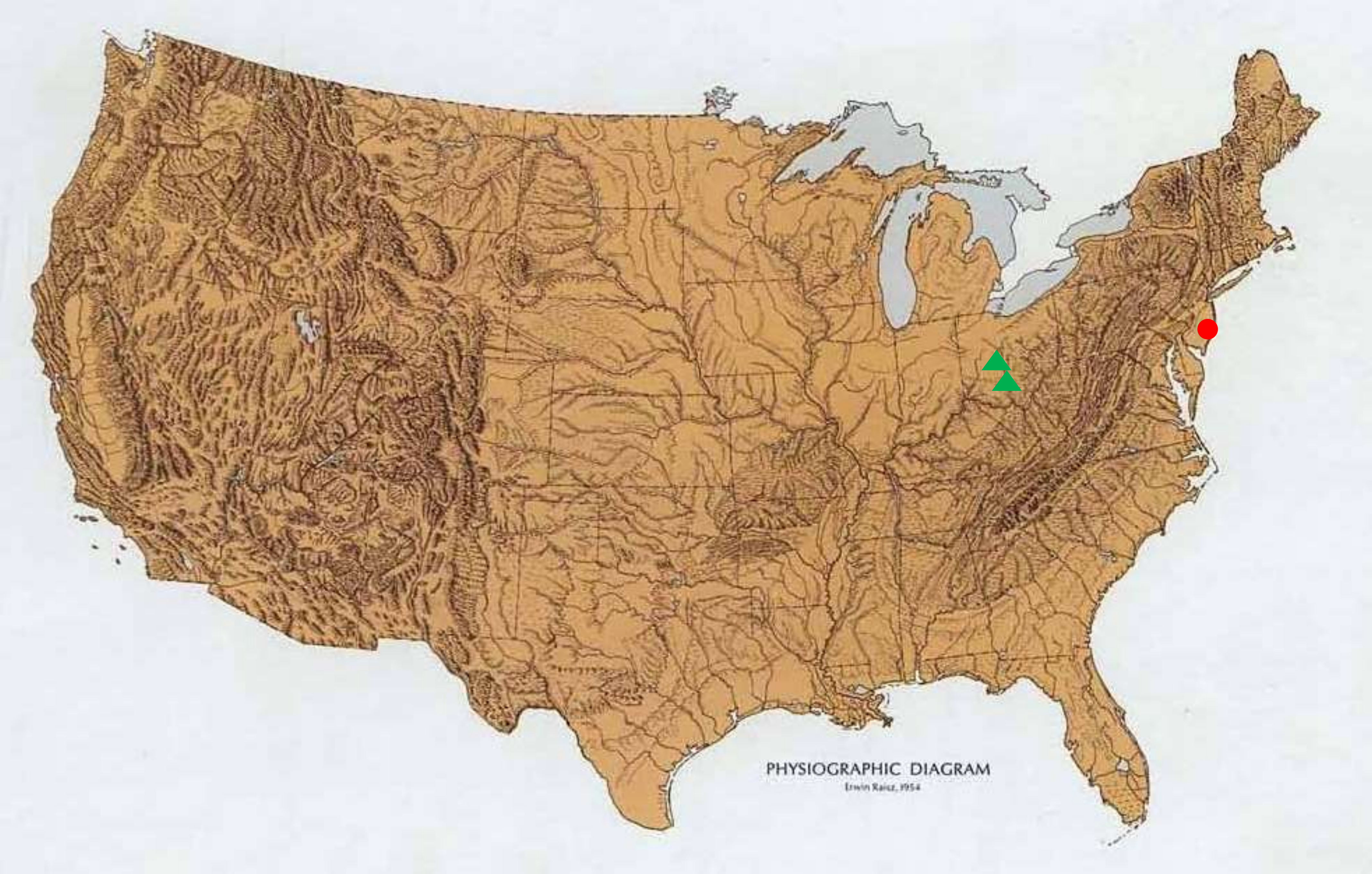
1990

2000

2010

Source: www.iftechnology.nl/

ATES Based District Heating & Cooling Systems in The United States



Richard Stockton College, Pamona, NJ (2 MW)

ATES Project Phasing

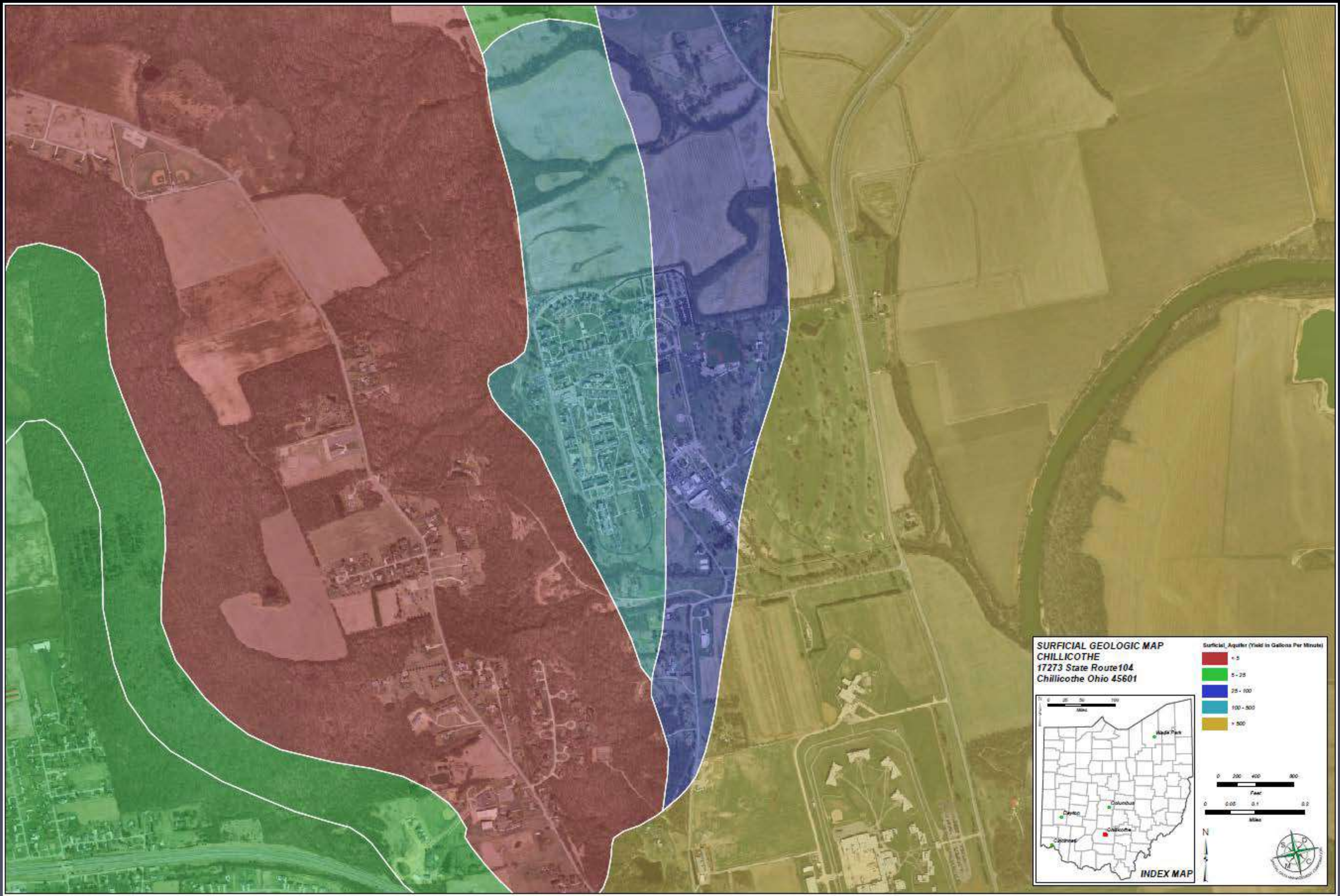
- Phase I – Desktop Feasibility Study
  - Non-intrusive, look for fatal flaws
  - Preliminary cost estimate
- Phase II – Pre-Design Work
  - Hydrogeologic characterization
  - Thermal and hydraulic modeling of well field
- Detail Design
  - Well and equipment specifications
  - Integration with MEP systems
  - Detailed cost estimate
- Construction
- Commissioning
- Operation, Maintenance & Monitoring

Phase I ATES
Feasibility Study Components

- Hydrogeologic Evaluation
  - Aquifer physical and hydraulic properties
  - Aquifer geochemical properties
- Engineering Evaluation
  - Cooling/Heating configuration evaluated
  - Conceptual design
  - Calculate electricity and emissions reductions
- Financial Evaluation
  - Estimate construction cost
  - Estimate financial benefit
  - Identify incentives and financing mechanisms
- Regulatory Evaluation
  - Identify permits required

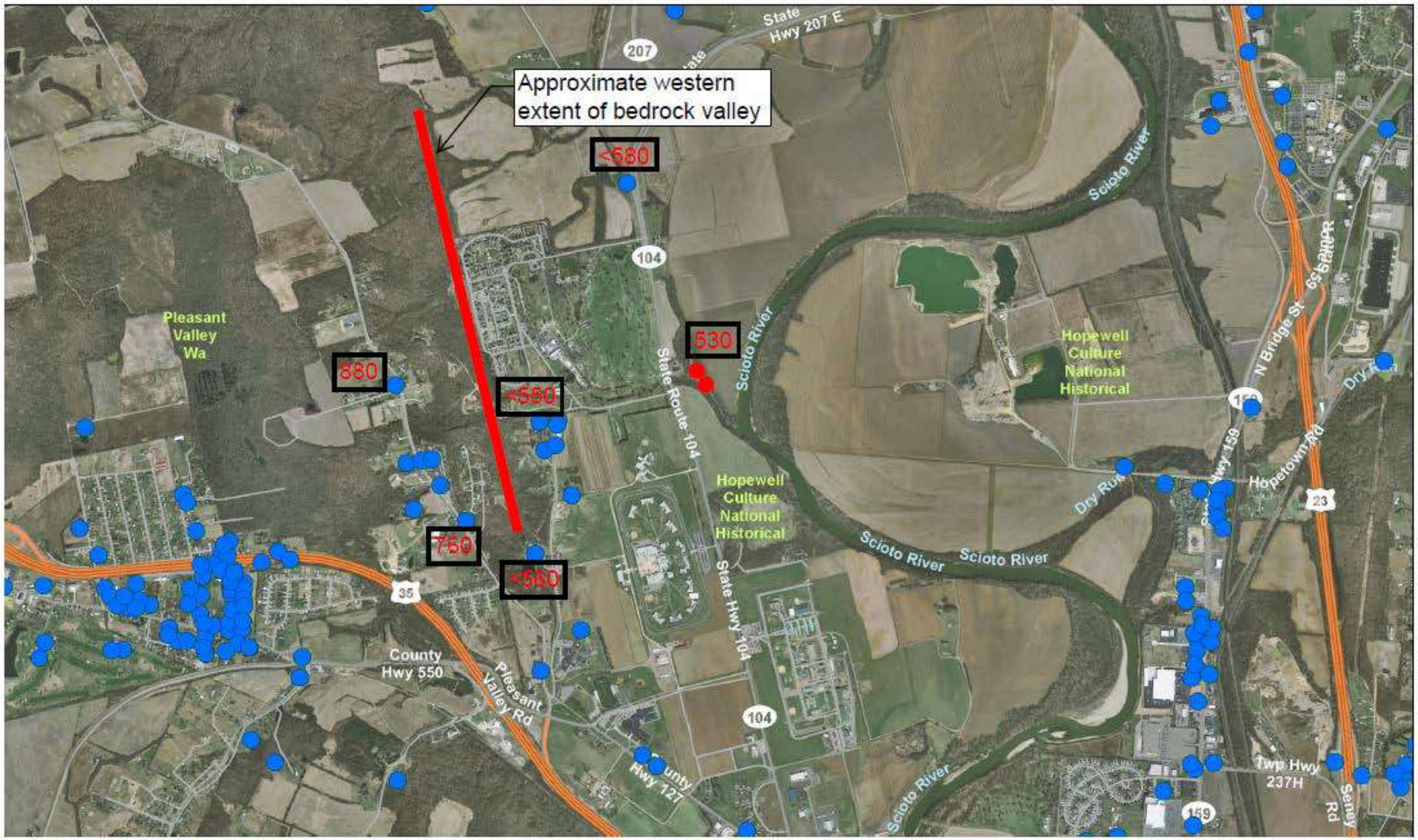
ATES Hydrogeologic Evaluation

Chillicothe, OH



ATES Hydrogeologic Evaluation

Chillicothe, OH



Notes: <560 Approximate bedrock elevation (ft MSL)

● Existing VA irrigation well

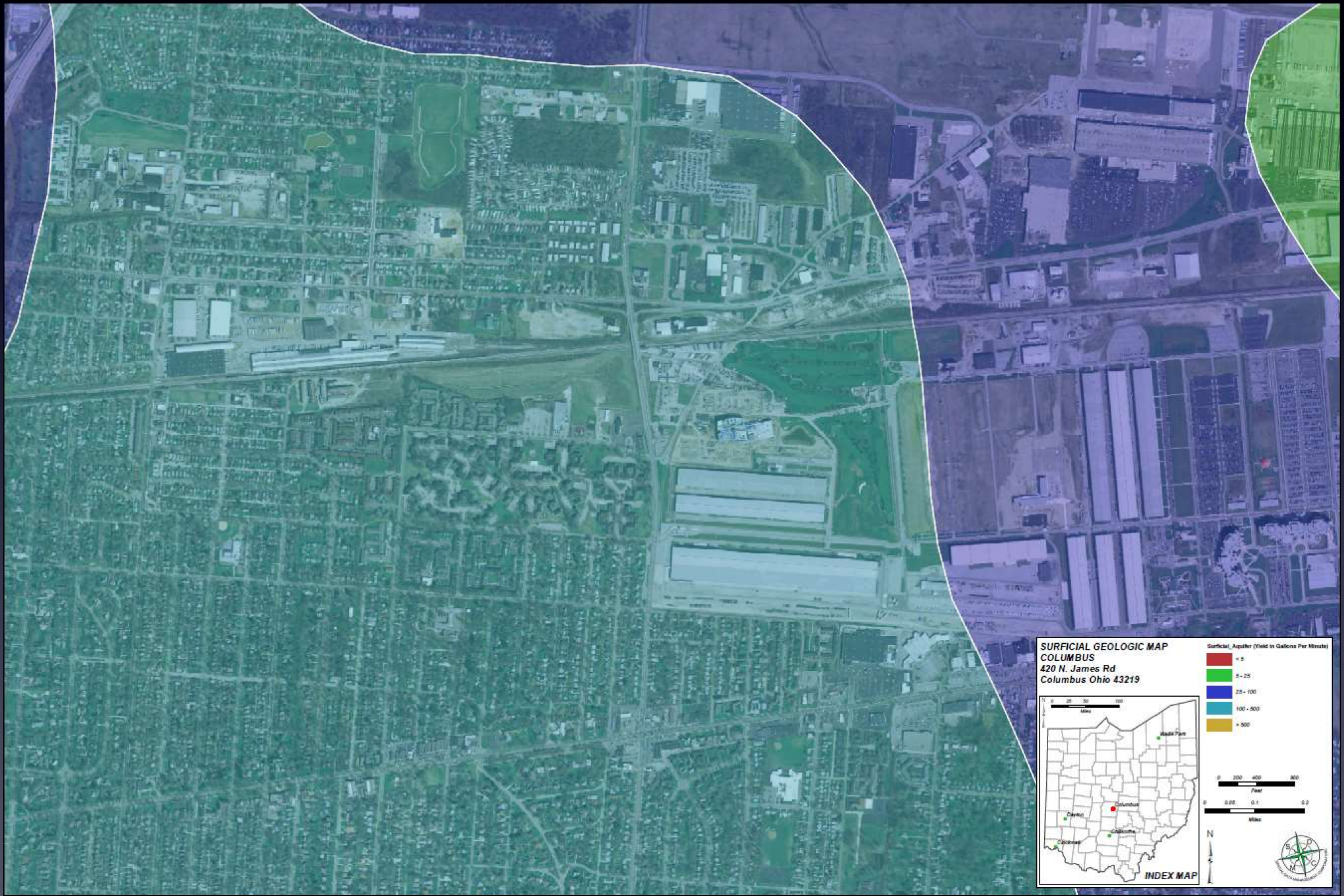
FIGURE 4
Available Well Logs in Site Vicinity

1.0 0.49 0.97

Note: These locations represent records that have coordinates in the ODNR Well Log Database. Please go to http://ohiodnr.com/water/maptechs/welllogs/appNew/Default.aspx to search additional records.

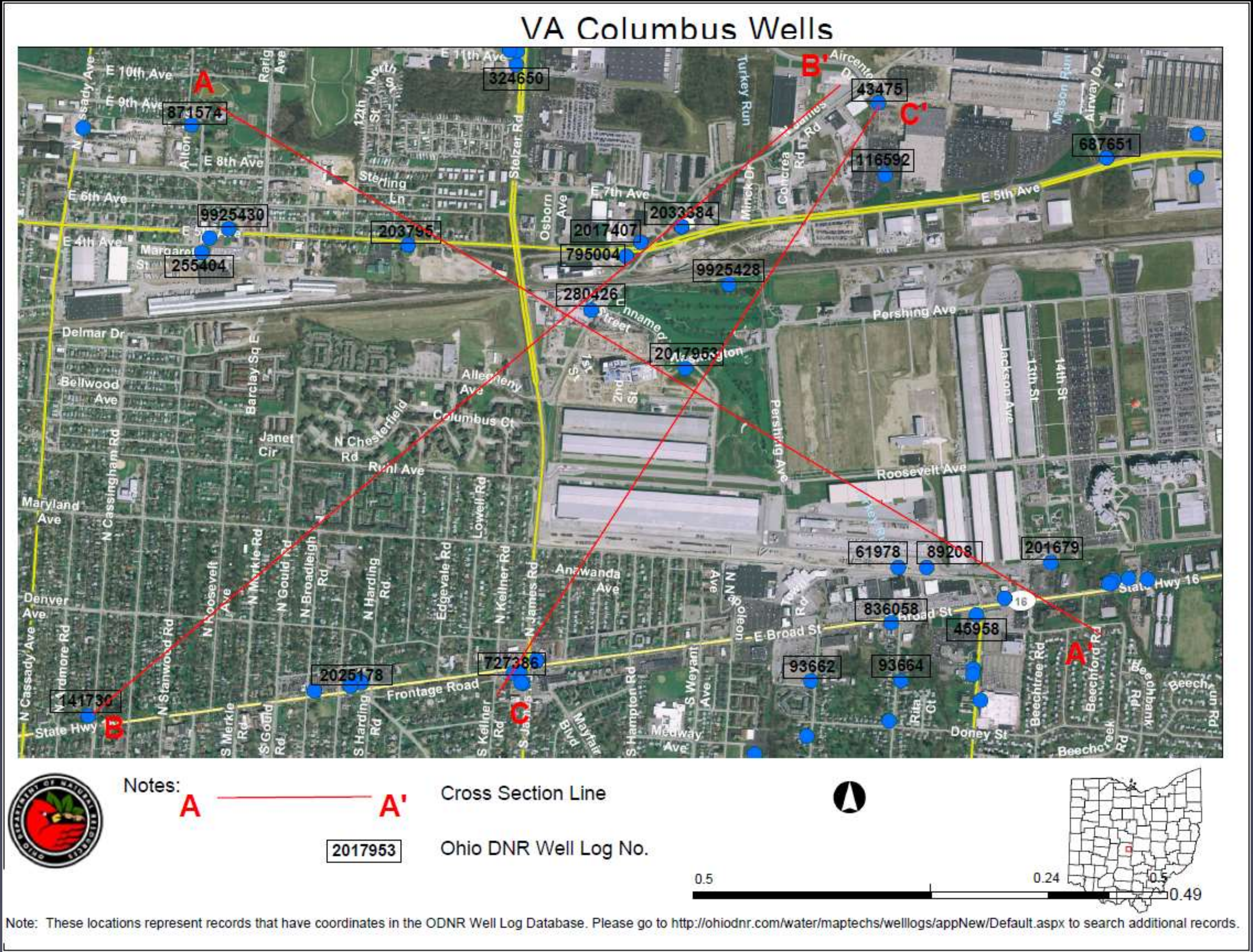
ATES Hydrogeologic Evaluation

Columbus, OH

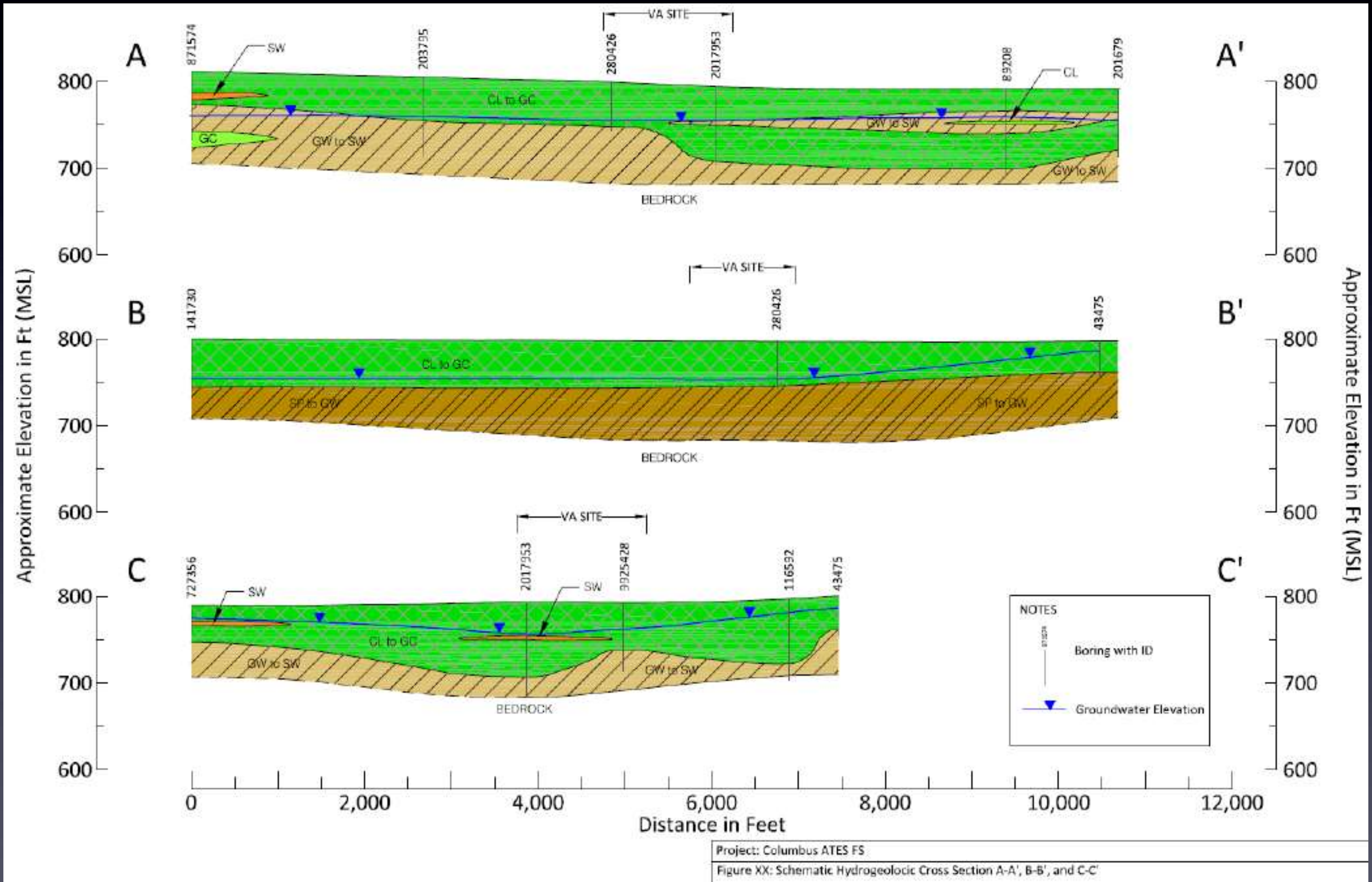


ATES Hydrogeologic Evaluation

Columbus, OH



ATES Hydrogeologic Evaluation
Columbus, OH



ATES Hydrogeologic Evaluation

Aquifer Hydraulic Properties

Parameter	Chillicothe	Columbus
Aquifer Saturated Thickness	98 ft (30m)	20-65 ft
Aquifer Saturated Thickness	98 ft (30m)	20-65 ft
Aquifer depth	115 ft (35m) below ground surface	~115 ft (35m) below ground surface
Aquifer hydraulic conductivity	1.5 x 10^{-1} cm/s	~ 10^{-1} cm/s
Aquifer transmissivity	320,000 gpd/ft (3,900 m^2/day)	8,000 – 800,000 gpd/ft (100 – 10,000 m^2/day)
Hydraulic Gradient	10^{-3}	10^{-2} - 10^{-3}
Aquifer storativity	0.042	?
Aquifer Porosity	0.35	0.35
Ambient Groundwater Temperature (est)	55 °F (12.8° C)	55 °F (12.8° C)
Groundwater depth in aquifer	17 ft (5.2m) below ground surface	40 ft (12m) below ground surface
Groundwater elevation in aquifer	621 ft MSL	755 ft MSL
Groundwater flow velocity	1.1 ft /day (0.33 m/day)	~2 ft /day (0.6 m/day)

ATES Hydrogeologic Evaluation

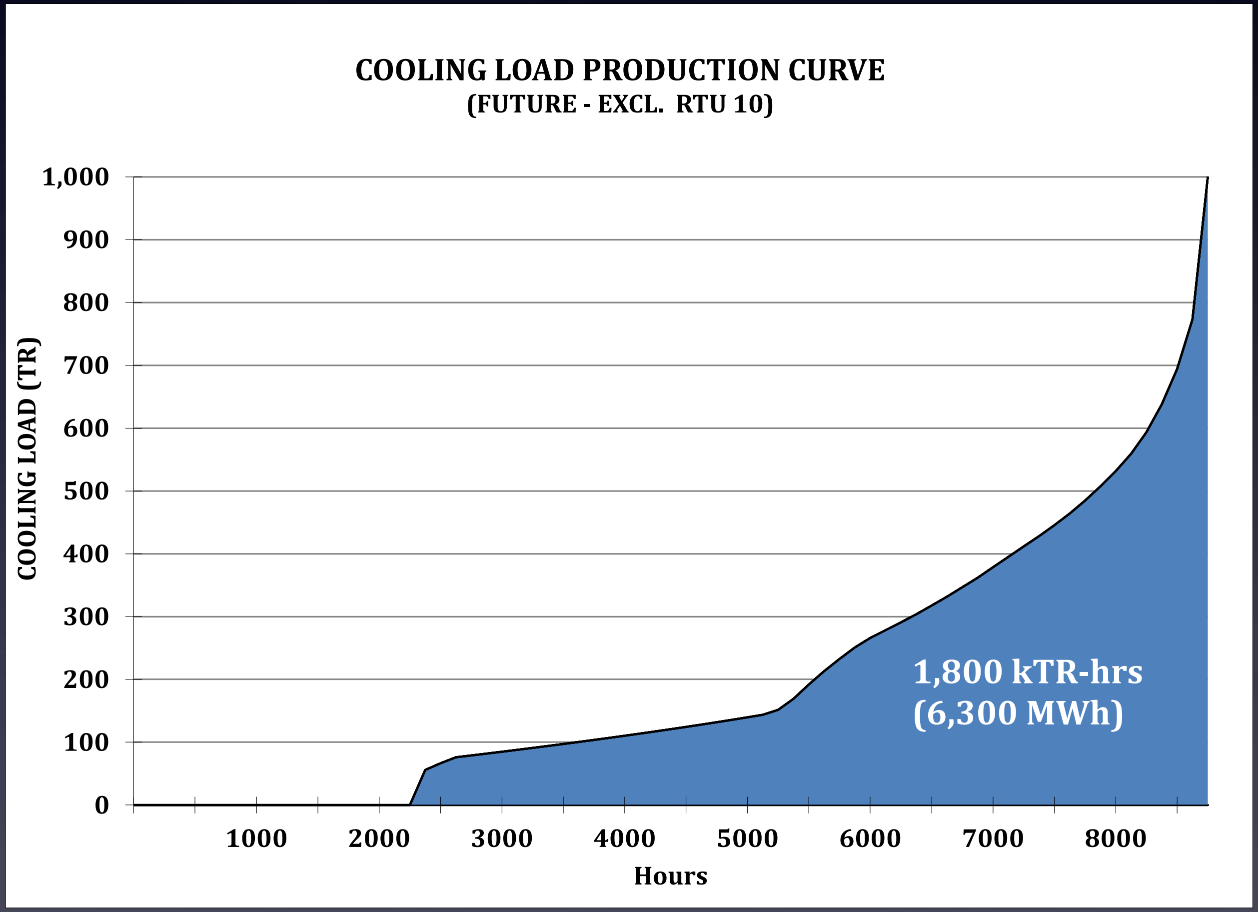
Aquifer Geochemistry

ANALYTE	Chillicothe			Columbus
	TH 1-86	**TH2-86**	**PW-1**	
Sample Date	2-13-1986	2-13-1986	6-10-1986	
Total Dissolved Solids (mg/L)	360	372	320	
Bicarbonate Alkalinity (mg/L)	204	226	218	
Bicarbonate (mg/L)	204	226	218	
Carbon Dioxide (mg/L)	12	13	14	
Chloride (mg/L)	9	9	36	
Sulfate (mg/L)	105	128	92	
Fluoride (mg/L)	0.28	0.32	0.18	
Silica (mg/L)	0.08	0.09	2.2	
Sodium (mg/L)	14.2	15.1	7.20	
Potassium (mg/L)	2.87	3.04	3.82	
Total hardness (mg/L)	286	298	364	
Calcium (mg/L)	68.0	71.2	122	
Magnesium Hardness (mg/L)	116	120	60	
Magnesium (mg/L)	0.02	0.02	17.3	
Total Iron (mg/L)	0.52	0.59	1.08	Up to 4
Manganese (mg/L)	33.4	34.6	0.17	
Copper (mg/L)	0.00	0.00	0.00	
Turbidity (NTU)	0.46	0.37	6.7	
pH (SU)	7.44	7.45	7.38	

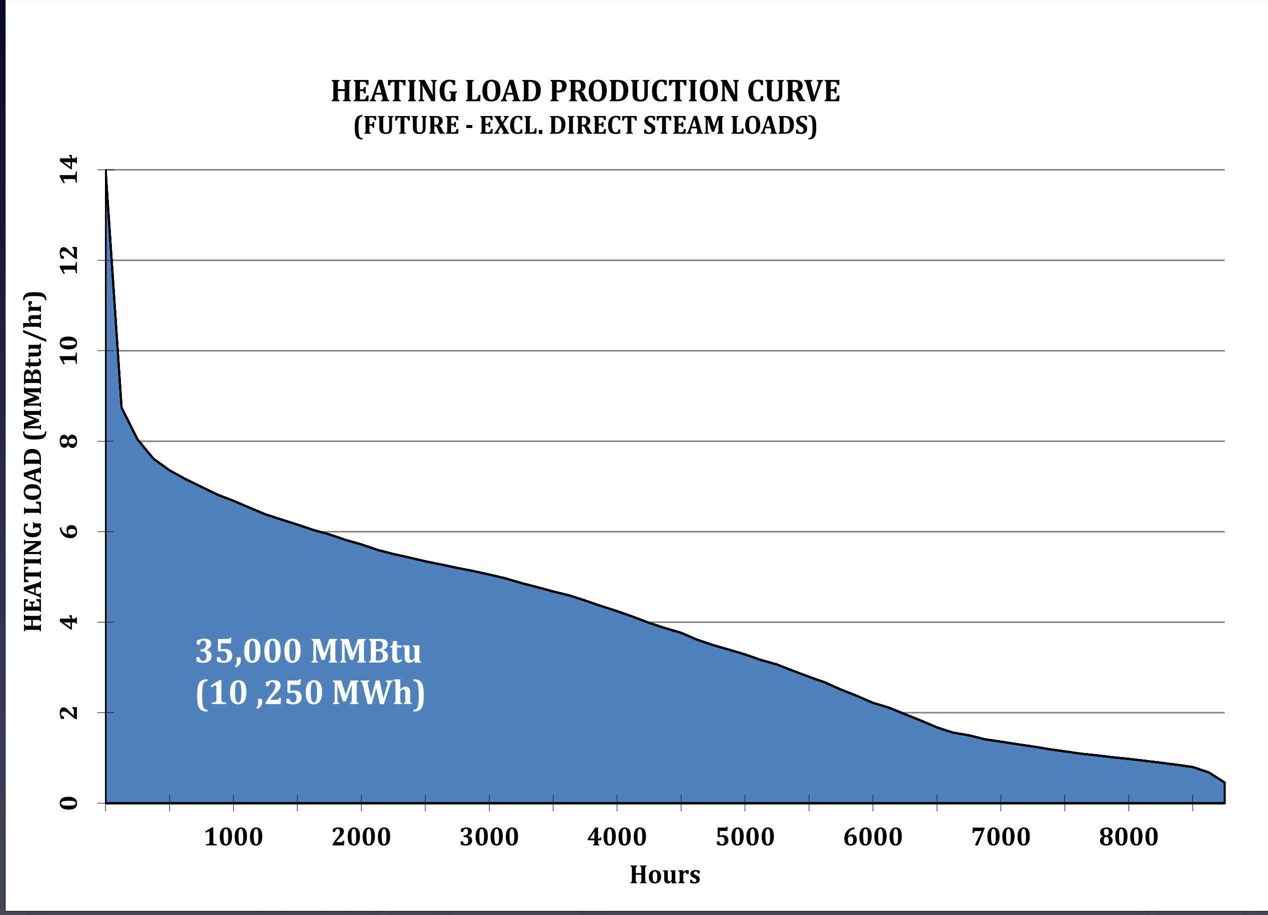
ATES Engineering Evaluation

Cooling and Heating Load Duration Curves (Columbus, OH)

Cooling LDC



Heating LDC



ATES Engineering Evaluation

Groundwater System Design Assumptions

Chillicothe

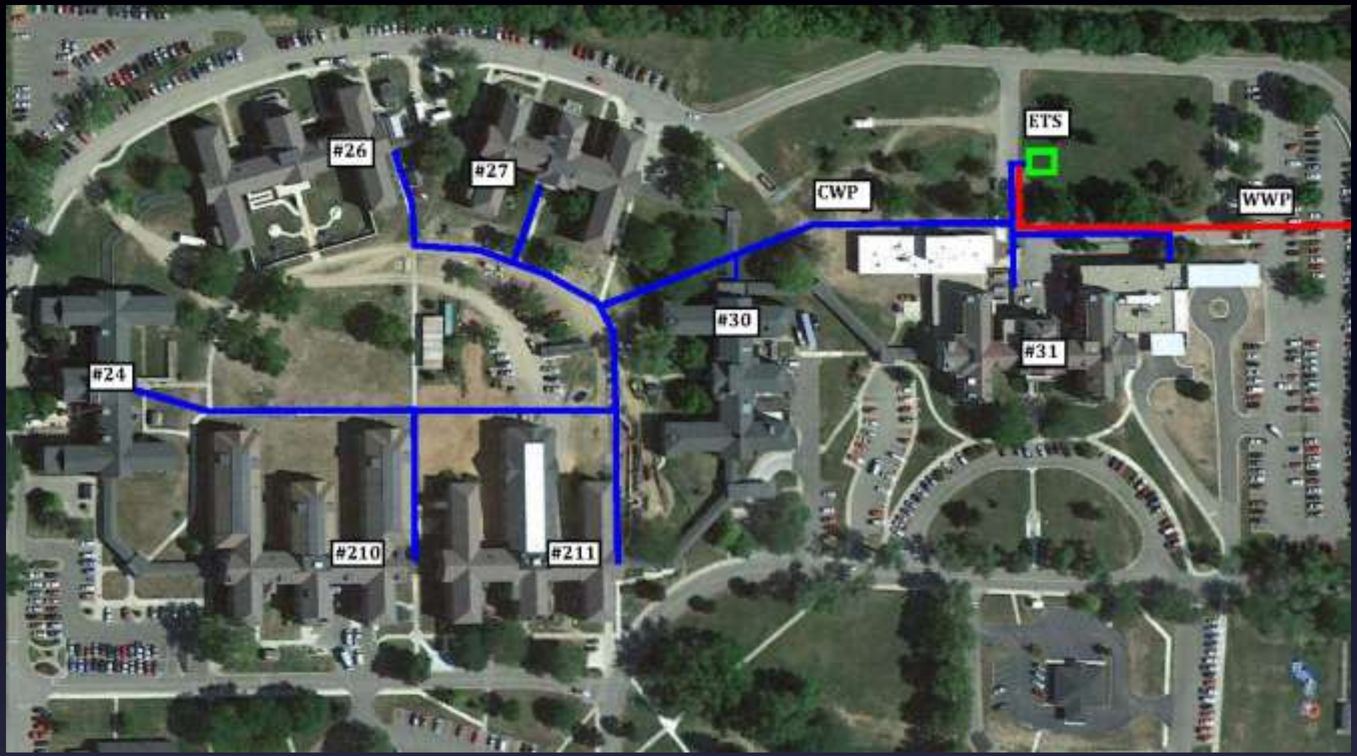
	Unit	Scenario 1	Scenario 2
Depth wells	feet	90	120
Maximum well yield	gpm	250-300	350-400
Number of doublets (pair of wells)		2	3
Maximum yield groundwater system	gpm	770	770
Natural groundwater temperature	°F (°C)	55 (12.8)	
Injection temperature cold wells, ATES storage temperature during loading operation	°F (°C)	39.2 (4.0)	
Extraction temperature cold wells, supply temperature	°F	41.0 → 46.4	

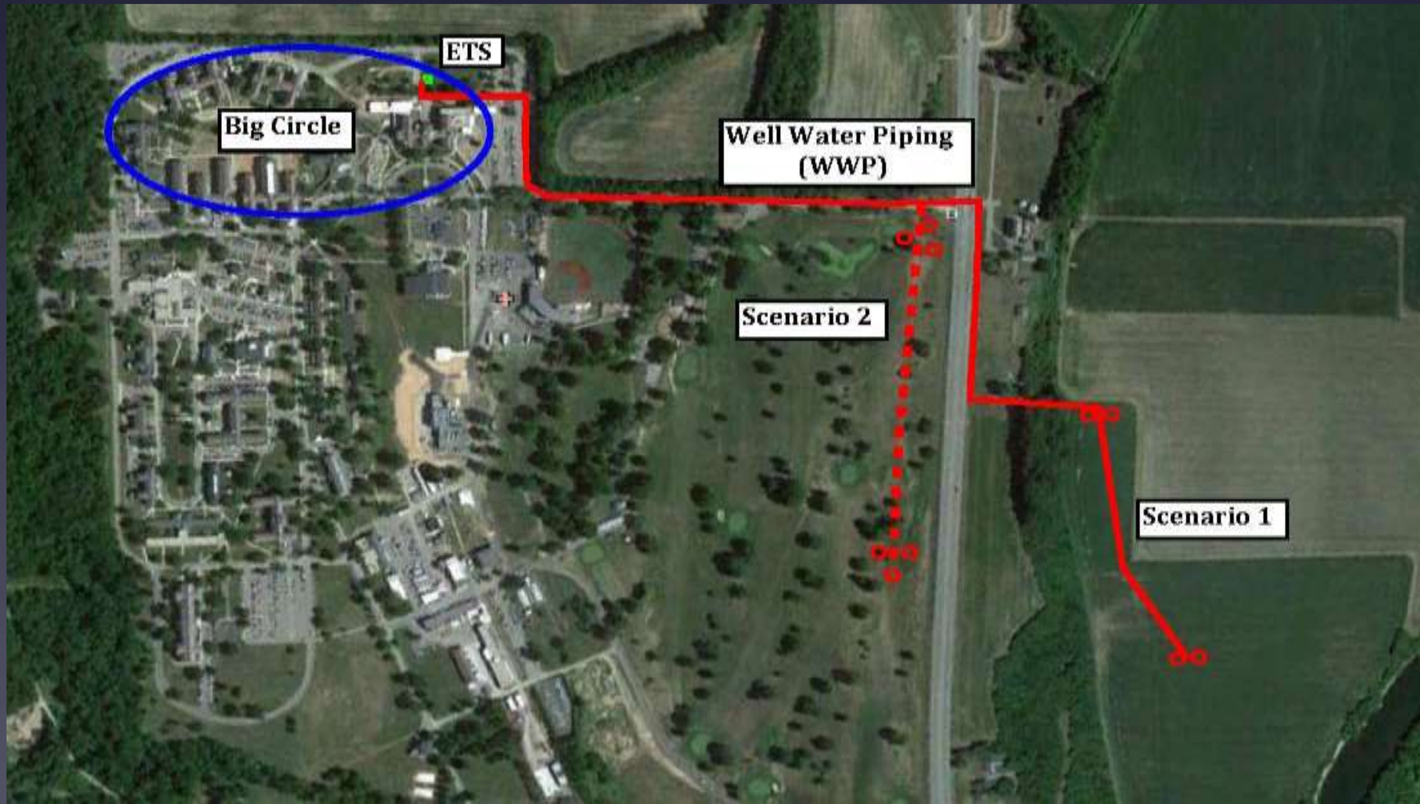
Columbus

	Unit	Scenario A	Scenario B1	Scenario B2
Depth wells	feet	110	110	110
Maximum well yield	gpm	230	180	180
Number of doublets (pair of wells)		3	2	2
Maximum yield groundwater system	gpm	700	360	360
Natural groundwater temperature	°F (°C)	55 (12.8)		
Injection temperature cold wells, ATES storage temperature during loading operation	°F (°C)	39.2 (4.0)	41.0 (5.0)	41 (5.0)
Extraction temperature cold wells, supply temp. from cold store during cooling operation	°F (°C)	41.0→44.6 (5.0→7.0)	42.8→46.4 (6.0→8,0)	42.8→46.4 (6.0→8,0)

ATES Engineering Evaluation

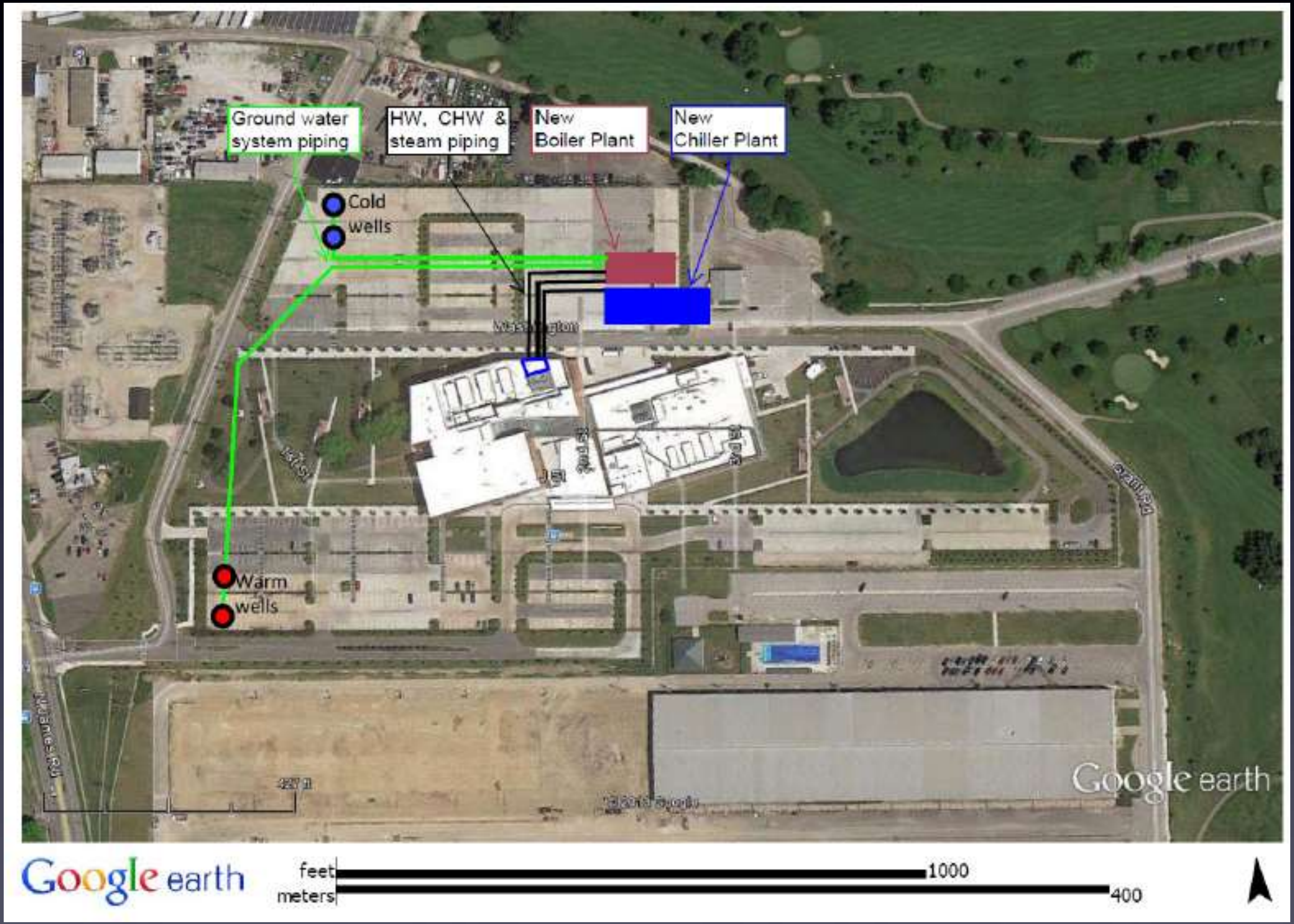
Chillicothe, OH





ATES Engineering Evaluation

Columbus, OH

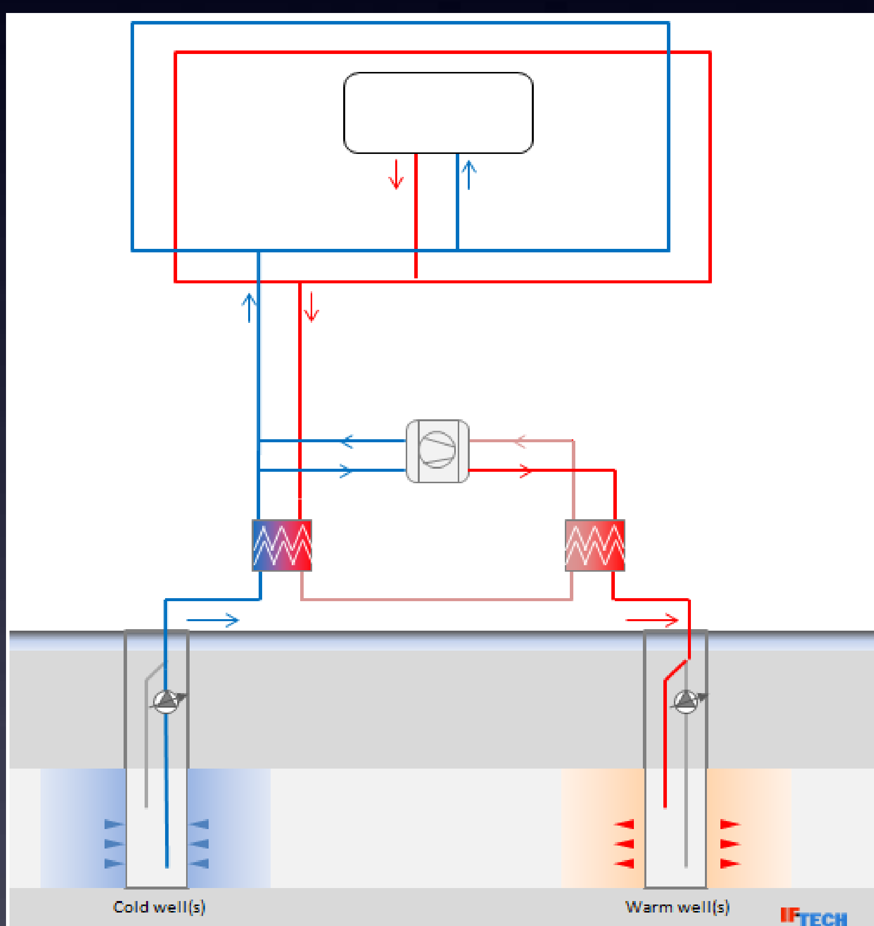


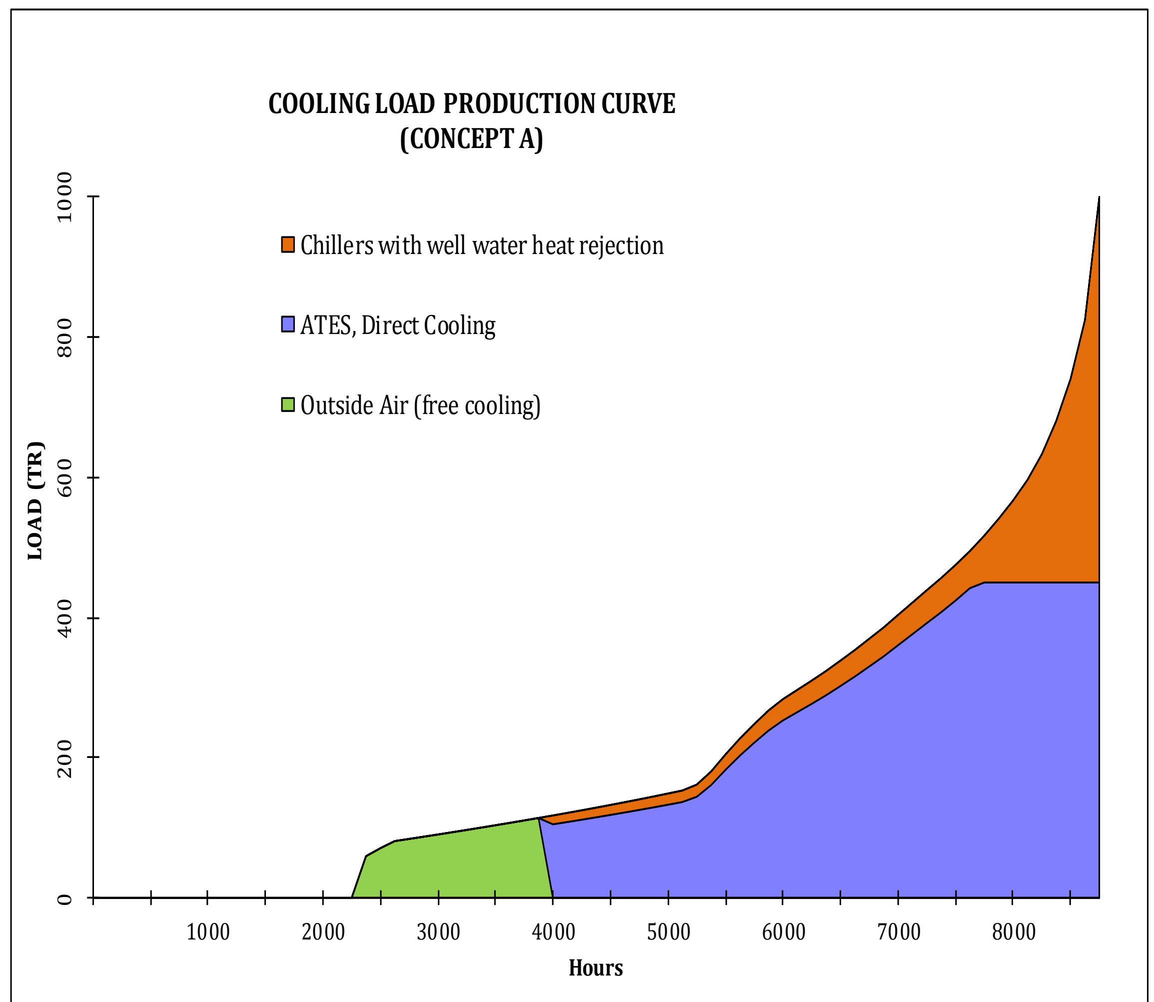
ATES Engineering Evaluation

Chillicothe, OH

ATES Implementation Concept A:

Direct cooling combined with new central chiller(s), rejection of condenser heat to wells





ENERGY PRODUCTION

COOLING LOAD, BUILDINGS (kTR-hrs)

Outside Air (free cooling)	150	kTR-hrs	8%
ATES, Direct Cooling	1,398	kTR-hrs	73%
Chillers, Well Water	363	kTR-hrs	19%
		kTR-hrs	
		kTR-hrs	
S:a	**1,911**	**kTR-hrs**	**100%**

COOLING LOAD, BUILDINGS (MWh)

Outside Air (free cooling)	528	MWh	8%
ATES, Direct Cooling	4,922	MWh	73%
Chillers, Well Water	1,277	MWh	19%
		MWh	
		MWh	
S:a	**6,727**	**MWh**	**100%**

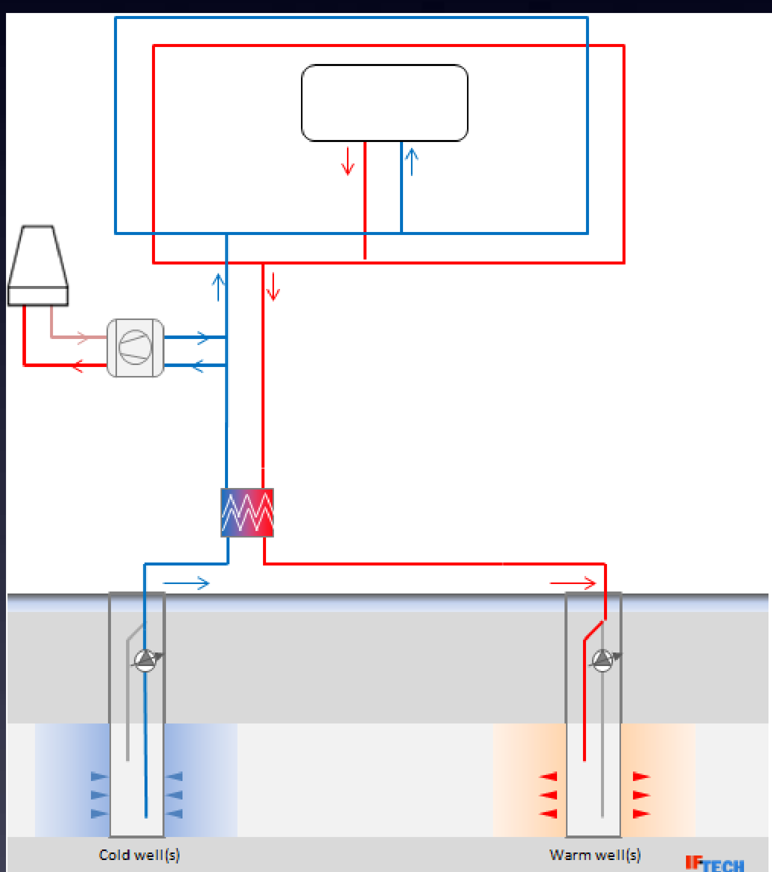
HEAT INJECTION TO WELLS (MWh)

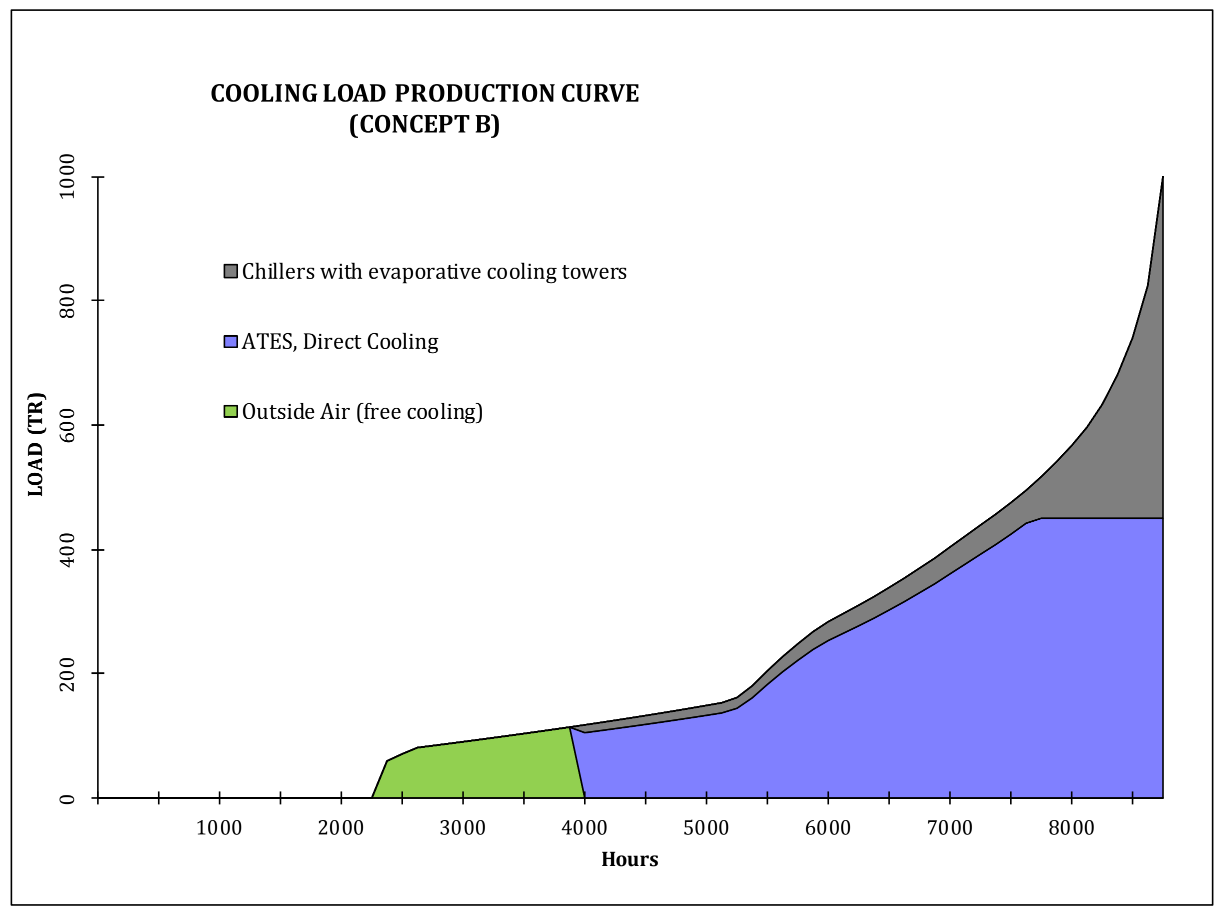
Outside Air (free cooling)		MWh	
ATES, Direct Cooling	4,922	MWh	77%
Chillers, Well Water	1,468	MWh	23%
		MWh	
		MWh	
S:a	**6,390**	**MWh**	**100%**

ATES Engineering Evaluation

Chillicothe, OH

ATES Implementation Concept B:
Direct cooling combined with new central chiller(s), rejection of condenser heat to cooling tower





ENERGY PRODUCTION

COOLING LOAD, BUILDINGS (kTR-hrs)

Outside Air (free cooling)	150	kTR-hrs	8%
ATES, Direct Cooling	1,398	kTR-hrs	73%
Chillers, Cooling Tower	363	kTR-hrs	19%
S:a	**1,911**	**kTR-hrs**	**100%**

COOLING LOAD, BUILDINGS (MWh)

Outside Air (free cooling)	528	MWh	8%
ATES, Direct Cooling	4,922	MWh	73%
Chillers, Cooling Tower	1,277	MWh	19%
S:a	**6,727**	**MWh**	**100%**

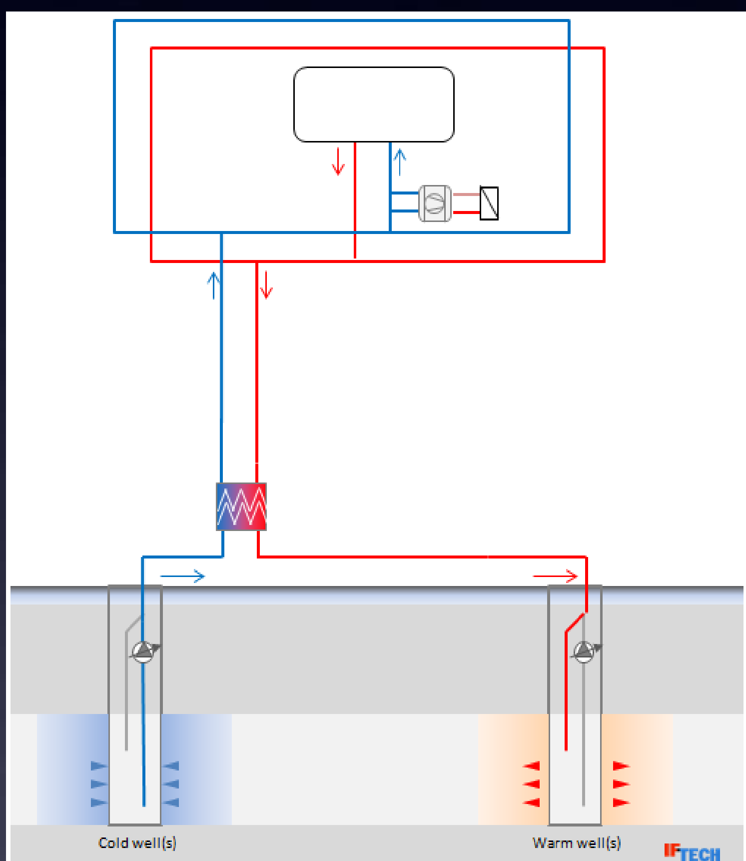
HEAT INJECTION TO WELLS (MWh)

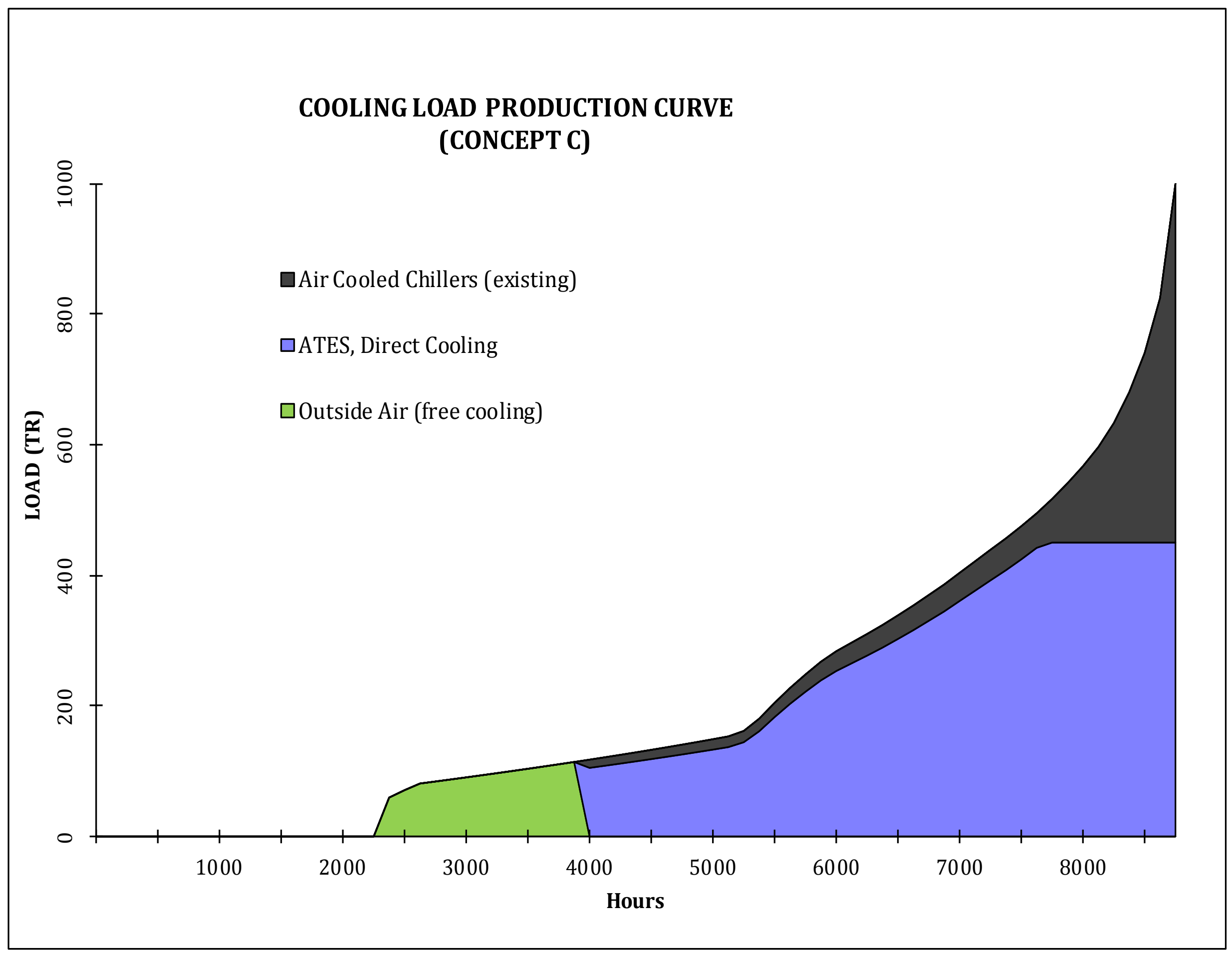
Outside Air (free cooling)		MWh	
ATES, Direct Cooling	4,922	MWh	100%
Chillers, Cooling Tower		MWh	
S:a	**4,922**	**MWh**	**100%**

ATES Engineering Evaluation

Chillicothe, OH

ATES Implementation Concept C:
Direct cooling combined with existing air cooled chillers at individual buildings





ENERGY PRODUCTION

COOLING LOAD, BUILDINGS (kTR-hrs)

Outside Air (free cooling)	150	kTR-hrs	8%
ATES, Direct Cooling	1,398	kTR-hrs	73%
Chillers, Air Cooled	363	kTR-hrs	19%
S:a	**1,911**	**kTR-hrs**	**100%**

COOLING LOAD, BUILDINGS (MWh)

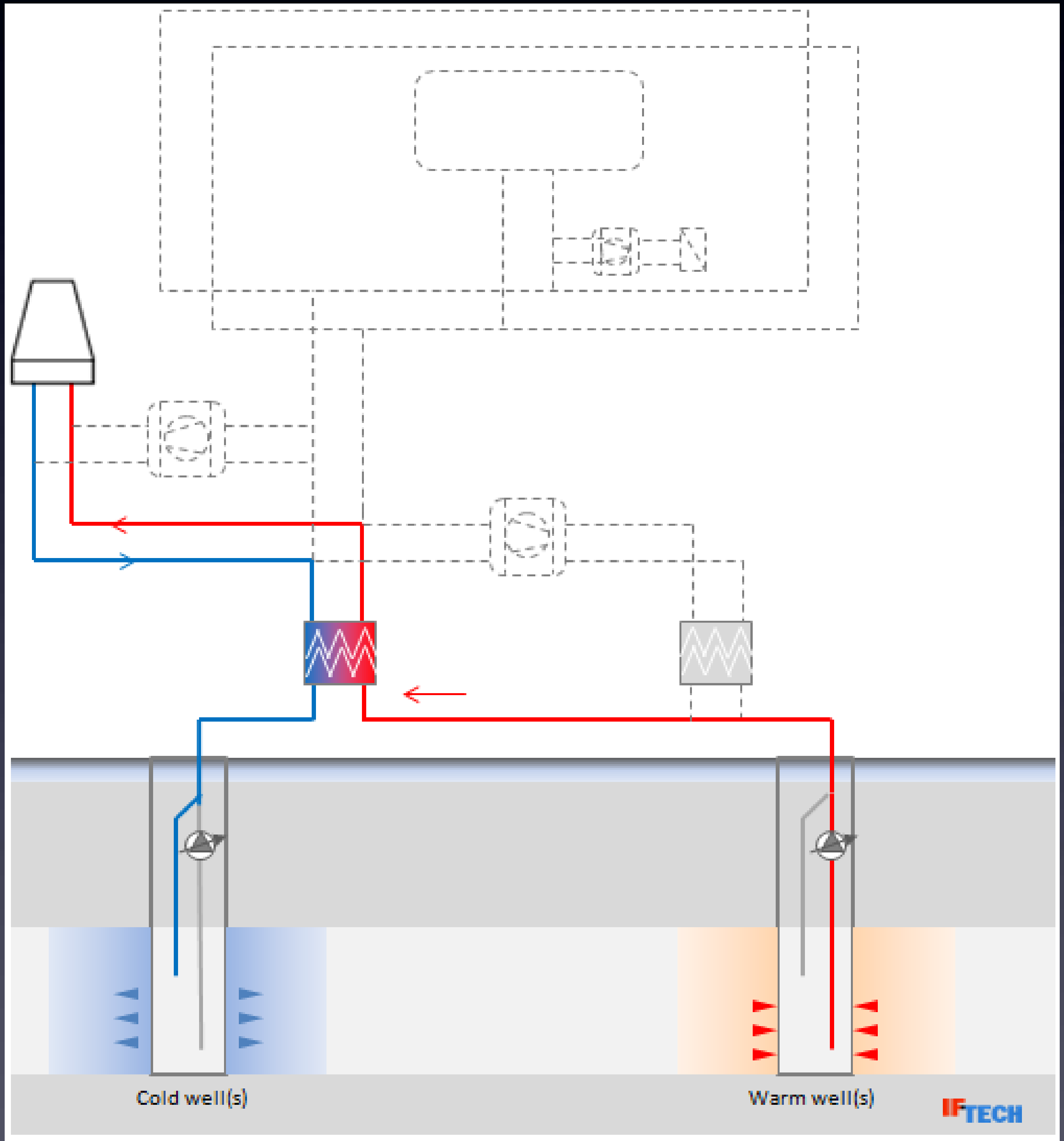
Outside Air (free cooling)	528	MWh	8%
ATES, Direct Cooling	4,922	MWh	73%
Chillers, Air Cooled	1,277	MWh	19%
S:a	**6,727**	**MWh**	**100%**

HEAT INJECTION TO WELLS (MWh)

Outside Air (free cooling)		MWh	
ATES, Direct Cooling	4,922	MWh	100%
Chillers, Air Cooled		MWh	
S:a	**4,922**	**MWh**	**100%**

ATES Engineering Evaluation

Concept A,B&C Winter Mode
“ATES charging”



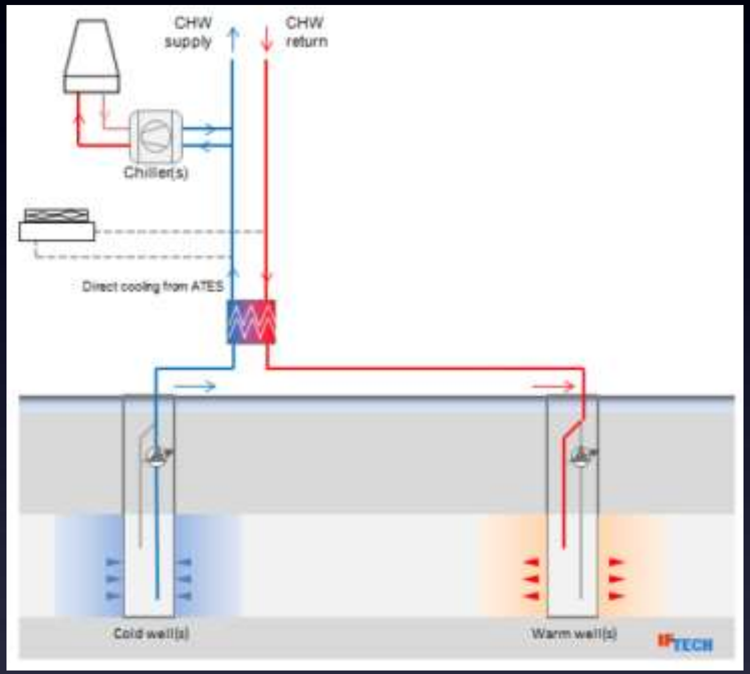
ATES Engineering Evaluation

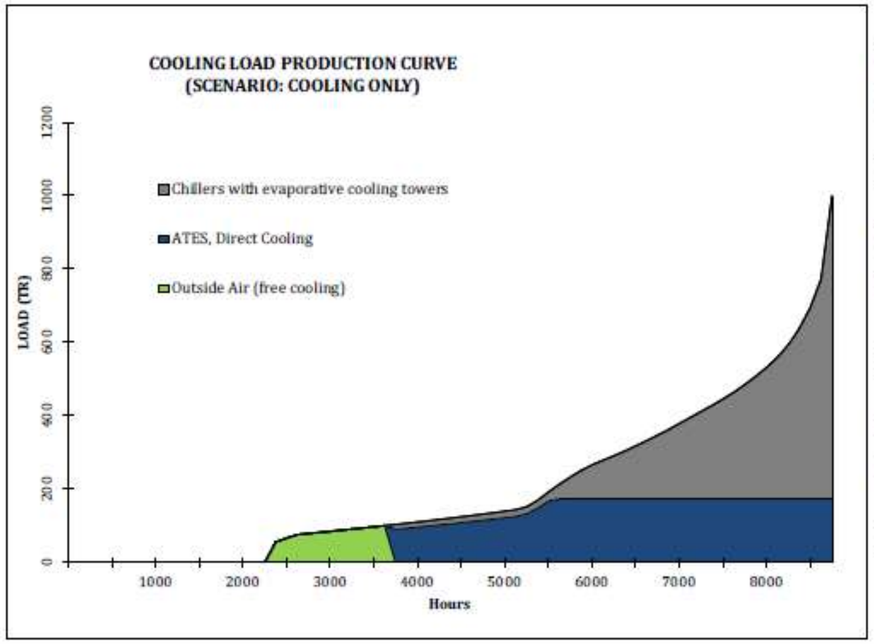
Columbus, OH

ATES Implementation Scenario A:

Direct cooling combined with chillers for peak capacity and supply temperature control

summer





ENERGY PRODUCTION

COOLING LOAD, BUILDINGS (kTR-hrs)

Outside Air (free cooling)	114	kTR-hrs	6%
ATES, Direct Cooling	780	kTR-hrs	43%
Chillers, Cooling Tower	906	kTR-hrs	50%
S:a	1,800	kTR-hrs	100%

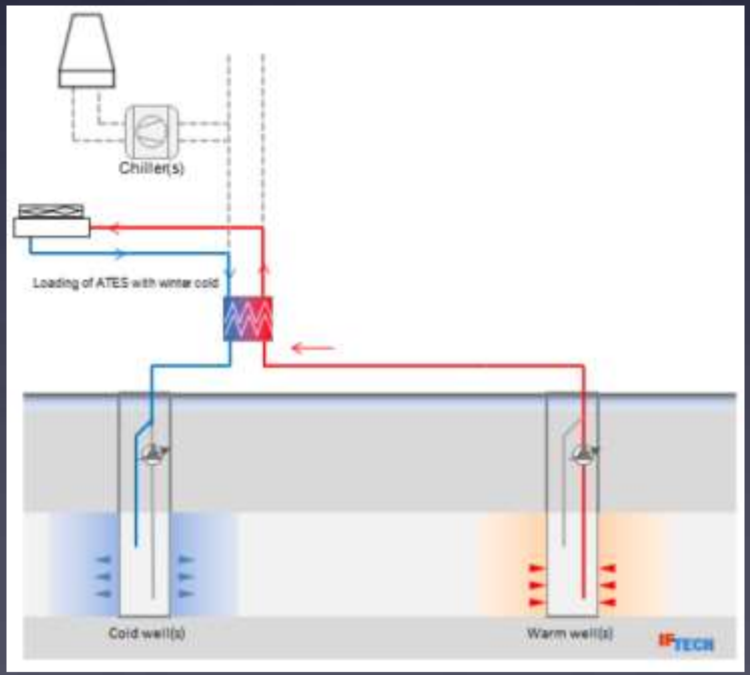
COOLING LOAD, BUILDINGS (MWh)

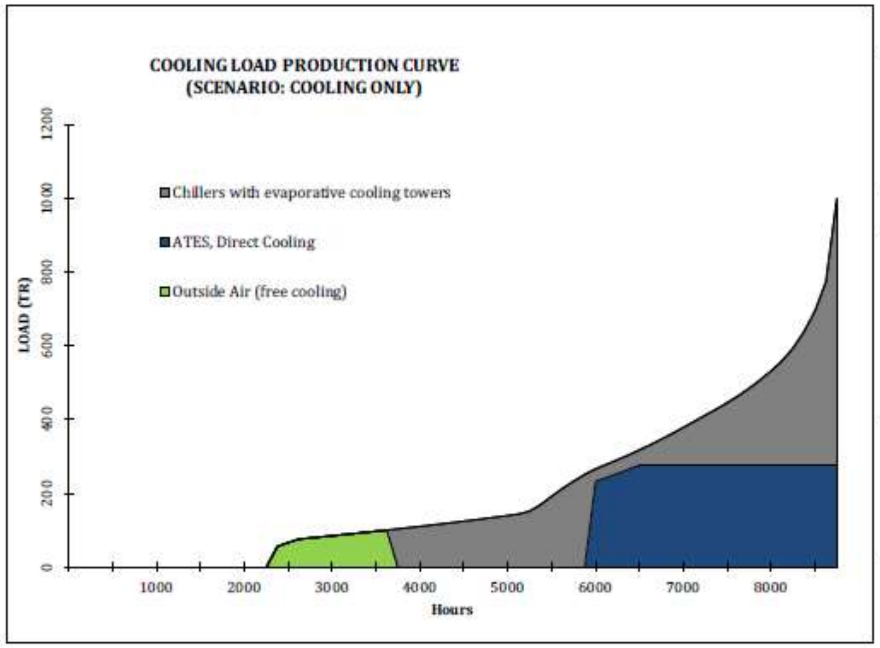
Outside Air (free cooling)	402	MWh	6%
ATES, Direct Cooling	2,745	MWh	43%
Chillers, Cooling Tower	3,189	MWh	50%
S:a	6,336	MWh	100%

HEAT INJECTION TO WELLS (MWh)

Outside Air (free cooling)		MWh	
ATES, Direct Cooling	2,745	MWh	100%
Chillers, Cooling Tower		MWh	
S:a	2,745	MWh	100%

winter





ENERGY PRODUCTION

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COOLING LOAD, BUILDINGS (MWh)

Outside Air (free cooling)	402	MWh	6%
ATES, Direct Cooling	2,745	MWh	43%
Chillers, Cooling Tower	3,188	MWh	50%
S:a	6,336	MWh	100%

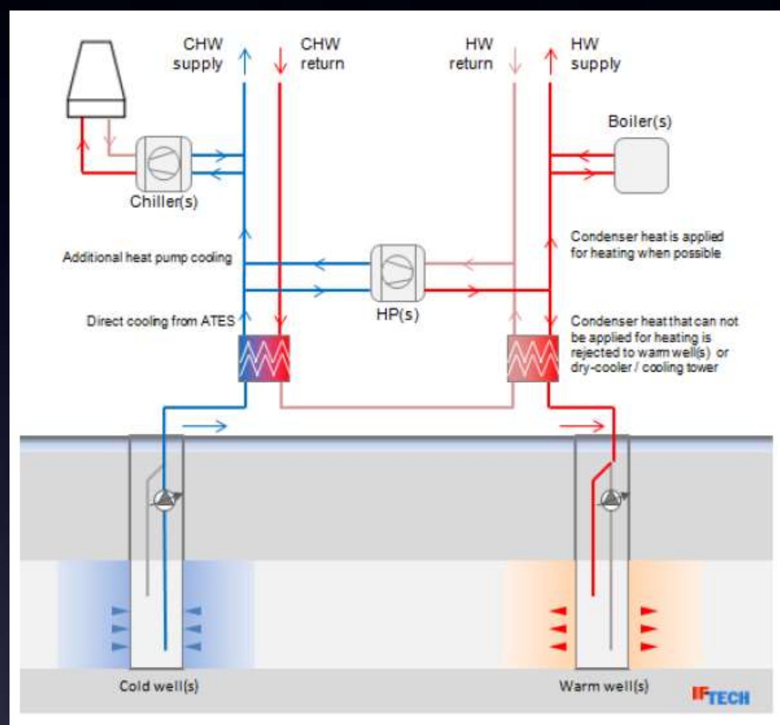
HEAT INJECTION TO WELLS (MWh)

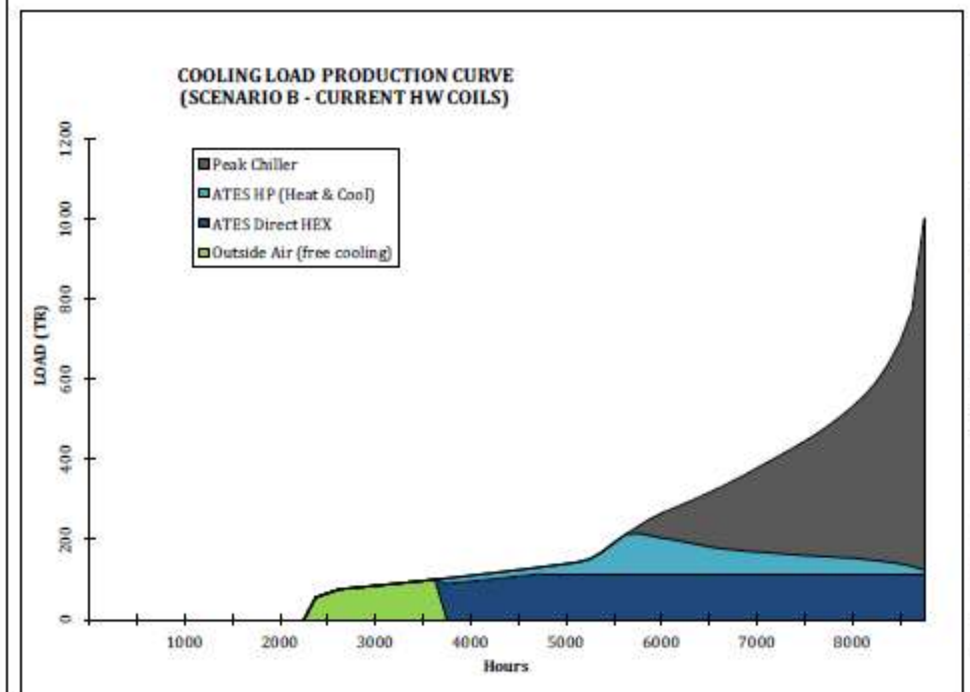
Outside Air (free cooling)		MWh	
ATES, Direct Cooling	2,745	MWh	100%
Chillers, Cooling Tower		MWh	
S:a	2,745	MWh	100%

ATES Engineering Evaluation
Columbus, OH

ATES Implementation Scenarios B1 and B2:
Heating and cooling with electric heat pump; natural-gas engine-driven heat pump

summer





ENERGY PRODUCTION

COOLING LOAD, BUILDINGS (kTR-hrs)

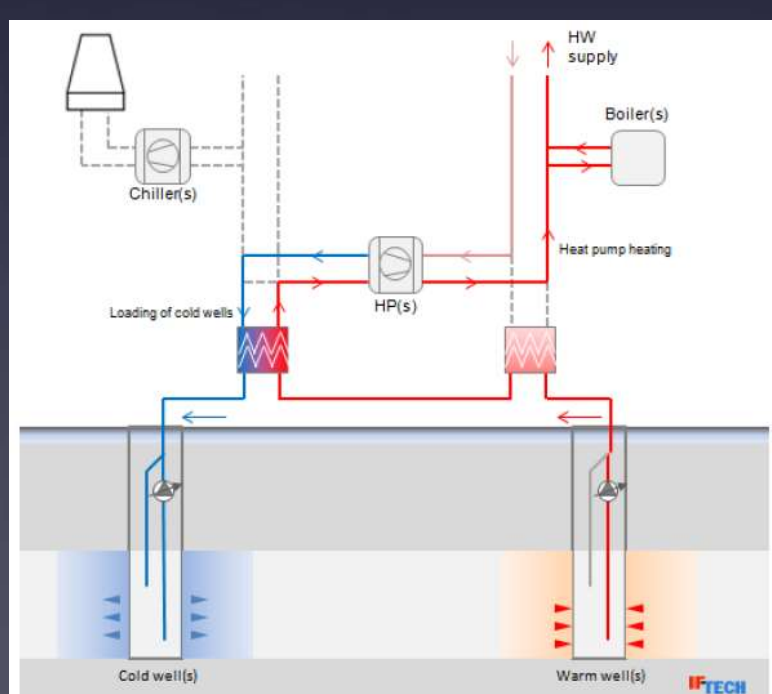
Outside Air (free cooling)	114 kTR-hrs	6%
ATES Direct HEX	573 kTR-hrs	32%
ATES HP (Heat & Cool)	228 kTR-hrs	13%
Peak Chiller	884 kTR-hrs	49%
S:a	1,800 kTR-hrs	100%

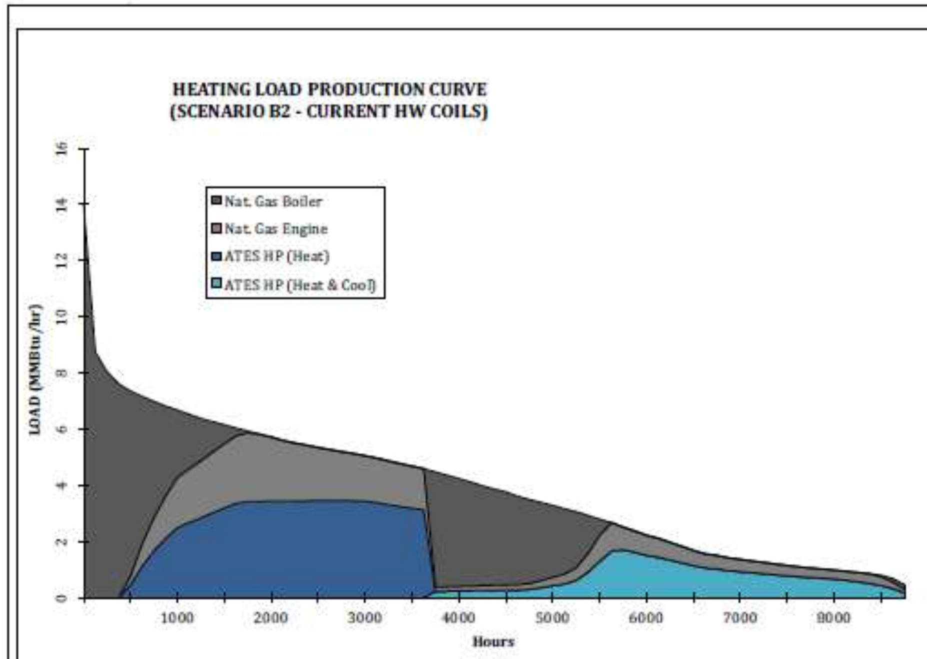
COOLING LOAD, BUILDINGS (MWh)

Outside Air (free cooling)	402 MWh	6%
ATES Direct HEX	2,018 MWh	32%
ATES HP (Heat & Cool)	804 MWh	13%
Peak Chiller	3,112 MWh	49%
S:a	6,336 MWh	100%

HEAT DISPERSAL FROM ATES Direct HEX		
	2,018 MWh	100%
HEAT DISPERSAL FROM ATES HP:		
Total	1,124 MWh	56%
To Building	-1,124 MWh	-56%
Sum	-0 MWh	0%
HEAT INJECTION TO WELLS (MWh)		
S:a	2,018 MWh	100%

winter





ENERGY PRODUCTION

HEATING LOAD, BUILDINGS (MMBtu)

ATES HP (Heat & Cool)	3,836 MMBtu	11%
ATES HP (Heat)	9,631 MMBtu	28%
Nat. Gas Engine	7,855 MMBtu	22%
Nat. Gas Boiler	13,679 MMBtu	39%
	0 MMBtu	0%
S:a	35,000 MMBtu	100%

HEATING LOAD, BUILDINGS (MWh)

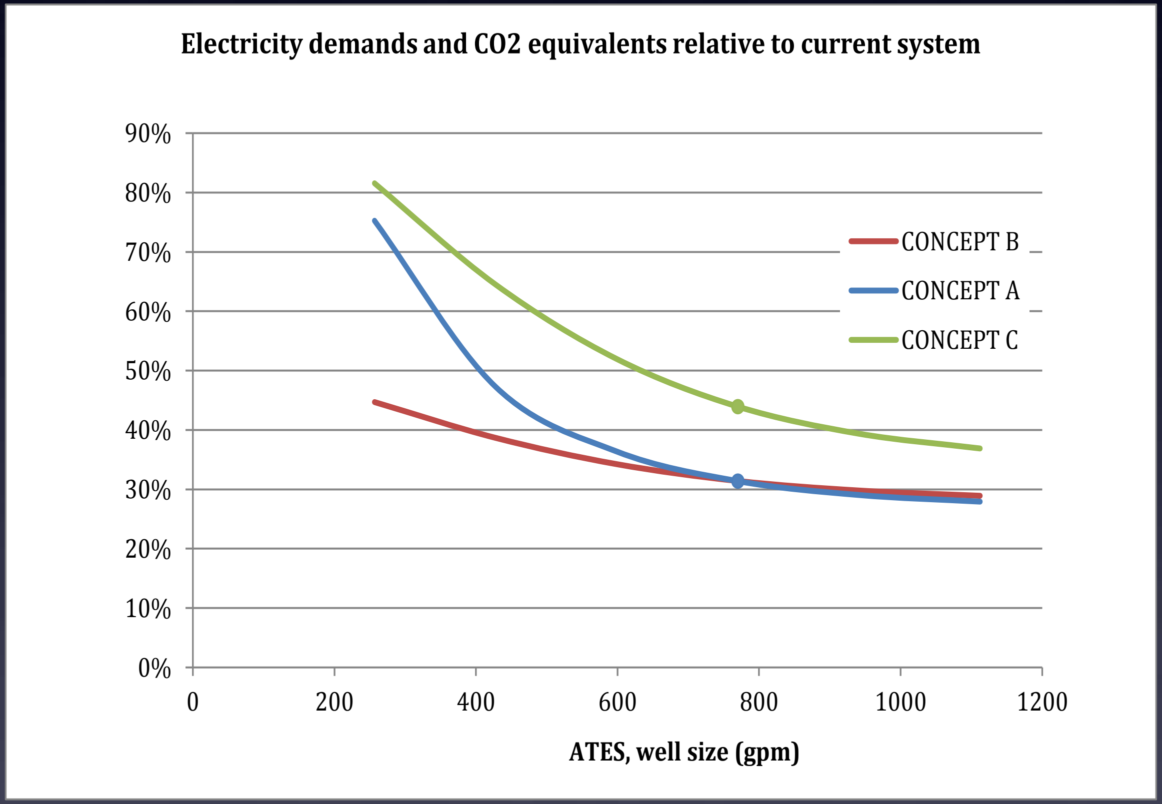
ATES HP (Heat & Cool)	1,124 MWh	11%
ATES HP (Heat)	2,822 MWh	28%
Nat. Gas Engine	2,302 MWh	22%
Nat. Gas Boiler	4,009	39%
	0	0%
S:a	10,257 MWh	100%

HEAT FROM WELLS (MWh)

ATES HP (Heat)	2,018 MWh	100%
	0	0%
S:a	2,018 MWh	100%

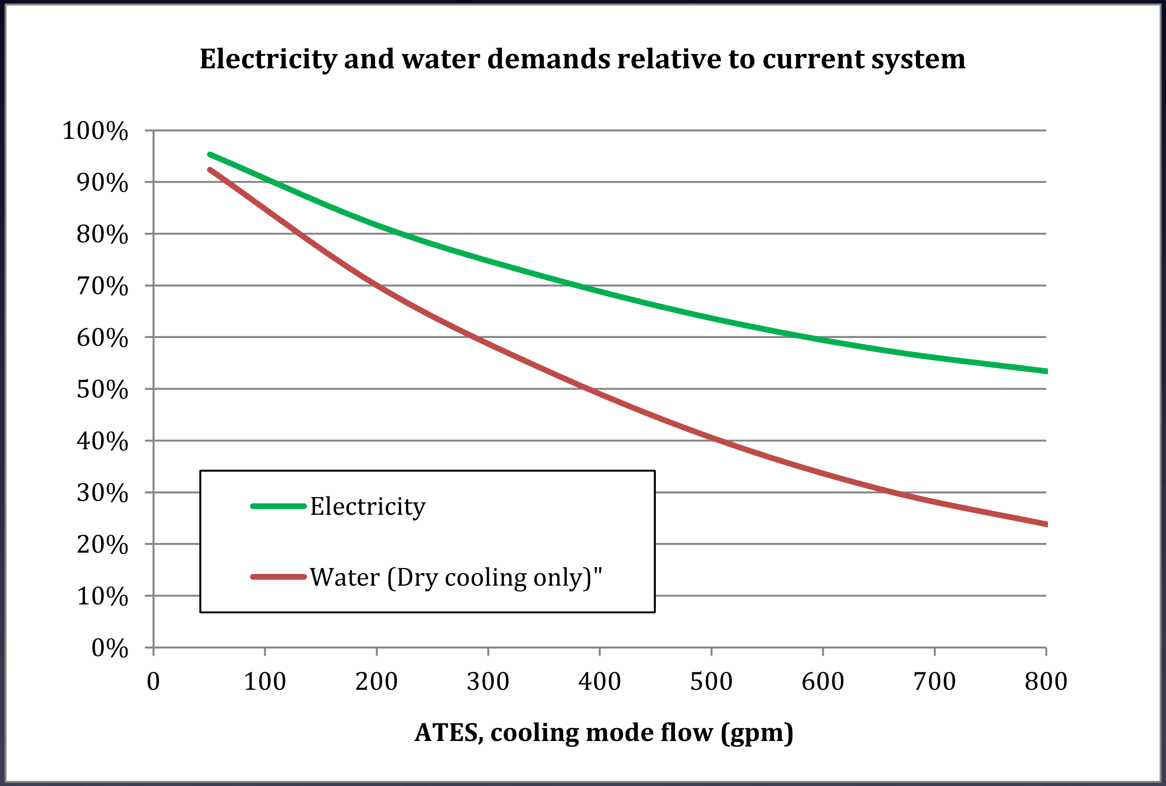
ATES Engineering Evaluation

Chillicothe



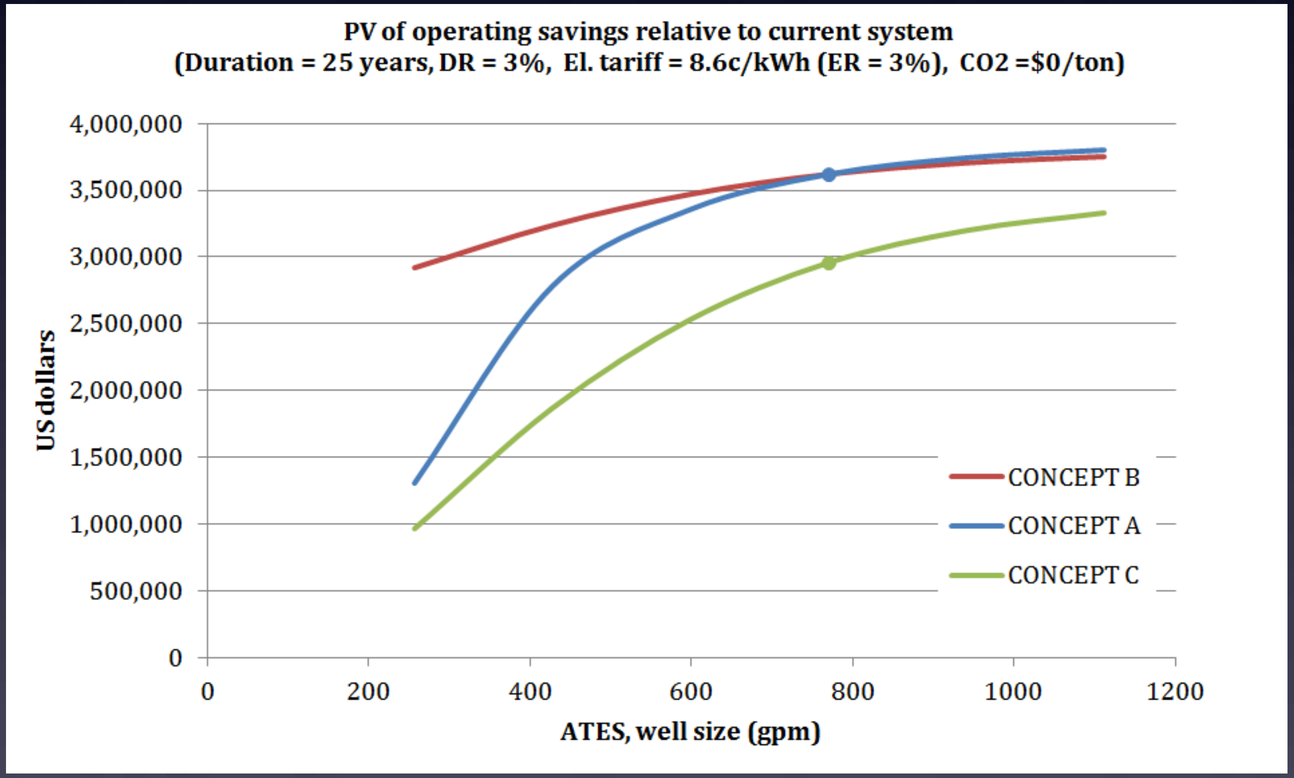
Columbus

(cooling-only scenario)

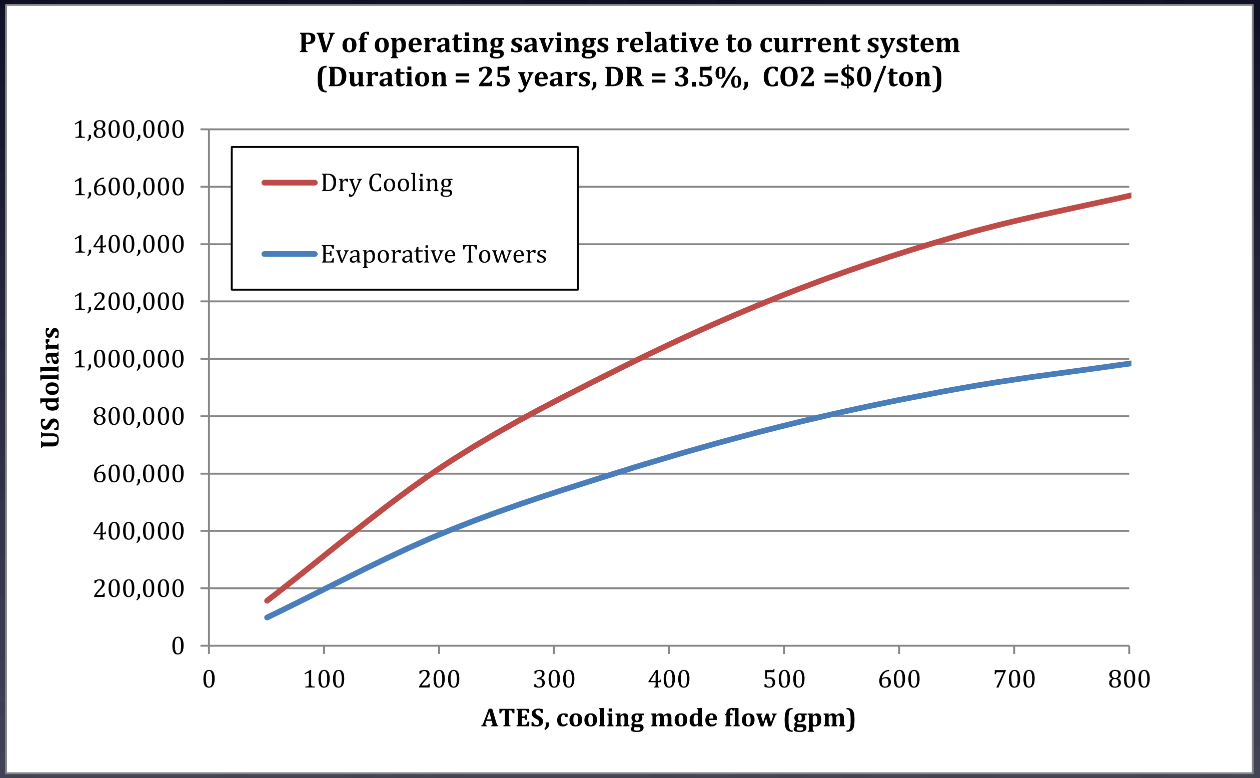


ATES Engineering Evaluation

Chillicothe



Columbus



ATES Financial Evaluation

Capital Expenditures

Chillicothe

Chillicothe ATES - CAPEX - Scenario 1	Concept A (k$)	Concept B (k$)	Concept C (k$)
Geothermal System	**$2,100**	**$2,100**	**$2,100**
2 x 2 24" wells, 90 ft deep	$380	$380	$380
Well housings, pumps & equipment	$250	$250	$250
Utility Services - Electricity for well pumps & equipment	$110	$110	$110
Piping and control cables between wells and ETS	$1,360	$1,360	$1,360
Energy Transfer Station	**$1,700**	**$1,820**	**$520**
Building	$160	$160	$80
Electrical	$550	$670	$100
Mechanical	$310	$310	$140
Major Equipment (PHE, Chillers,CT, EG etc)	$680	$680	$200
DC Distribution Piping	**$1,000**	**$1,000**	**$840**
Underground DC Piping and control cables	$880	$880	$720
Building Interconnections	$120	$120	$120
Customer Buildings	**$370**	**$370**	**$370**
Piping and control cables within building	$100	$100	$100
Building system modifications (delta T related)	$240	$240	$240
Addition constr. cost for building #31	$30	$30	$30
GC Admin, OH&P & Sales Tax	**$620**	**$640**	**$350**
Subtotal Construction	**$5,790**	**$5,930**	**$4,180**
Soft Costs			
Engineering	$460	$480	$300
Owners Costs	$370	$380	$210
Subtotal Soft Costs	**$830**	**$860**	**$510**
TOTAL Project Costs			
Construction Costs	**$5,790**	**$5,930**	**$4,180**
Soft Costs	**$830**	**$860**	**$510**
TOTAL	**$6,620**	**$6,790**	**$4,690**

Columbus

Columbus ATES - CAPEX	Scen. A (k$)	Scen. B1 (k$)	Scen. B2 (k$)
Geothermal System	**$1,190**	**$810**	**$810**
Wells	$510	$340	$340
Well housings, pumps & equipment	$340	$240	$240
Utility Services - Electricity for well pumps & equipment	$80	$60	$60
Piping and control cables between wells and ETS	$260	$170	$170
Energy Transfer Station	**$300**	**$520**	**$1,030**
Electrical	$30	$50	$80
Mechanical	$100	$160	$240
Major Equipment (HEX, HP,CT etc)	$170	$310	$710
Distribution Piping	**$0**	**$80**	**$80**
Underground HW DPS and control cables	$0	$80	$80
Customer Buildings	**$60**	**$150**	**$150**
HW Piping and control cables within building	$0	$50	$50
Building system modifications (delta T related)	$60	$100	$100
GC Admin, OH&P, Constr. Supervision	**$230**	**$230**	**$310**
Subtotal Construction	**$1,780**	**$1,790**	**$2,380**
Soft Costs			
Engineering	$230	$230	$270
Owners Costs	$130	$130	$180
Subtotal Soft Costs	**$360**	**$360**	**$450**
TOTAL Project Costs			
Construction Costs	**$1,780**	**$1,790**	**$2,380**
Soft Costs	**$360**	**$360**	**$450**
TOTAL	**$2,140**	**$2,150**	**$2,830**

ATES Financial Evaluation

Present Value of Financial Benefit (25 yrs)

Chillicothe

(kUSD)	Inv.	Avoided Exp.	Var. op. savings	Fix. op. savings	TOT
Concept A	-6,620	3,280	3,620	500	780
Concept B	-6,790	3,280	3,620	500	610
Concept C	-4,690	0	2,960	0	-1,730

Columbus

(k$)	Inv.	Avoided Exp.	Var. op. savings	Fix. op. savings	NET
Scenario A	-2,140	1,020	950	180	10
Scenario B1	-2,150	750	1,920	-50	470
Scenario B2	-2,830	750	2,950	-350	520

- Avoided expenditures
  - No need for immediate additional chiller capacity due to planned expansion of Buildings 30 and 31.
  - Reduction of future chiller replacements.
    - Due to reduced chiller loads and to refrigerant phase out schedule
- Operating savings
  - Electrical cost savings
  - Centralized chillers reduce the costs of operating and maintaining individual building chillers
- Potential for Utility Rebate from AEP Prescriptive Program
  - $80/ton for ground-sourced heat pump systems with EER >17
  - $30/hp for variable speed drives on chillers
  - Assistance with design fees

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 100,000 or more gallons per day (gpd) 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.

Phase I Conclusions

- ATES is feasible at both VAMC facilities, and no fatal flaws have been identified in Phase I.
- Buildings connected to the ATES system will need to be retrofitted to provide a higher return temperature and improve ΔTs.
- Other than localized thermal impacts in the aquifer and temporary construction impacts, the ATES projects will have minimal adverse environmental impact.
- Subject to utility review and approval, a prescriptive program for a utility rebate from AEP could provide approximately $50k toward new equipment, and also help offset design fees.
- Prior to Phase II FS work, a hydrogeologic investigation is being performed confirm aquifer extents, ATES well locations, yields, and to verify that the hydraulic gradient and geochemistry are suitable for ATES.

Summary

Phase I ATES Feasibility Study

	Chillicothe	Columbus
ATES System Size	450 tons cooling	380 tons cooling 5,260 MBH heating
ATES System Flow Rate	770 gpm	360-700 gpm
ATES Percent of Cooling Load	73%	43%
Reduction in Electricity Use	70%	28-49%
25-year CO_2 Reduction	34,000 metric tons	13,000-32,000 metric tons
Capital Cost	\$6.6 M	\$2.2 M
Capital cost / Ton Cooling	\$14,700/Ton	\$5,600/Ton
NPV	\$0.8 M	\$0.5 M

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.