#3016

A Groundwater-Source Heat Pump System with Enhanced Aquifer Thermal Energy Storage (E-ATES) for Cooling and Heating of Shinshu University Building

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28.4 - Session 2 - Groundwater for energy and mining (13:45-14:00)

Outline of the Research Project

- In 2010, a pilot project of **enhanced aquifer thermal energy storage** (E-ATES) was initiated **for cooling and heating** lecture rooms (108 m^2 each) at Shinshu University **with or without heat pumps**.
- Main feature of this project is to **maximize heat and cold recovery** by optimizing withdrawal and injection at distributed wells.
- **Numerical simulations** were also performed to analyze heat and cold in aquifer systems in order to achieve the optimization.
- Results of **the heating experiments** during November 2011 to March 2012 and **the cooling experiments** from this June up to now will be summarized here.

Why is the E-ATES for Groundwater-Source HP System?

◆ Goal of this project is to establish Groundwater-Source HP systems

- which assure SCOP **that is 1.7 times higher** than conventional Air-Source HP systems,
- which assure **low initial cost** that can be recovered within 10 years,
- which assure **long life**.

SCOP : **S**ystem **C**o-efficient **o**f **P**erformance

$$= \frac{\textit{Quantity of Heat Supplied or Removed}}{\textit{Energy Required by the Whole System}}$$

How does the E-ATES for Groundwater-Source HP System work?

◆ E-ATES is based on

- **efficient underground storage** of cold and heat that is discharged from Groundwater-Source HP systems,
- **maximized recovery** of stored cold and heat in aquifer systems by controlling groundwater flow,
- installation of **water treatment** for preventing clogging of geologic pores and adhesion of scaling materials to pipes and HPs
- use of **free cooling** during summer.

◆ Side effects of this new technology are

- to **save energy** consumption,
- to reduce **CO_2 emission**,
- to mitigate **heat island** in big cities,
- to protect **ecosystems** by controlling thermal plumes.

Project Site of the E-ATES is located in

Well Arrangement for the E-ATES

Hydrogeologic Survey for

Geologic Core Sampling at A3
Electrical Logging at B
Monitoring of Temperature and Piezometric Surface at A1, A2, E1, E2,C1,C2,D1,D2
Thermal Response Tests at TRT site

Recovery Wells

D1 for recovering cold water (Summer)
D2 for recovering warm water (Winter)

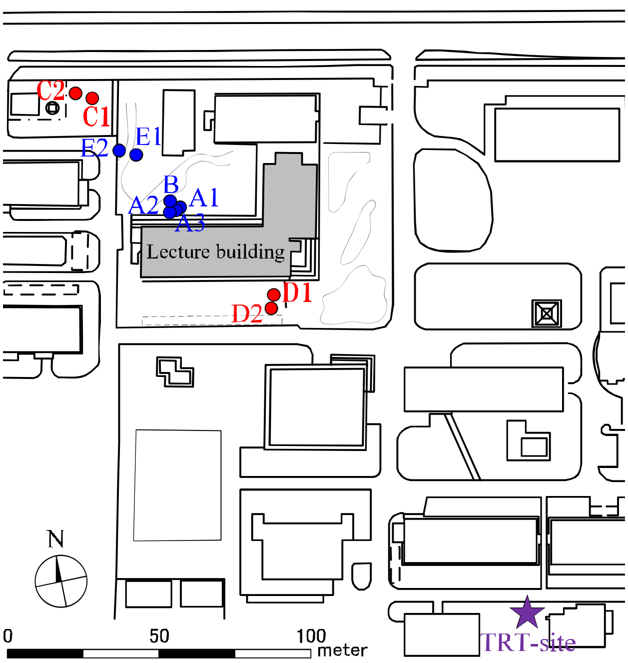
Injection Wells

C1 for injecting cold water (Winter)
C2 for injecting warm water (Summer)

Wells for controlling groundwater flow

A,B, C, D by withdrawal and injection

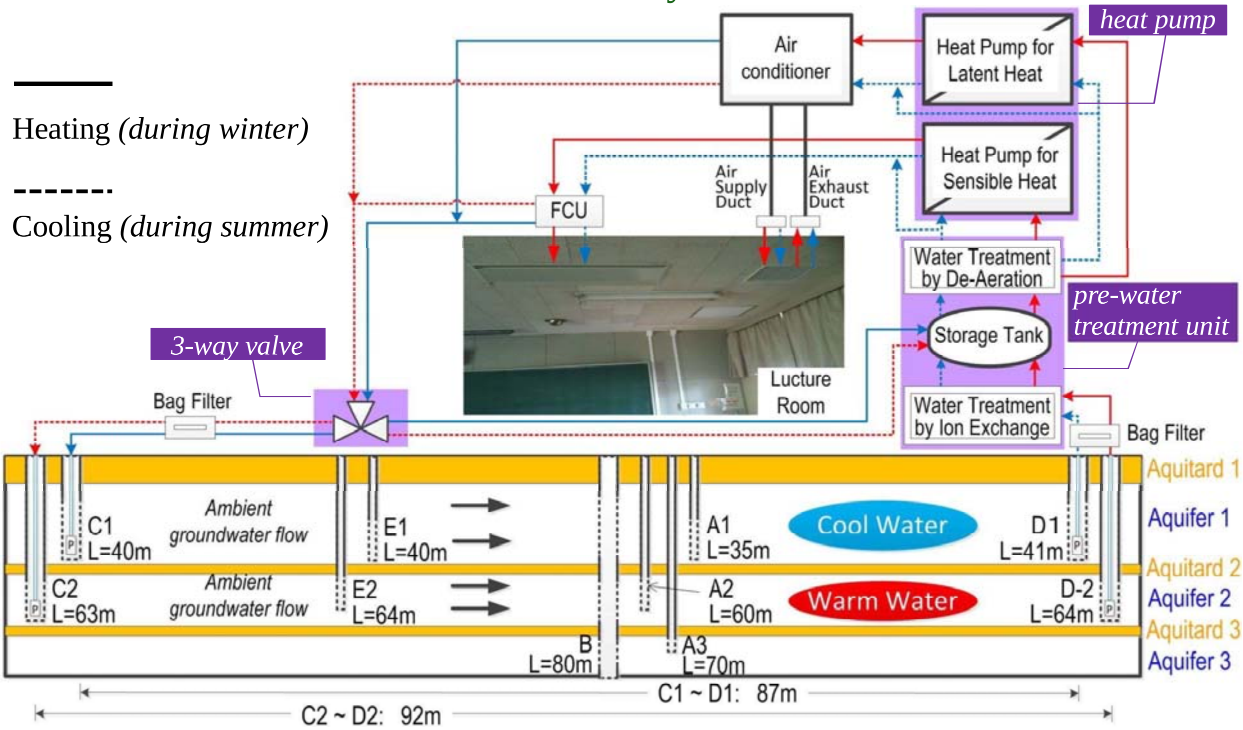
the location of wells for the E-ATES



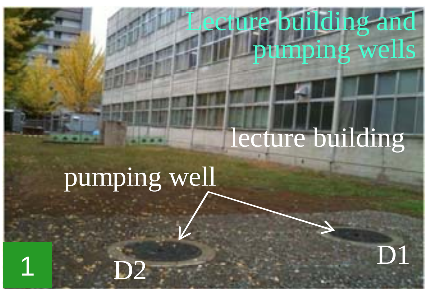
Schematic Diagram of Groundwater-source HP System with E-ATES

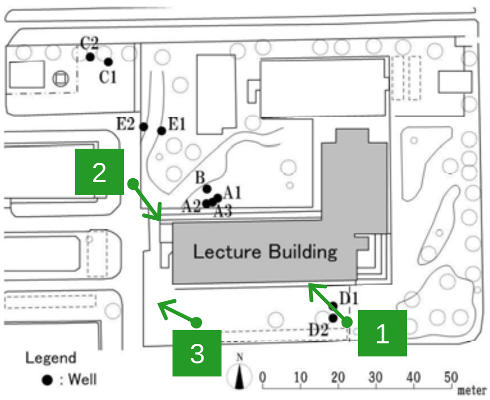
Heating *(during winter)*

Cooling *(during summer)*



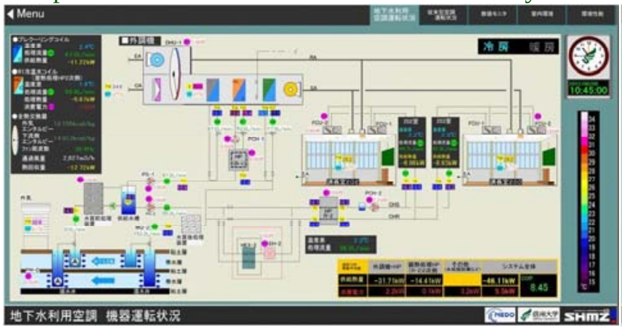
Pilot Project Site



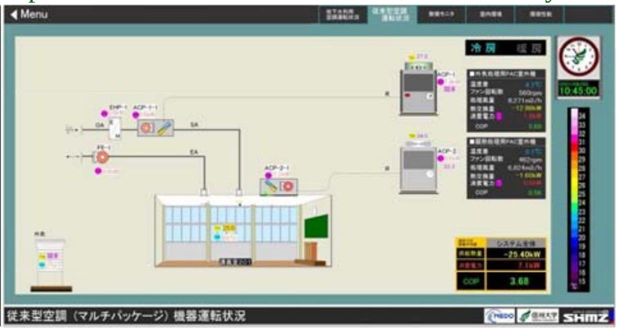


Monitoring System for Groundwater-SHP and Air-SHP systems

Operational State of the Groundwater-SHP system



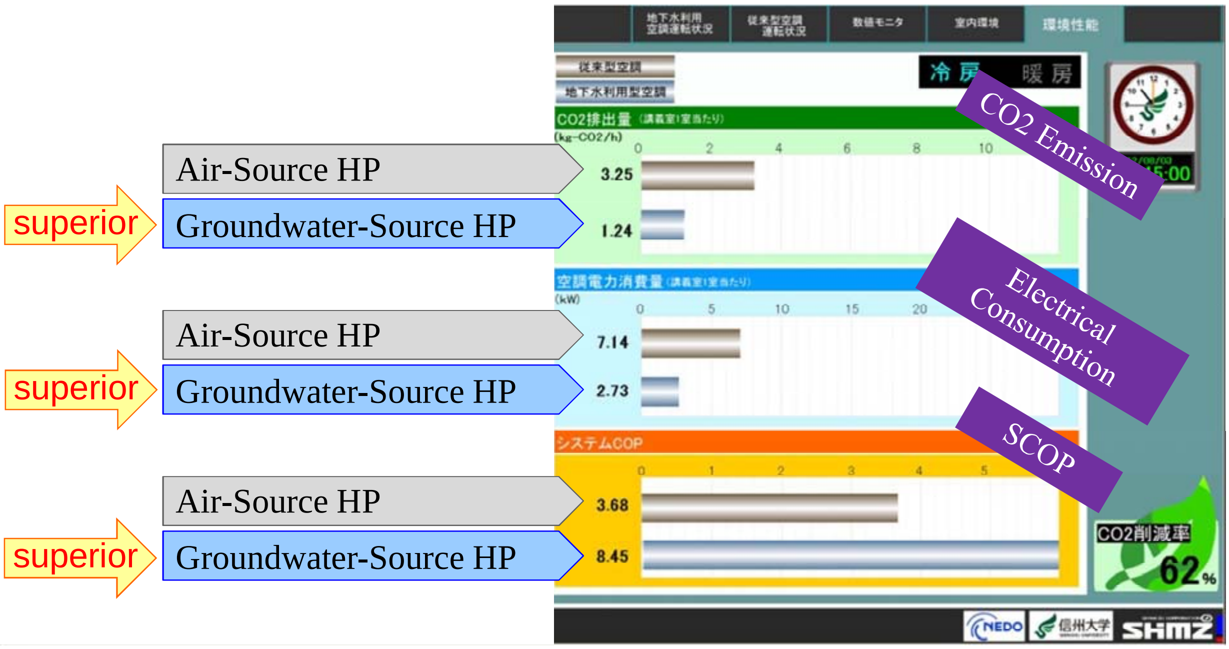
Operational State of the Conventional Air-SHP system



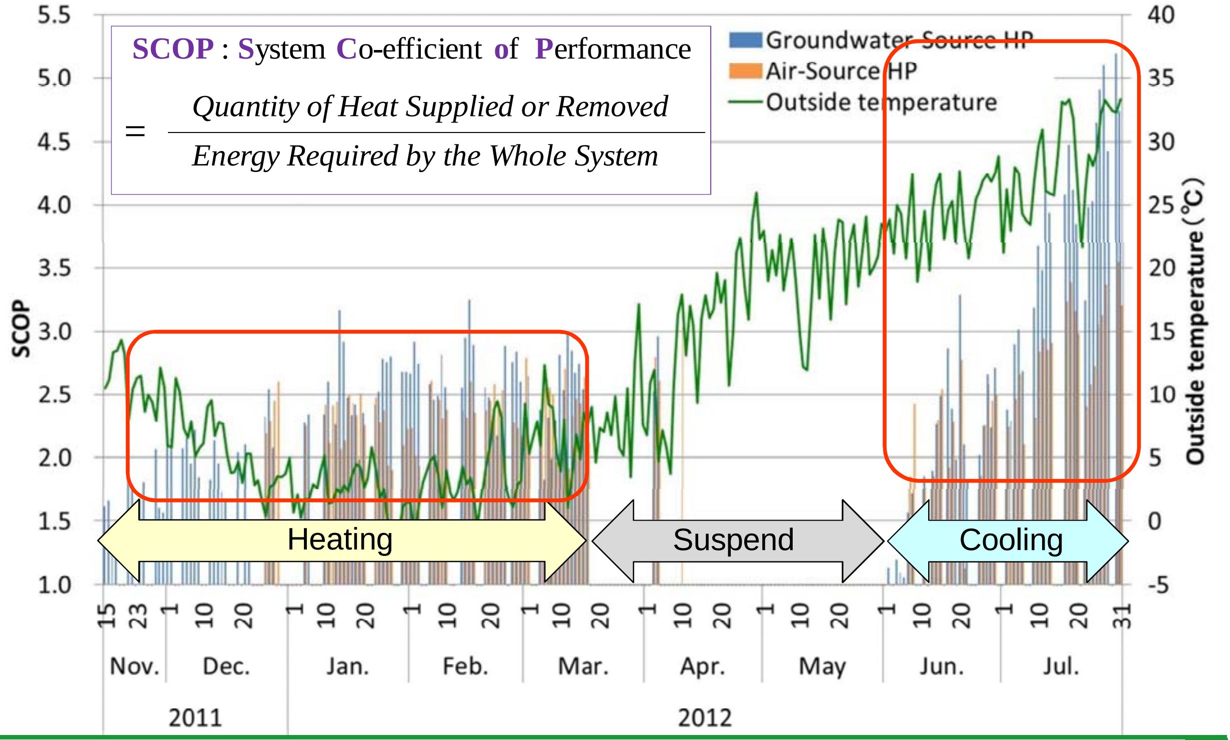
Real Time Display of SCOP for GSHP and ASHP with CO2 Emission, Electrical Consumption

Comparison of CO2 Emission, Electrical Consumption and SCOP between Groundwater-SHP and Air-SHP

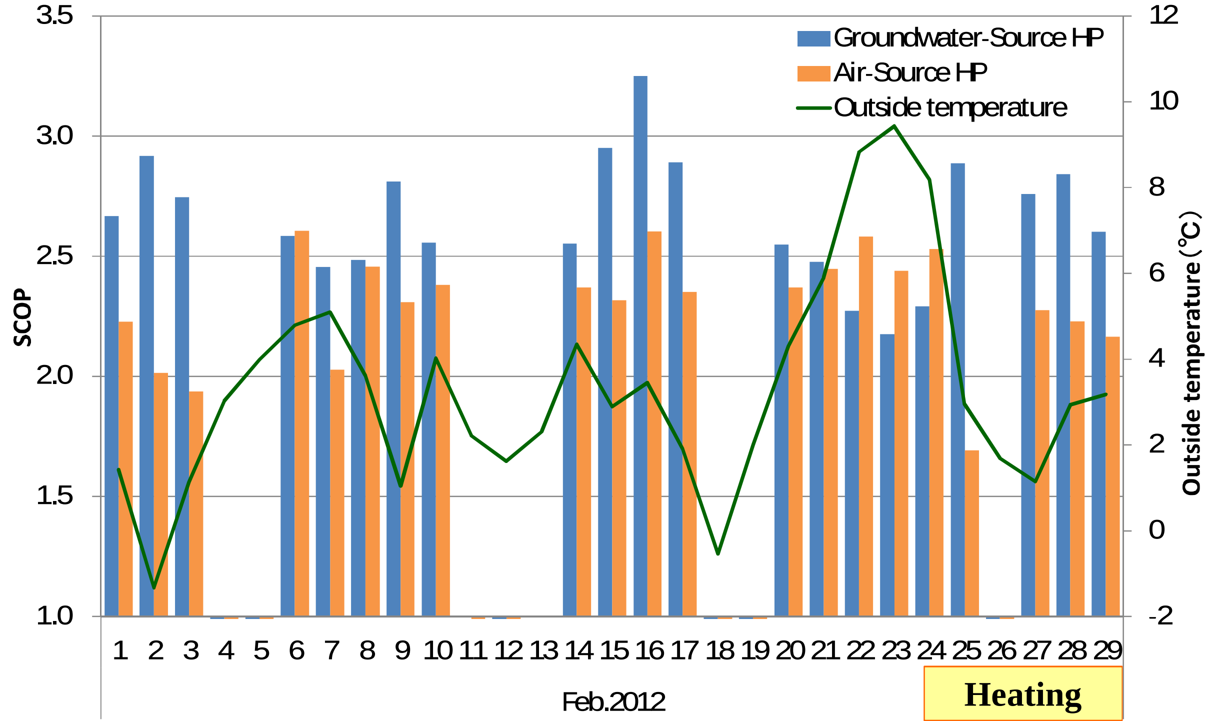
Recorded on 3 Aug, 2012 (during cooling)



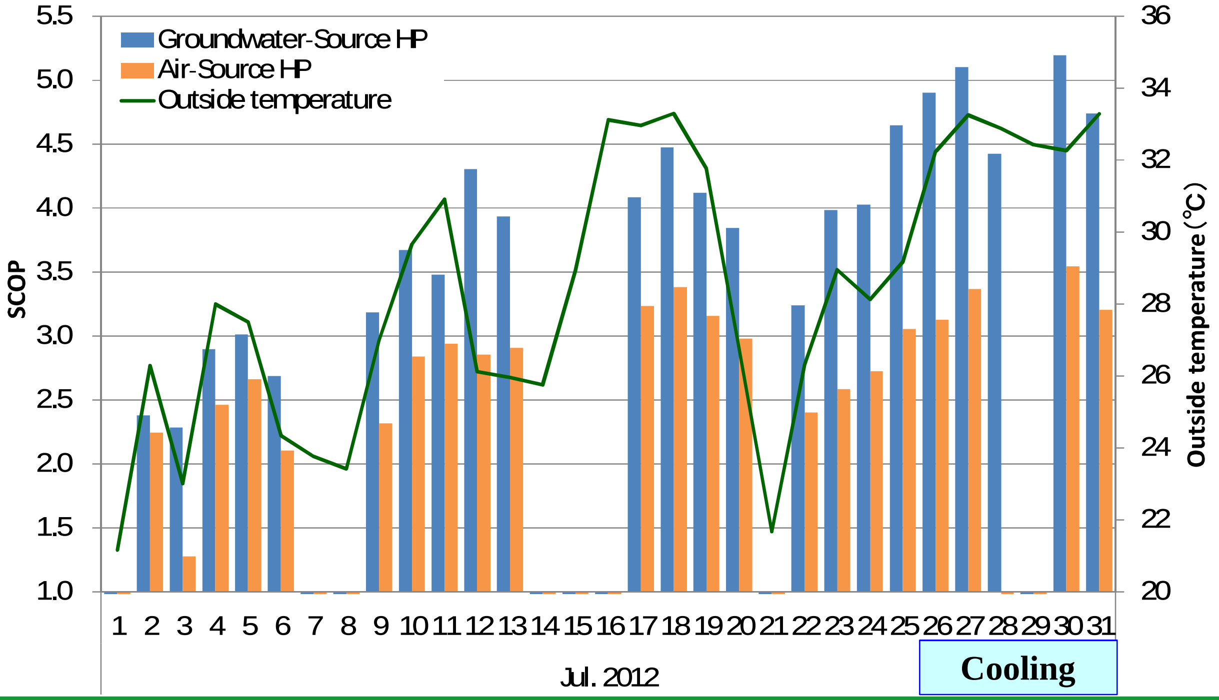
SCOP of Groundwater-SHP and Air-SHP



Comparison of SCOP between Groundwater-SHP and Air-SHP during Heating Operation



Comparison of SCOP between Groundwater-SHP and Air-SHP during Cooling Operation



Conditions Performed for Heating Operation

Operation mode	Period	Pumping and injection rate	Injected water temperature
	Date	(㎥/hour)	
Heating	2011/11/15～2012/3/17	1.3～11.5	8.2～13.9 C°
Suspend	2012/3/18～2012/5/31	-	-

◆The above condition was incorporated into numerical simulations for calculating stored cold during the period from November 2011 to March 2012.

Numerical Simulation code applied to the E-ATES

SWATER

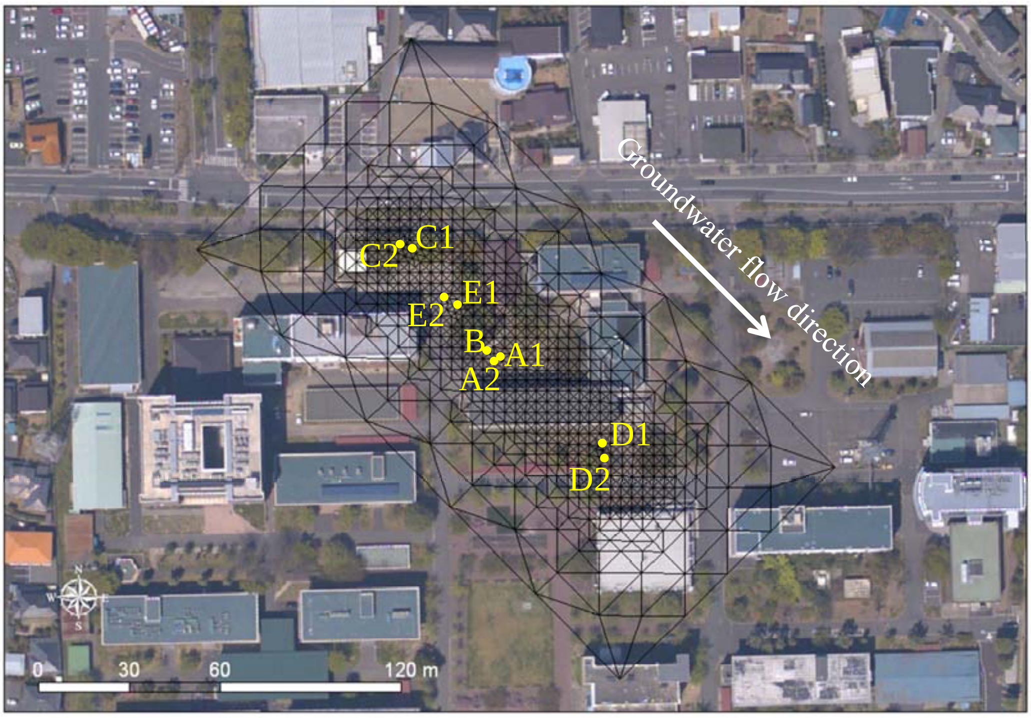
(**S**ubsurface **W**ater **A**nd **T**hermal **E**nergy **R**esources)

coded by K.Fujinawa

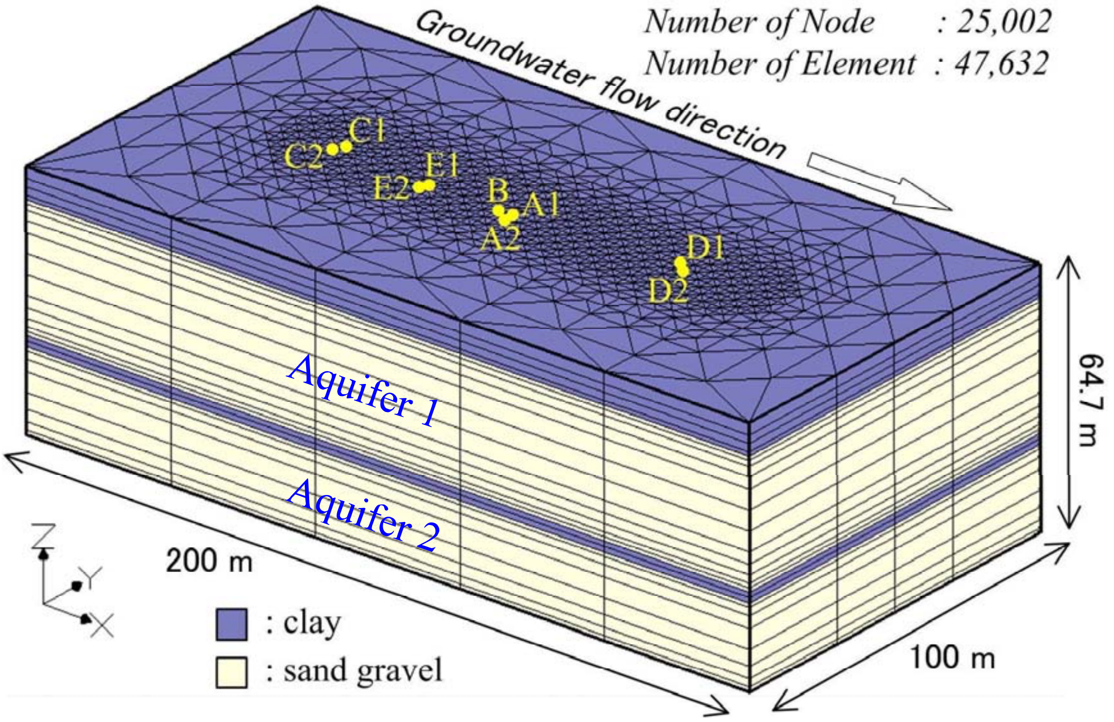
SWATER can solve

- *three dimensional coupled problems*
- *of density-dependent, saturated-unsaturated flow,*
- *and heat transport affected by thermal conduction, thermal dispersion, and forced and natural convection,*
- *based on the Finite Element Method for the flow problem*
- *and the Characteristic Finite Element Method for the heat transport problem*

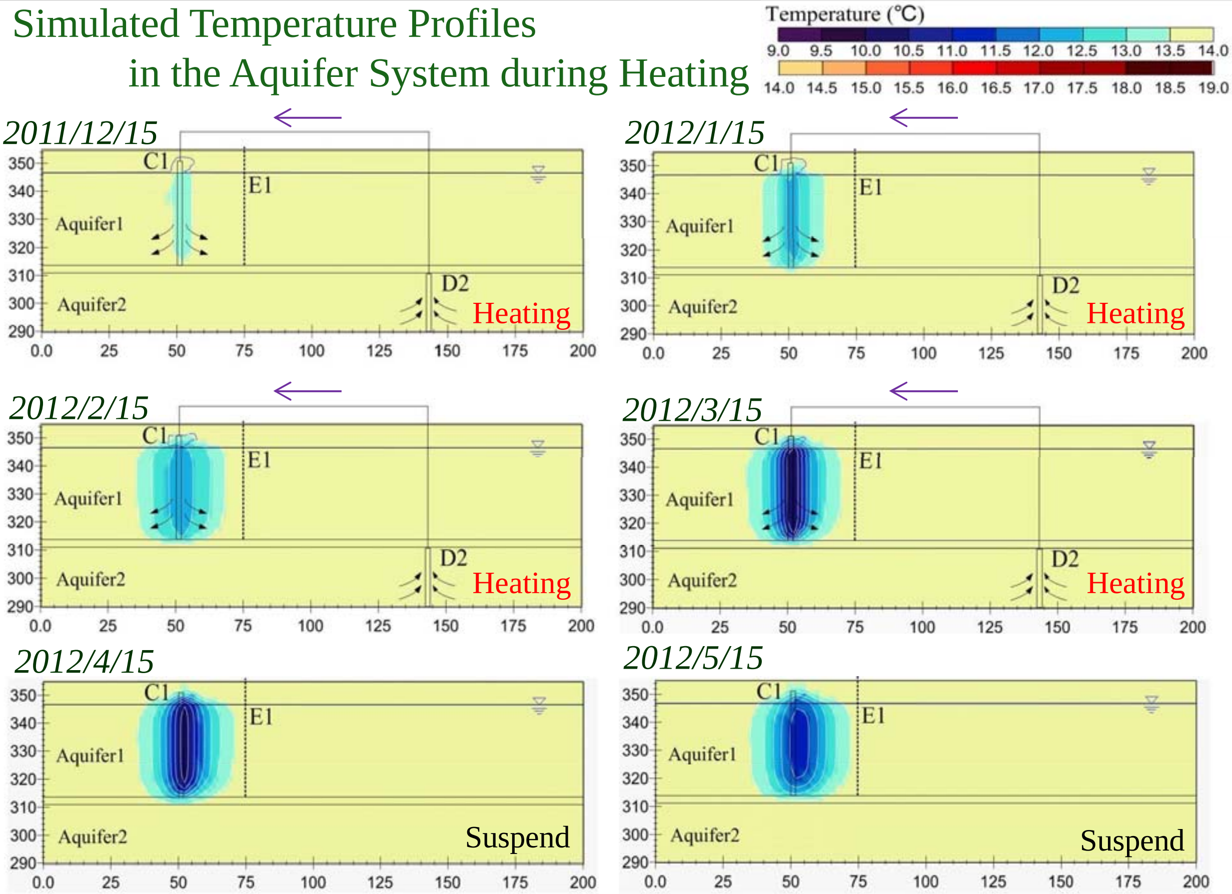
Plane View of Prism Mesh for the Numerical Simulation



3D - FE Mesh Used for Simulating Pilot Project of the E-ATES



Simulated Temperature Profiles in the Aquifer System during Heating

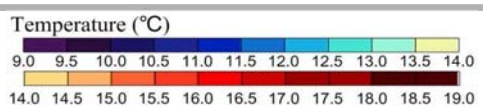


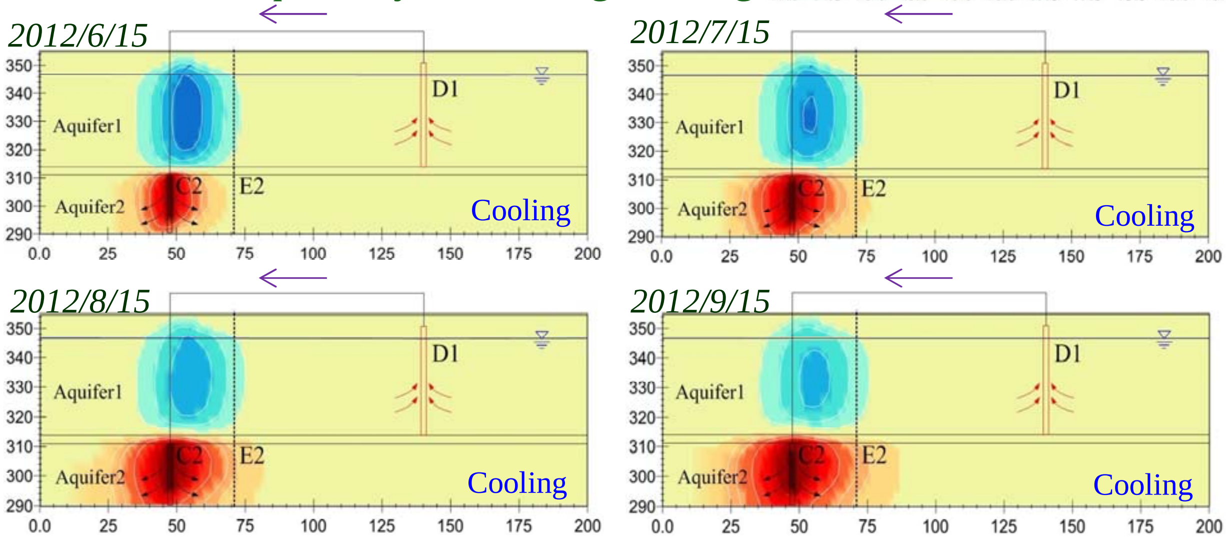
Conditions Projected for Cooling Operation

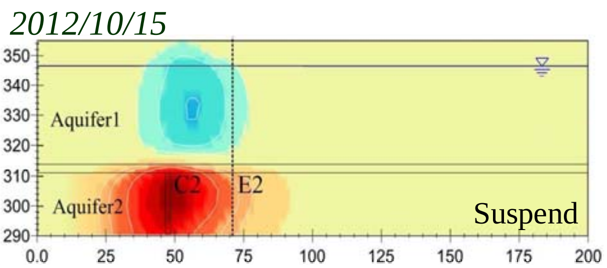
Operation mode	Period / Date	Pumping and injection rate (㎥/hour)	Injected water temperature
Cooling	2012/6/1～2012/9/30	5.0	19.0 C°
Suspend	2012/10/1～2012/10/31	-	-

◆The above condition was incorporated into numerical simulations for calculating stored heat during the period from June 2012 to September 2012.

Simulated Temperature Profiles in the Aquifer System during Cooling







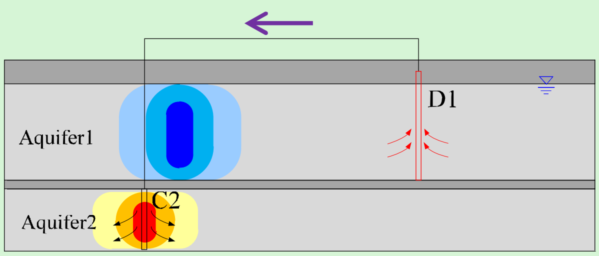
At the moment, groundwater has been withdrawn from D1 and recharged into C2.

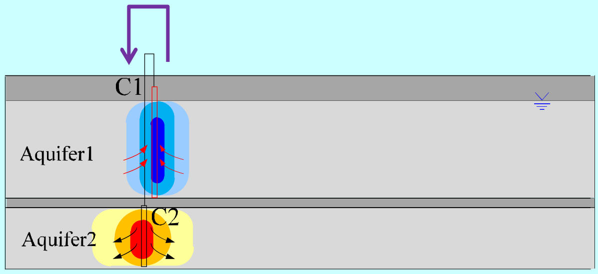
The stored cold during the first winter cannot be recovered during the first summer.

Another Scenario for Recovering Cold

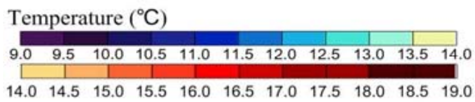
◆In accordance with evolved groundwater conditions, another pumping and recharging scenario was added for trial simulation.

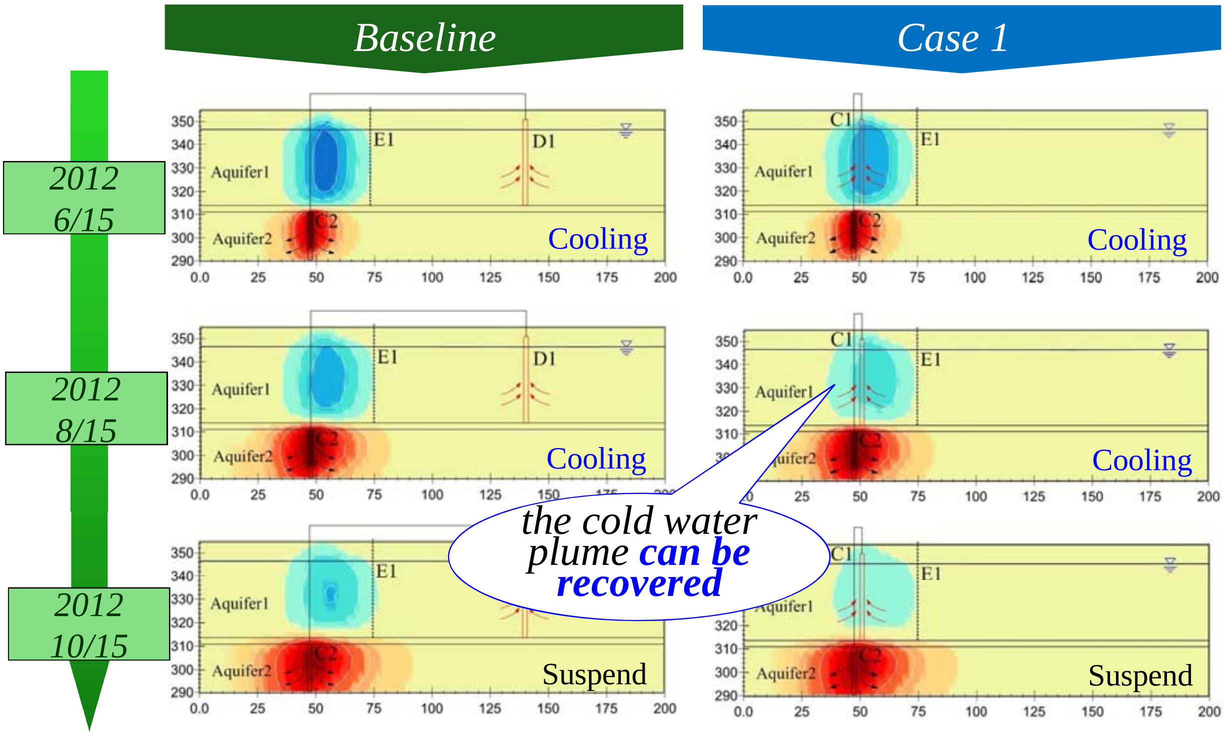
Baseline (Real Operation)	Case1 (Trial Operation)
Pumped from D1 and Recharged into C2	*Pumped from C1 and Recharged into C2*





Comparison of Baseline Temperature Distribution with the Trial Case





Conclusion

- The results of performed experiments during heating from November 2011 to March 2012 revealed that the Groundwater-Source HP system is superior to the conventional Air-Source HP systems.
- Monitoring data of the Groundwater-Source HP system under cooling experiments is exhibiting much higher performance than the heating experiment.
- Results of trial numerical simulations show that the recovery of cold water can be improved by changing pumping and recharging well.

Acknowledgments

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  - Dr. K. Yoneyama of *Shimizu Corp.*, who is in charge of hydraulic analysis,
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Thank you for your attention.