Status for modellering af vand- og varmestrømning

WP7 Interaktion med omgivende grundvandssystem

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GeoEnergi følgegruppemøde 10/4-2013

Disposition

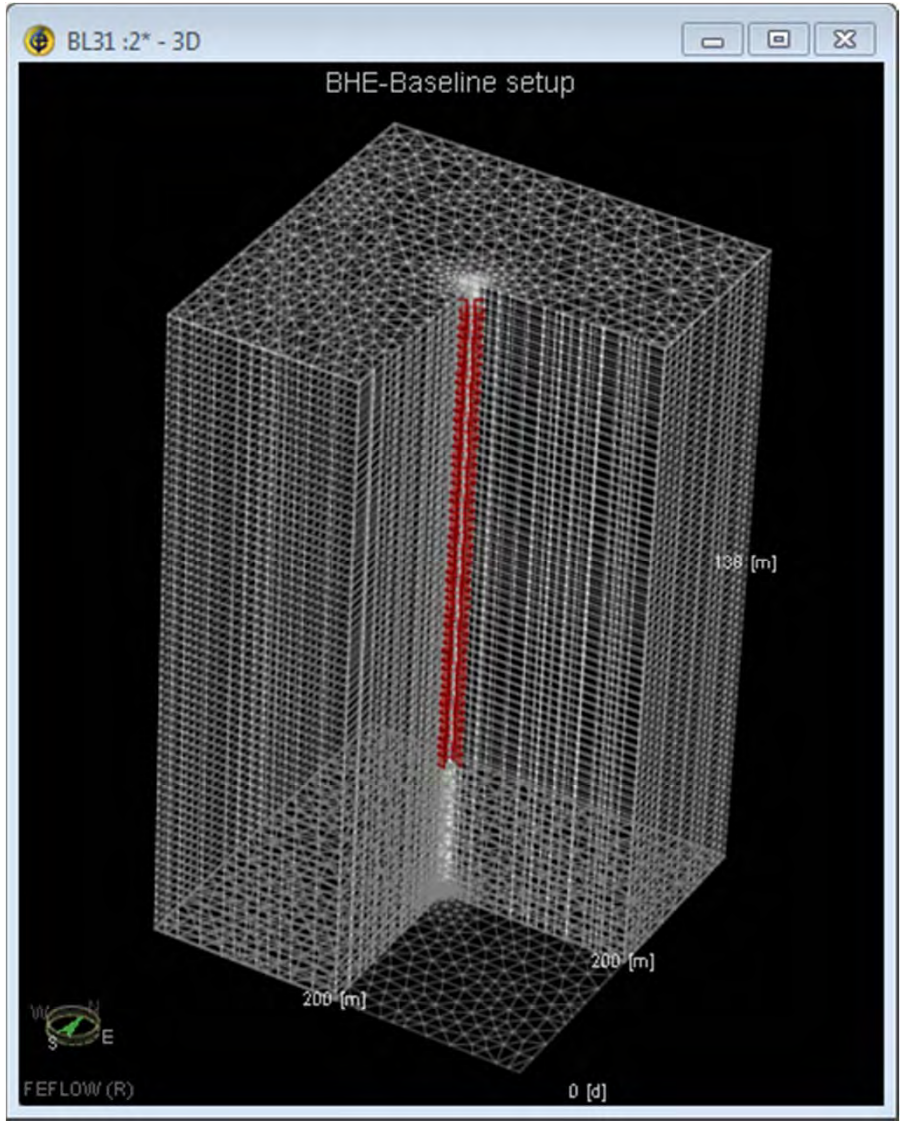
- Formål
- Modelopsætning
- Basis scenarie
- Eksempler på følsomhedsanalyse
- Eksempler på model output
- Udestående udfordringer
- Det videre arbejde
- Sammenfatning

Formål

- Belyse interaktion mellem vertikale varmeboringer og omgivende grundvandssystem:
  - Betydningen af variationer i undergrunden for potentialet for anvendelse af vertikale varmeboringer
  - Vurdere installationernes effekt på det omgivende miljø
  - Scenarier typiske danske hydrogeologiske forhold

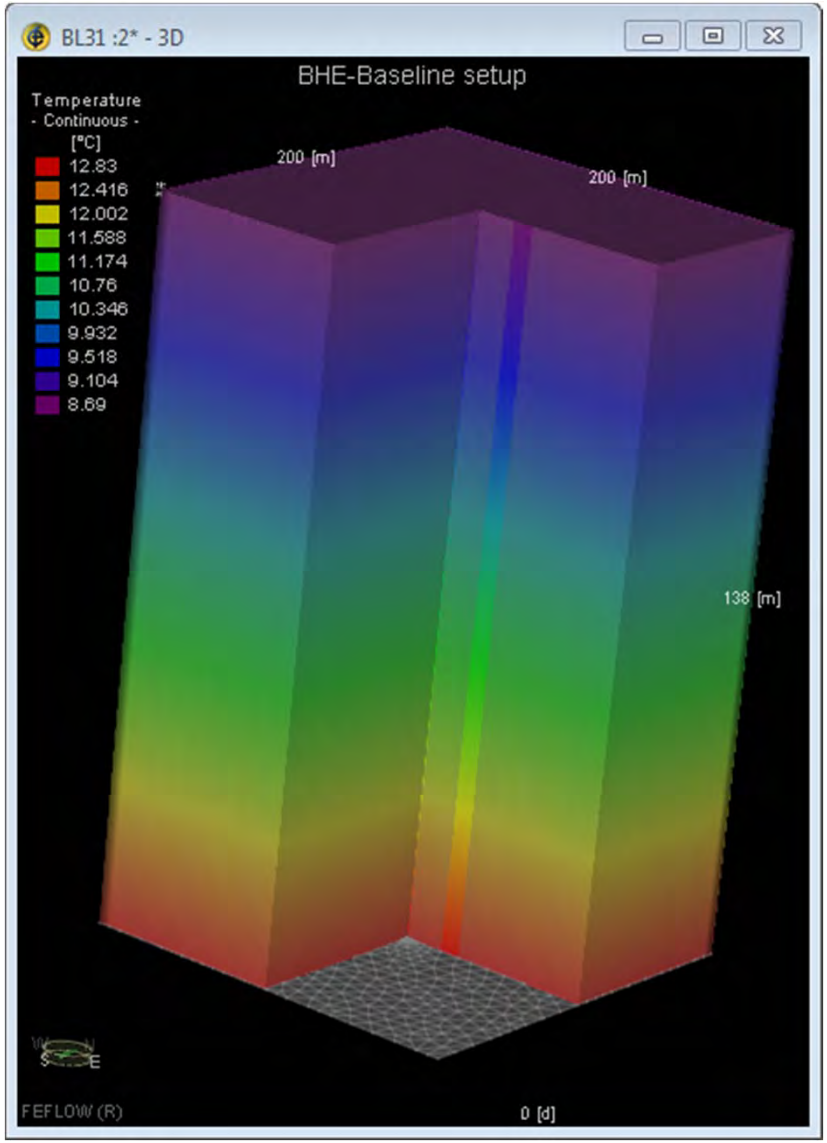
Modelopsætning (1)

- Feflow
  - Modellering af mættet grundvandssystem
  - Vand og temperatur
  - Randbetingelser
    - Fx trykniveau og temperaturgradient
  - Parameterværdier
    - Fx hydraulisk ledningsevne og termisk varmeledningsevne

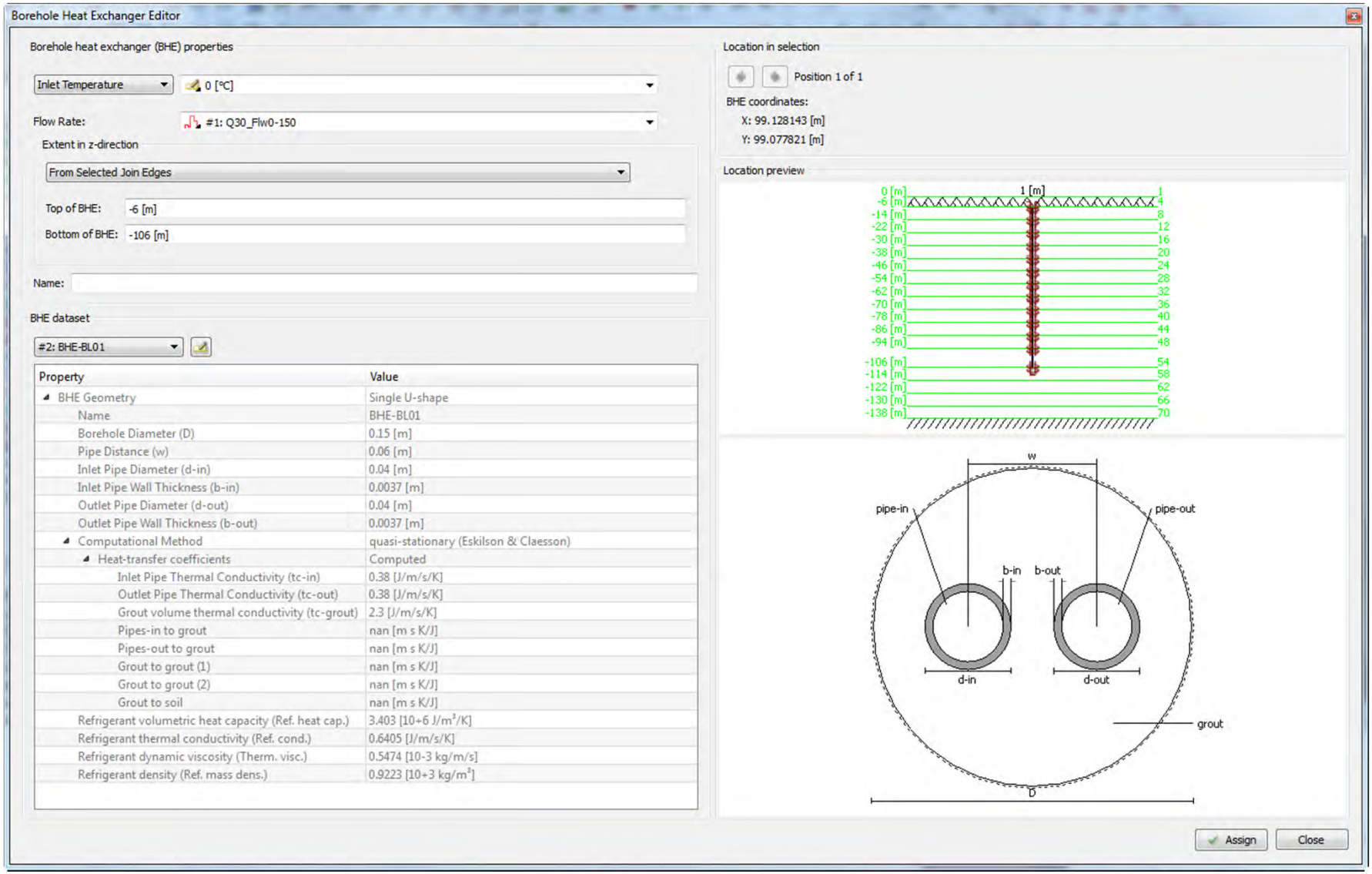


Modelopsætning (2)

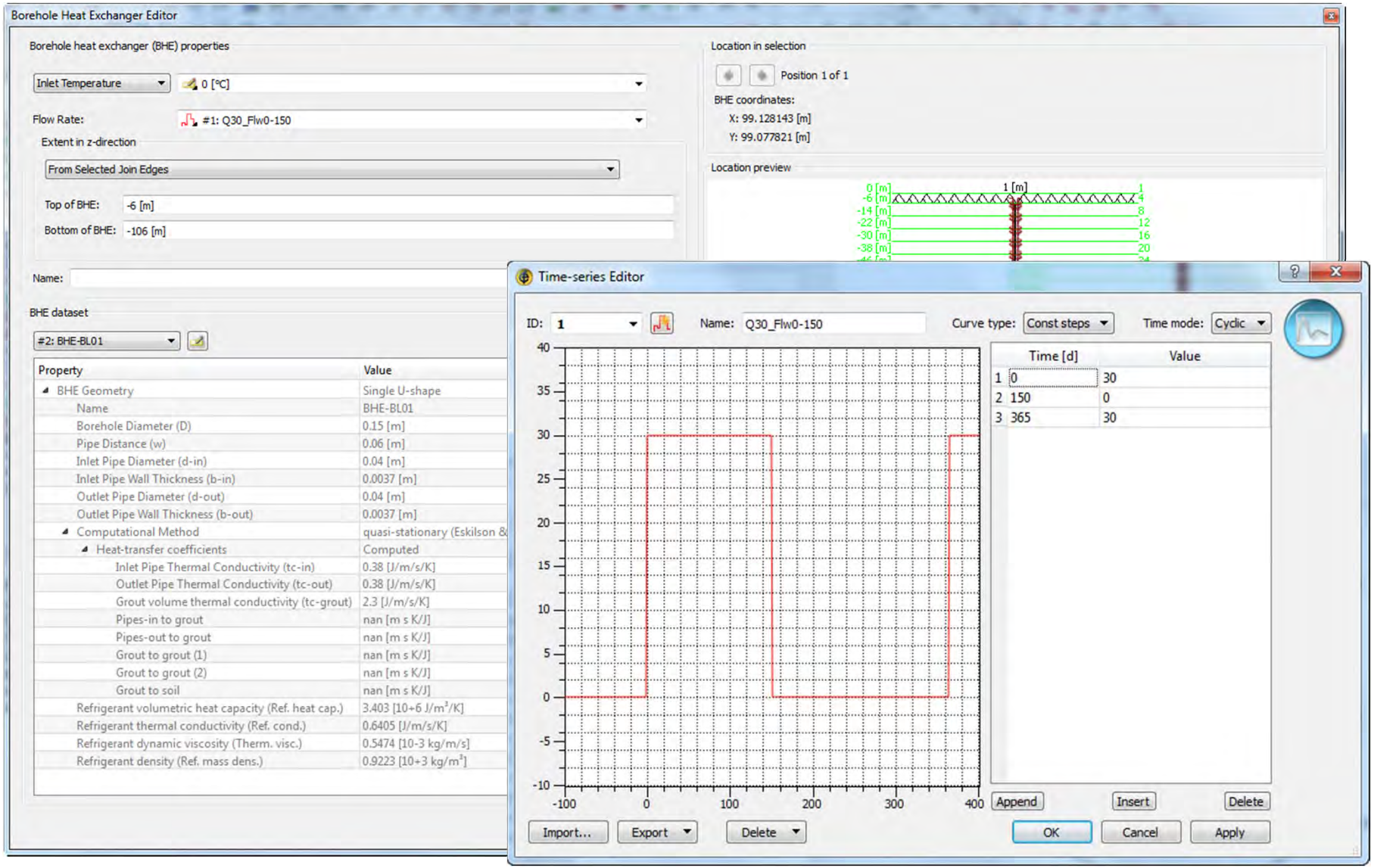
- Feflow
  - Modellering af mættet grundvandssystem
  - Vand og temperatur
  - Randbetingelser
    - Fx trykniveau og temperaturgradient
  - Parameterværdier
    - Fx hydraulisk ledningsevne og termisk varmeledningsevne



Modelopsætning (3)



Modelopsætning (4)



Basis scenarie

GeoEnergi Følsomhedsanalayse				
Variable			enhed	Baseline
Aquifer				
		x	m	200
		y	m	200
		z	m	138
	Sand			
		Hor. hydraulic conductivity (Kx=Ky)	m/s	1,00E-04
		Vertical hydraulic conductivity (Kz)	m/s	1,00E-05
		Porosity	-	0,3
		Longitudinal dispersivity	m	0,2
		Transverse dispersivity	m	0,02
		Volumetric heat capacity	J/m3/K	2,640E+06
		Thermal conductivity	J/m/s/K	2,4
		Anisotropy?	-	1
	Vand			
		Volumetric heat capacity	J/m3/K	4,20E+06
		Thermal conductivity	J/m/s/K	0,65
		Temperature	C	8,69
	Rand			
		Gradient, grundvandsstrømning	promille	3
		Temperatur gradient	C/100m	3
		Temperatur rand, top (3C/100m)	C	8,69
		Temperatur rand, bund (3C/100m)	C	12,83
Borehole				
		Depth	m	100
		Diameter	m	0,15
		Volumetric heat capacity of grout	J/m3/K	2,190E+06
		Grout volume thermal conductivity	J/m/s/K	2,3
Pipes				
		Outer diameter	m	0,04
		Pipe wall thickness	m	0,0037
		Pipe distance (center to center)	m	0,06
		Thermal conductivity of pipe walls	J/m/s/K	0,38
Brine				
		Volumetric heat capacity	J/m3/K	3,403E+06
		Thermal conductivity	J/m/s/K	0,6405
		Dynamic viscosity	kg/m/s	5,4741E-04
		Mass density	kg/m3	9,2225E+02
Operation				
		Inlet T	C	0
		Discharge	m3/d	30
		Flow duration	d	150
		Total time	year	20

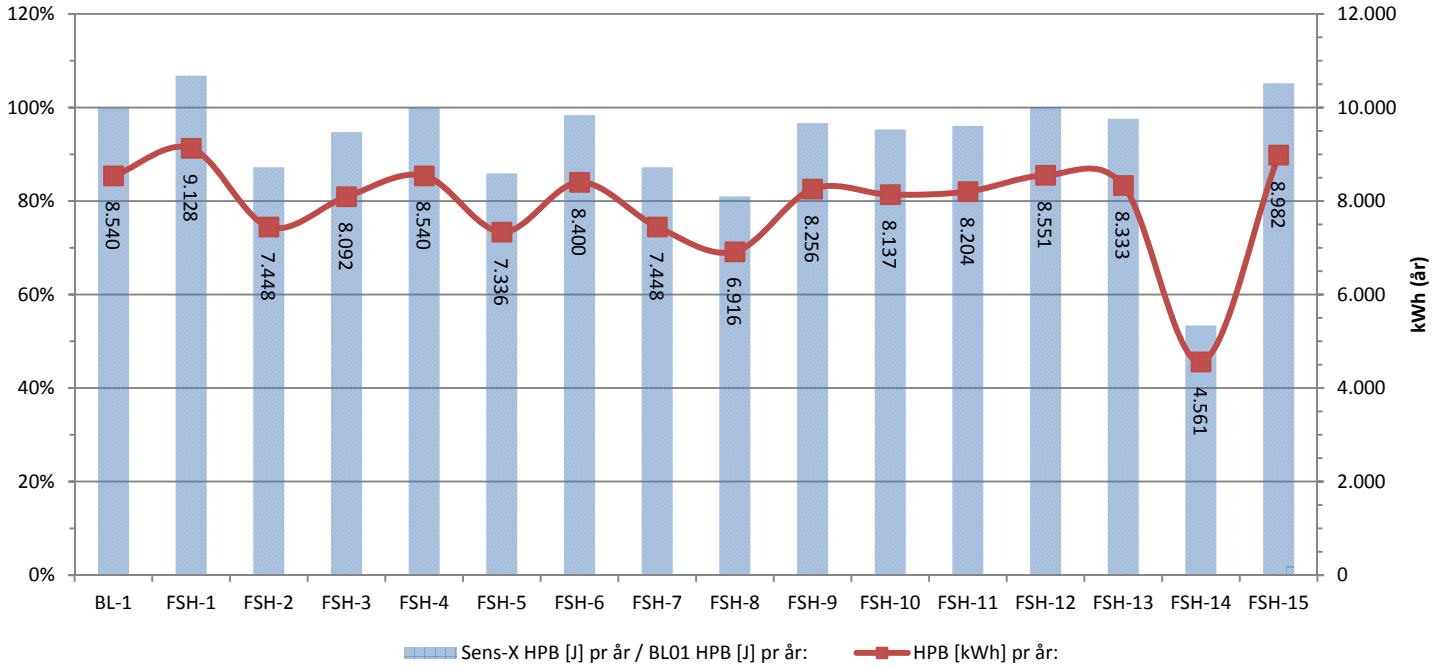
Eksempler på følsomhedsanalyse (1)

GeoEnergi Følsomhedsanalayse																		
Variable		enhed	Baseline	FSH-1	FSH-2	FSH-3	FSH-4	FSH-5	FSH-6	FSH-7	FSH-8	FSH-9	FSH-10	FSH-11	FSH-12	FSH-13	FSH-14	FSH-15
Aquifer																		
	Sand																Plast.ler	Granit
		Hor. hydraulic conductivity (Kx=Ky)	m/s	1,00E-04							1,00E-06						9,70E-08	2,62E-07
		Vertical hydraulic conductivity (Kz)	m/s	1,00E-05							1,00E-07						9,70E-09	2,62E-08
		Longitudinal dispersivity	m	0,2														
		Volumetric heat capacity	J/m3/K	2,640E+06						1,32E+06								
		Thermal conductivity	J/m/s/K	2,4													1,0	3,4
	Rand																	
		Gradient, grundvandsstrømning	promille	3	5	0			0									
		Temperatur gradient	C/100m	3			2											
		Temperatur rand, top (3C/100m)	C	8,69				ingen	ingen									
		Temperatur rand, bund (3C/100m)	C	12,83				ingen	ingen									
Borehole																		
		Depth	m	100							75	110	120	125	100	125		
Pipes																		
		Pipe distance (center to center)	m	0,06											0,07	0,07		

Eksempler på følsomhedsanalyse (2)

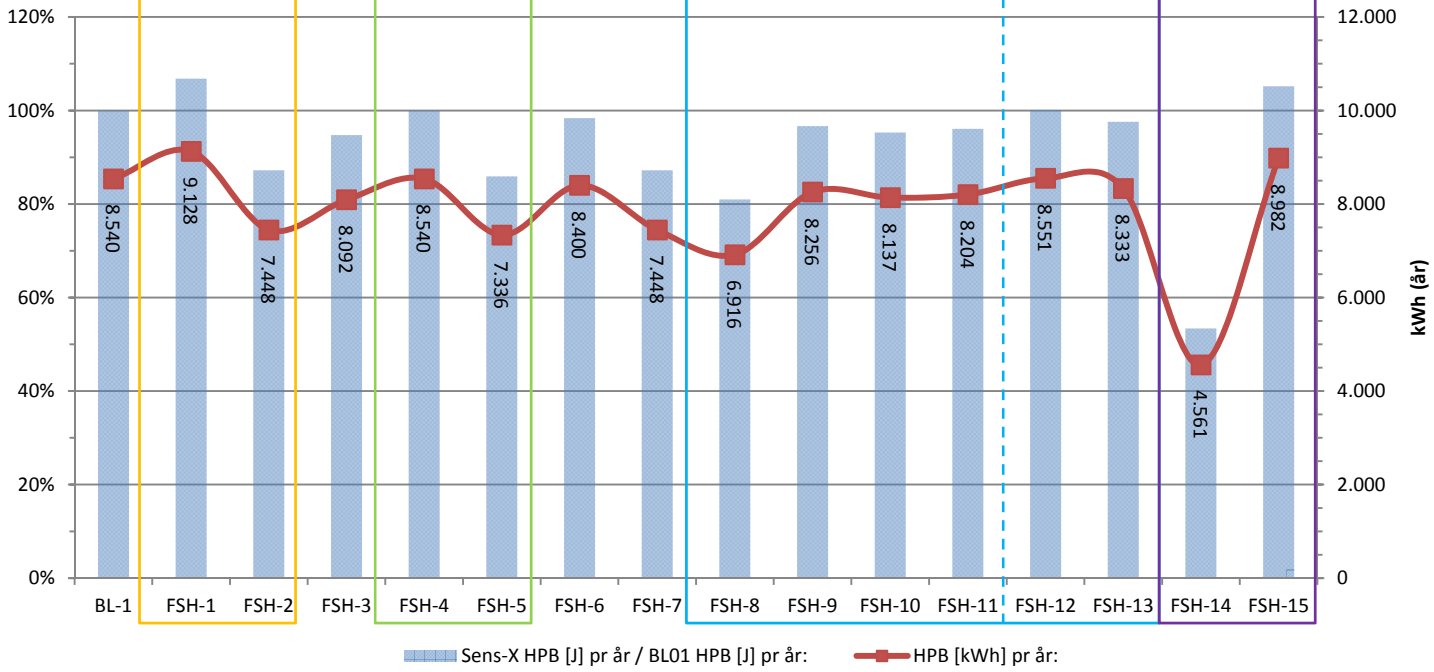
GeoEnergi Følsomhedsanalayse																		
Variable		enhed	Baseline	FSH-1	FSH-2	FSH-3	FSH-4	FSH-5	FSH-6	FSH-7	FSH-8	FSH-9	FSH-10	FSH-11	FSH-12	FSH-13	FSH-14	FSH-15
Aquifer																		
	Sand																Plast.ler	Granit
		Hor. hydraulic conductivity (Kx=Ky)	m/s	1,00E-04							1,00E-06						9,70E-08	2,62E-07
		Vertical hydraulic conductivity (Kz)	m/s	1,00E-05							1,00E-07						9,70E-09	2,62E-08
		Longitudinal dispersivity	m	0,2														
		Volumetric heat capacity	J/m3/K	2,640E+06						1,32E+06								
		Thermal conductivity	J/m/s/K	2,4													1,0	3,4
	Rand																	
		Gradient, grundvandsstrømning	promille	3	5	0			0									
		Temperatur gradient	C/100m	3			2											
		Temperatur rand, top (3C/100m)	C	8,69				ingen	ingen									
		Temperatur rand, bund (3C/100m)	C	12,83				ingen	ingen									
Borehole																		
		Depth	m	100							75	110	120	125	100	125		
Pipes																		
		Pipe distance (center to center)	m	0,06											0,07	0,07		

Eksempler på følsomhedsanalyse (3)

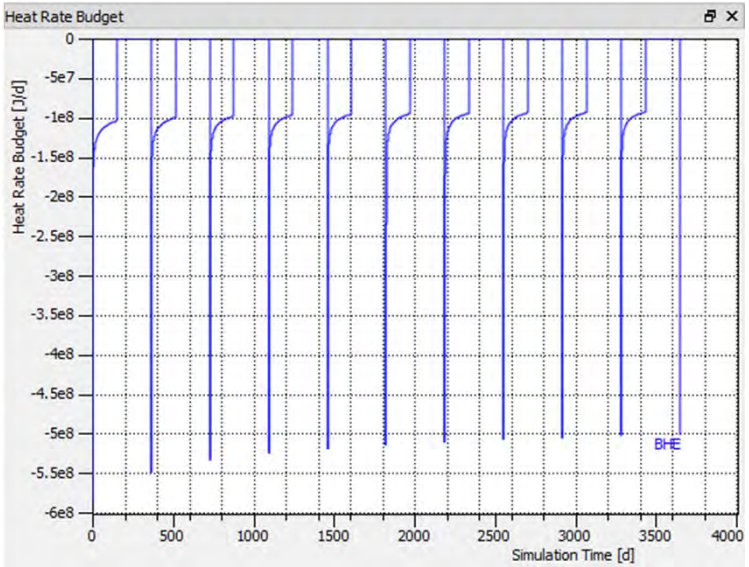


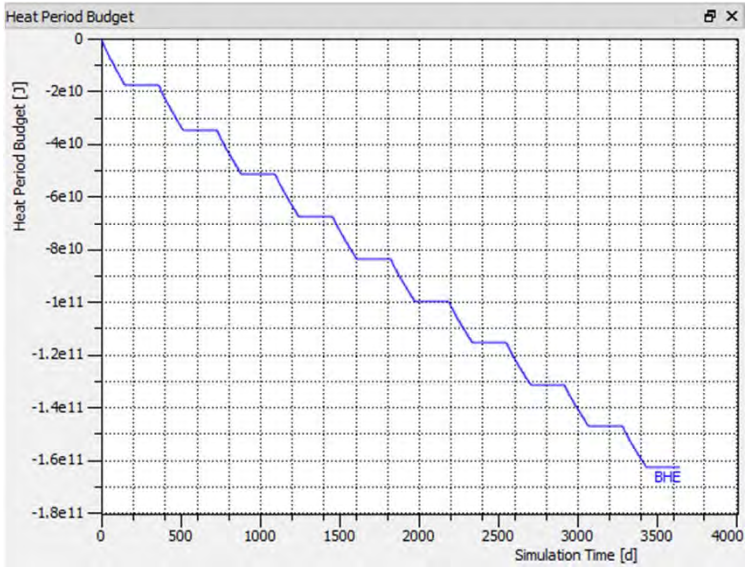
Eksempler på følsomhedsanalyse (4)

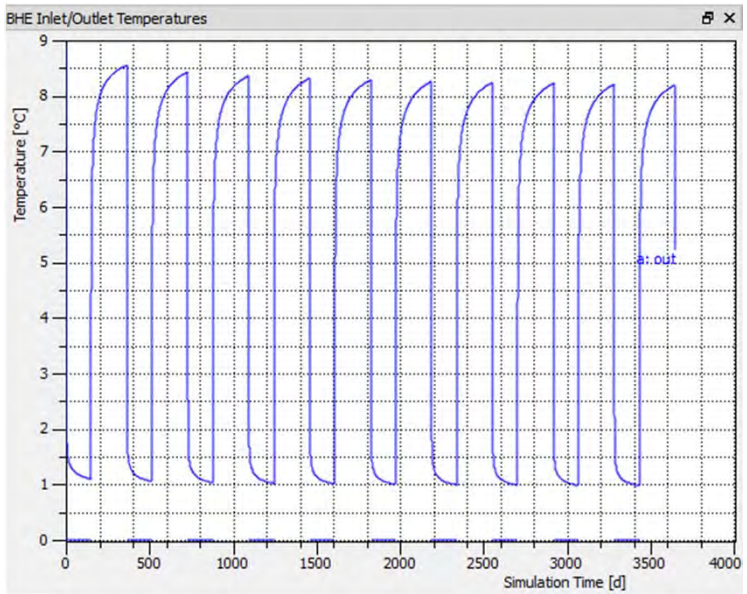
GeoEnergi Følsomhedsanalayse																		
Variable		enhed	Baseline	FSH-1	FSH-2	FSH-3	FSH-4	FSH-5	FSH-6	FSH-7	FSH-8	FSH-9	FSH-10	FSH-11	FSH-12	FSH-13	FSH-14	FSH-15
Aquifer																		
	Sand																Plast.ler	Granit
		Hor. hydraulic conductivity (Kx=Ky)	m/s	1,00E-04							1,00E-06						9,70E-08	2,62E-07
		Vertical hydraulic conductivity (Kz)	m/s	1,00E-05							1,00E-07						9,70E-09	2,62E-08
		Longitudinal dispersivity	m	0,2														
		Volumetric heat capacity	J/m3/K	2,640E+06						1,32E+06								
		Thermal conductivity	J/m/s/K	2,4													1,0	3,4
	Rand																	
		Gradient, grundvandsstrømning	promille	3	5	0			0									
		Temperatur gradient	C/100m	3			2											
		Temperatur rand, top (3C/100m)	C	8,69				ingen	ingen									
		Temperatur rand, bund (3C/100m)	C	12,83				ingen	ingen									
Borehole																		
		Depth	m	100							75	110	120	125	100	125		
Pipes																		
		Pipe distance (center to center)	m	0,06											0,07	0,07		

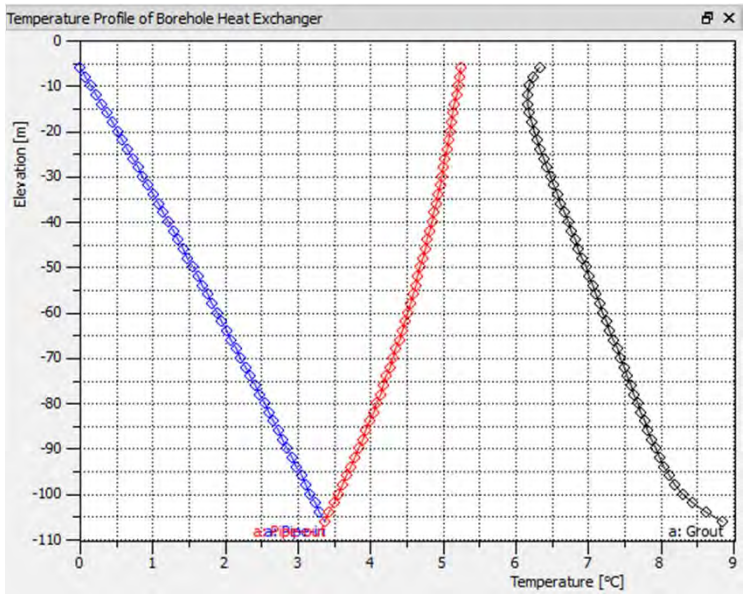


Eksempler på model output (1)







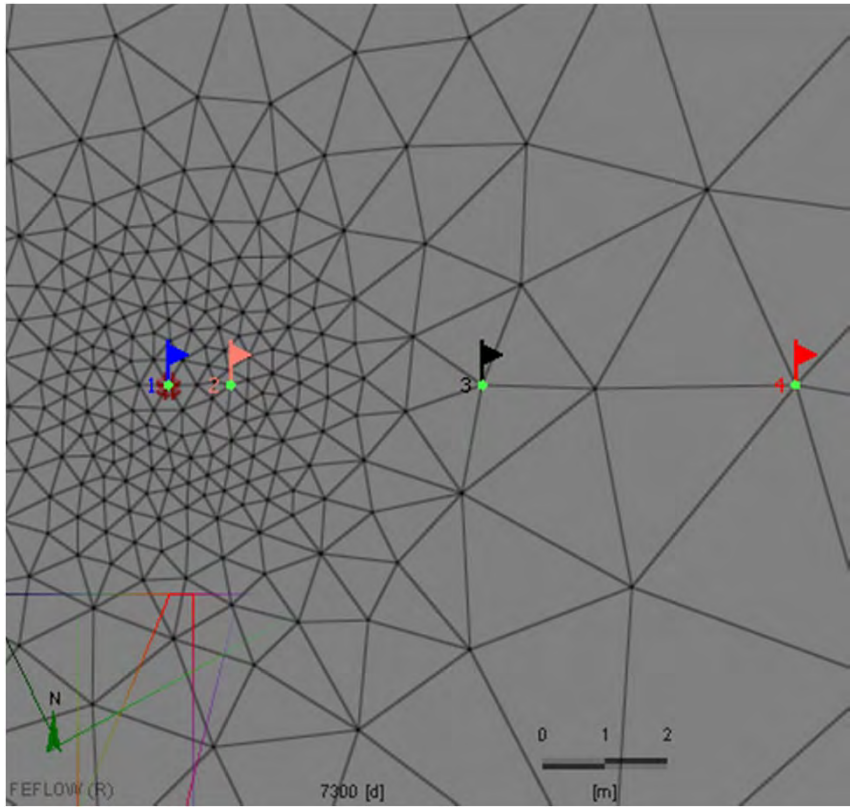


Observationspunkter

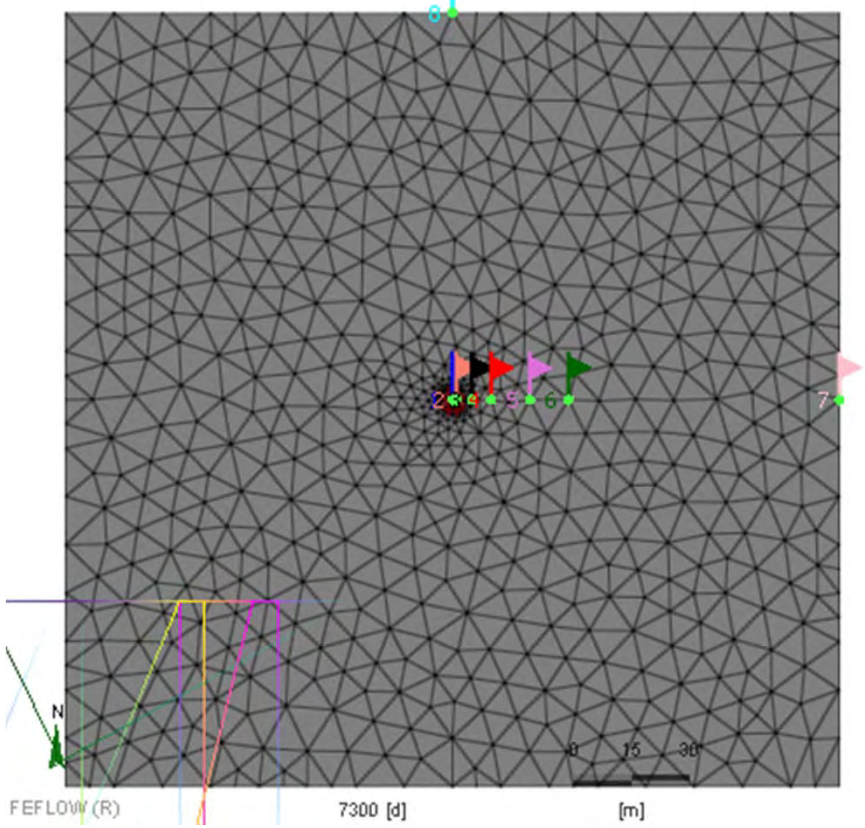
Dybde: 50 m u.t. Modellag: 26

Obs. Pkt.	Afstand fra boring [m]	Retning ift. grundvands strømning
1	0	Nedstrøms
2	1	Nedstrøms
3	5	Nedstrøms
4	10	Nedstrøms
5	20	Nedstrøms
6	30	Nedstrøms
7	100	Nedstrøms
8	100	

Horisontalt snit, modellag 26, zoom til obs. Pkt. 1-4

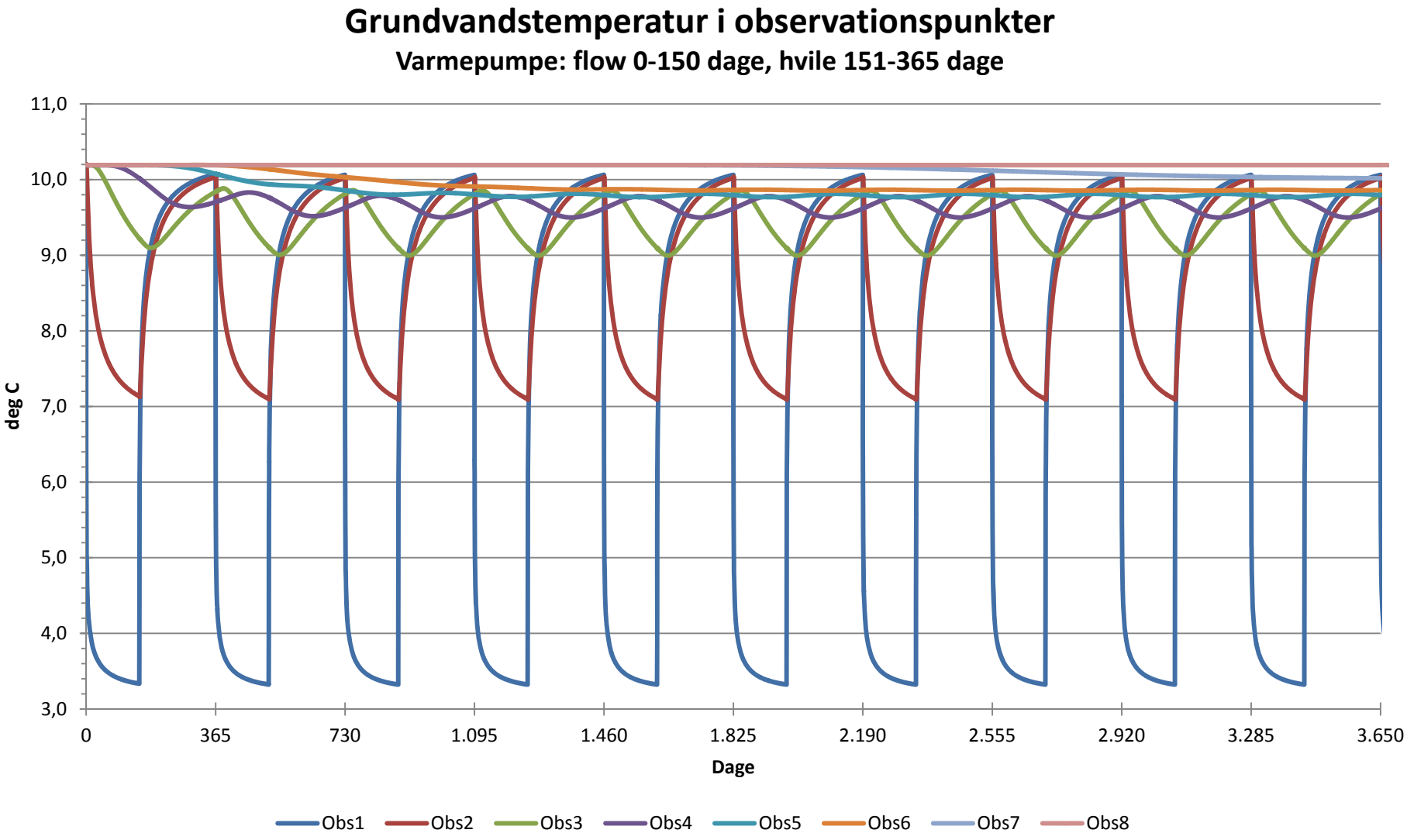


Horisontalt snit, modellag 26, hele modelområde, 200 x 200 m

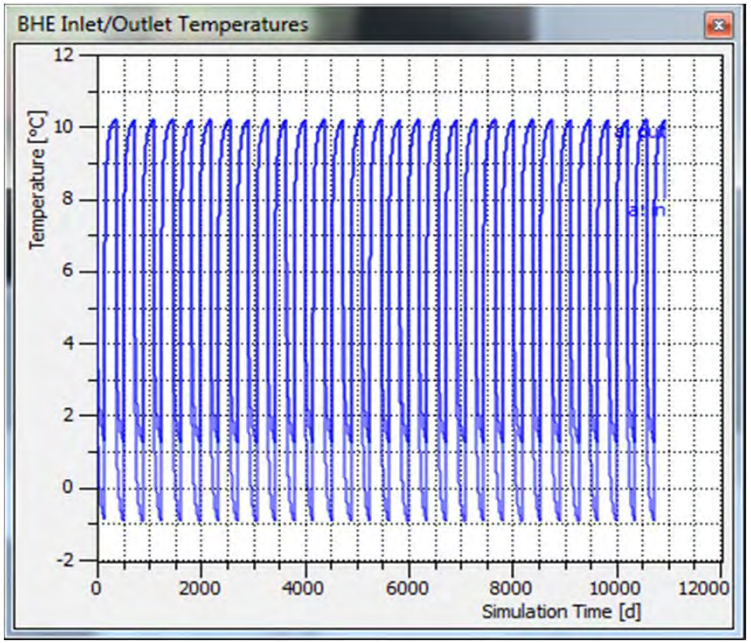


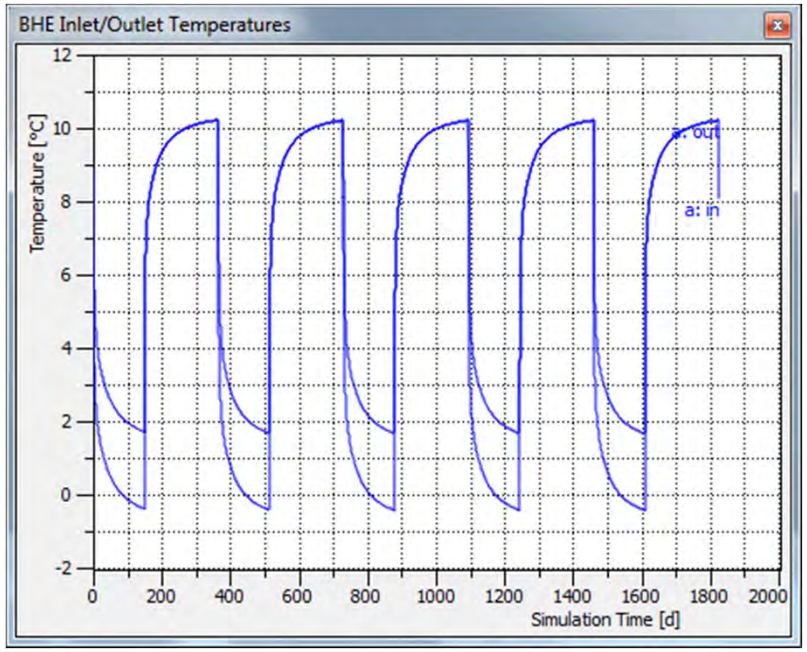
Eksempler på model output (2)

Eksempler på model output (3)



Flow 0-150 d & dT < 0; Flow 150-365 d & dT = 0

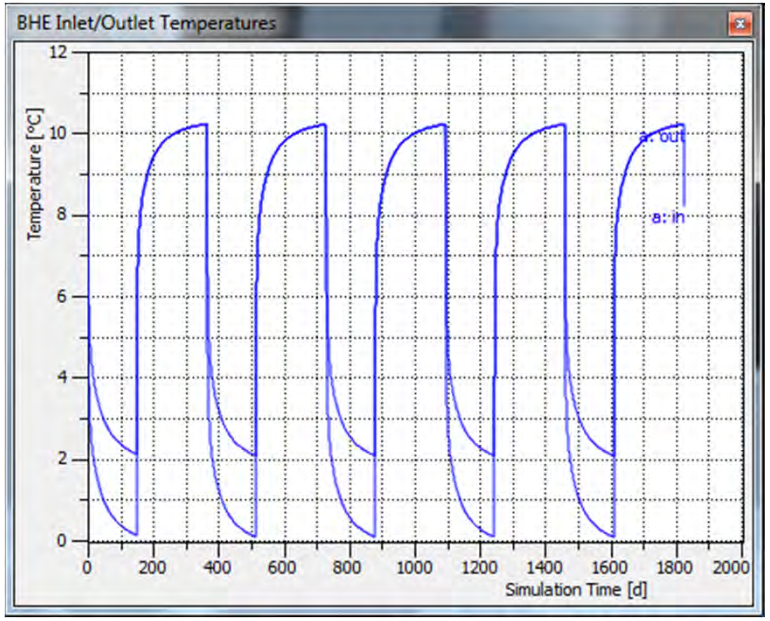


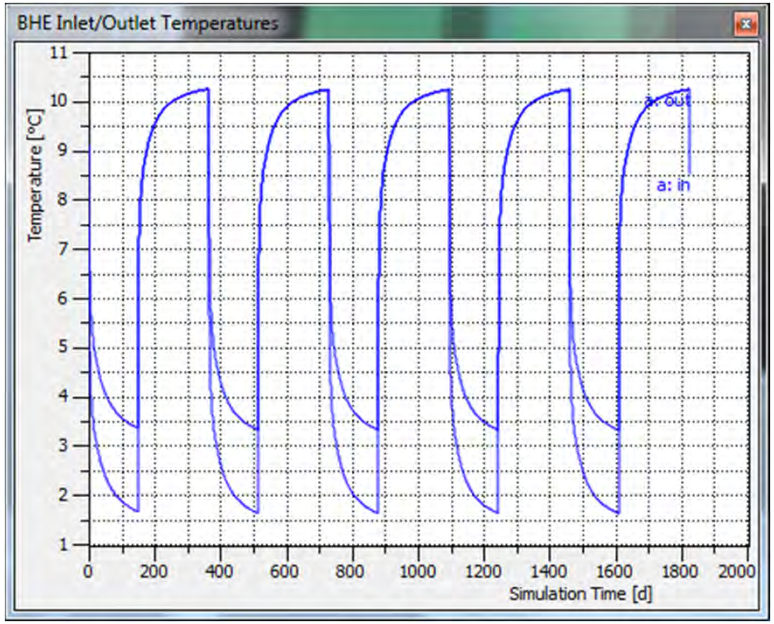


-2.2 -2.1

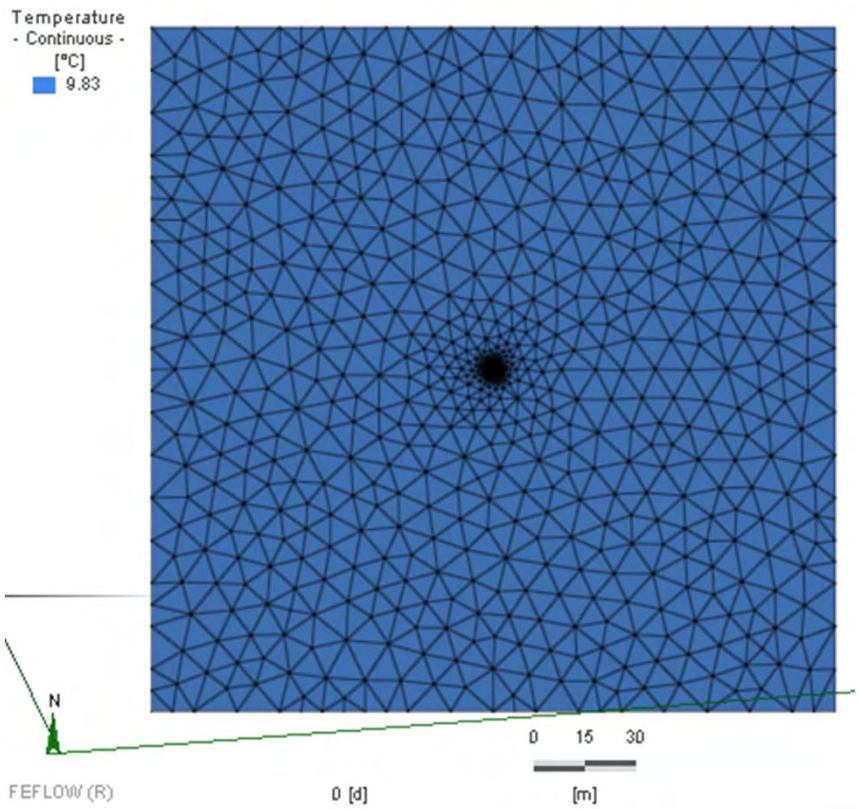
dT

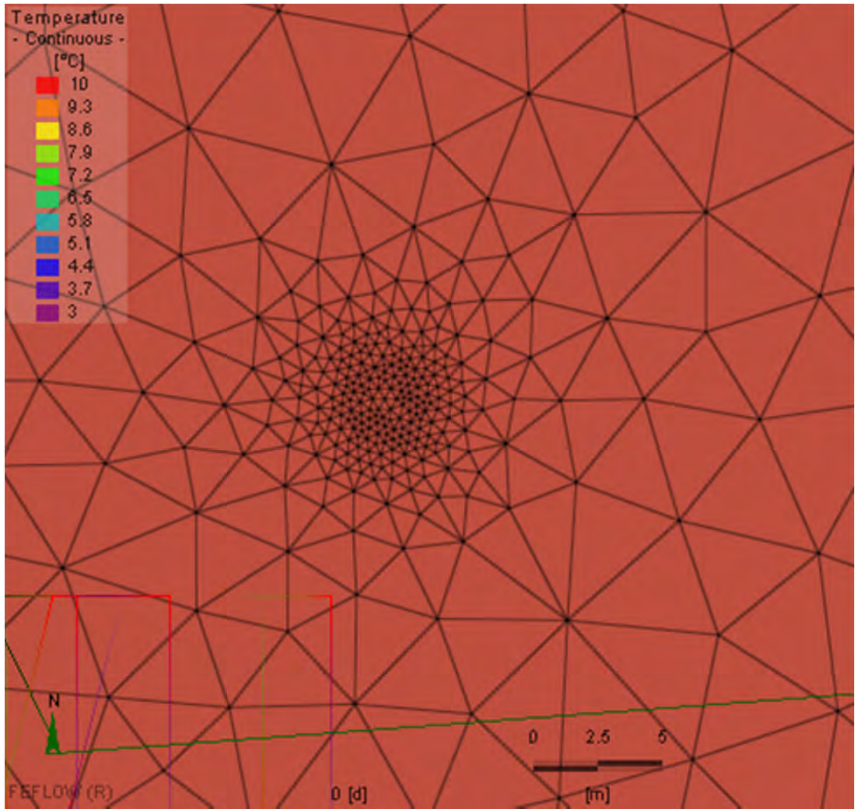
-2.0 -1.7



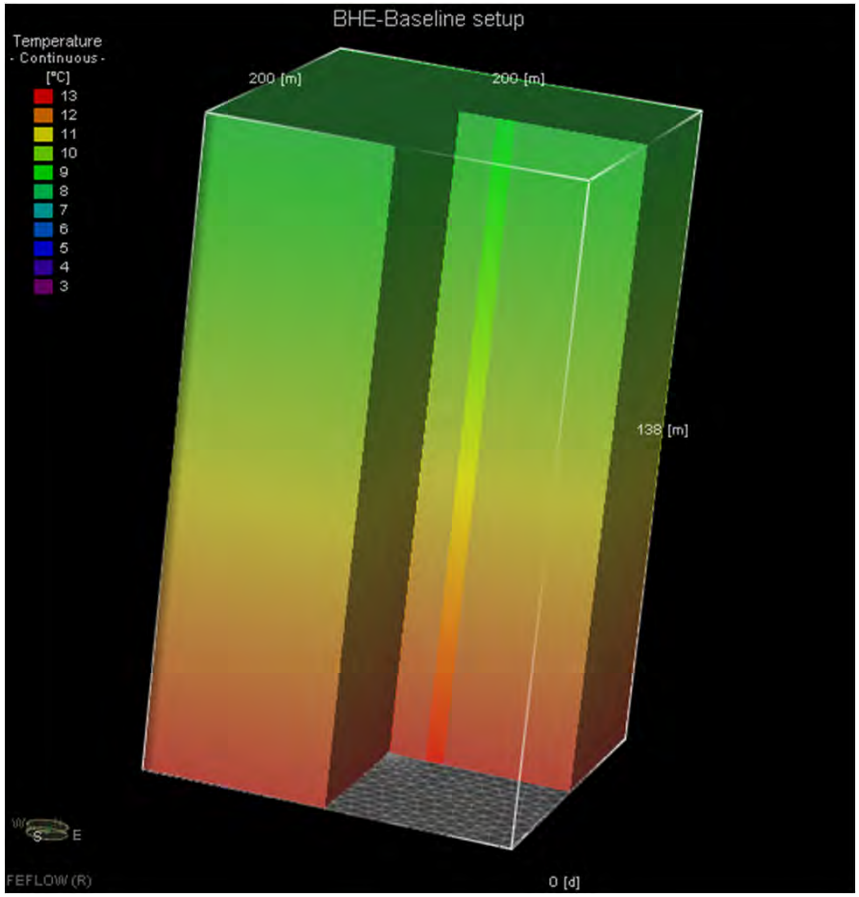


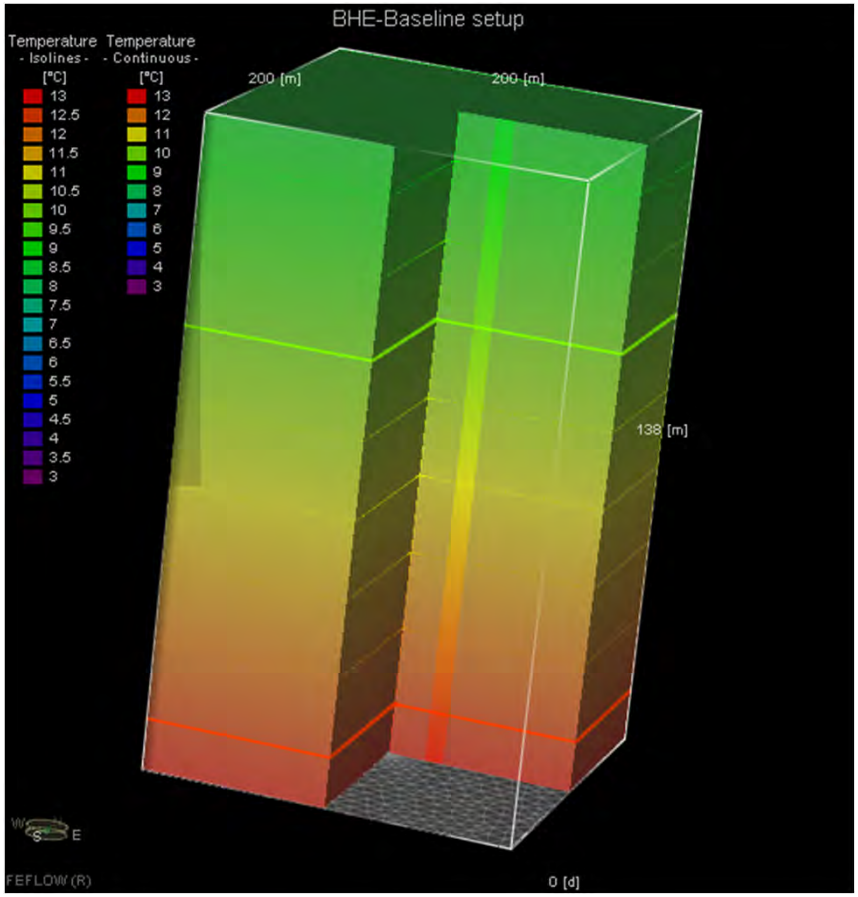
Eksempler på model output (5)



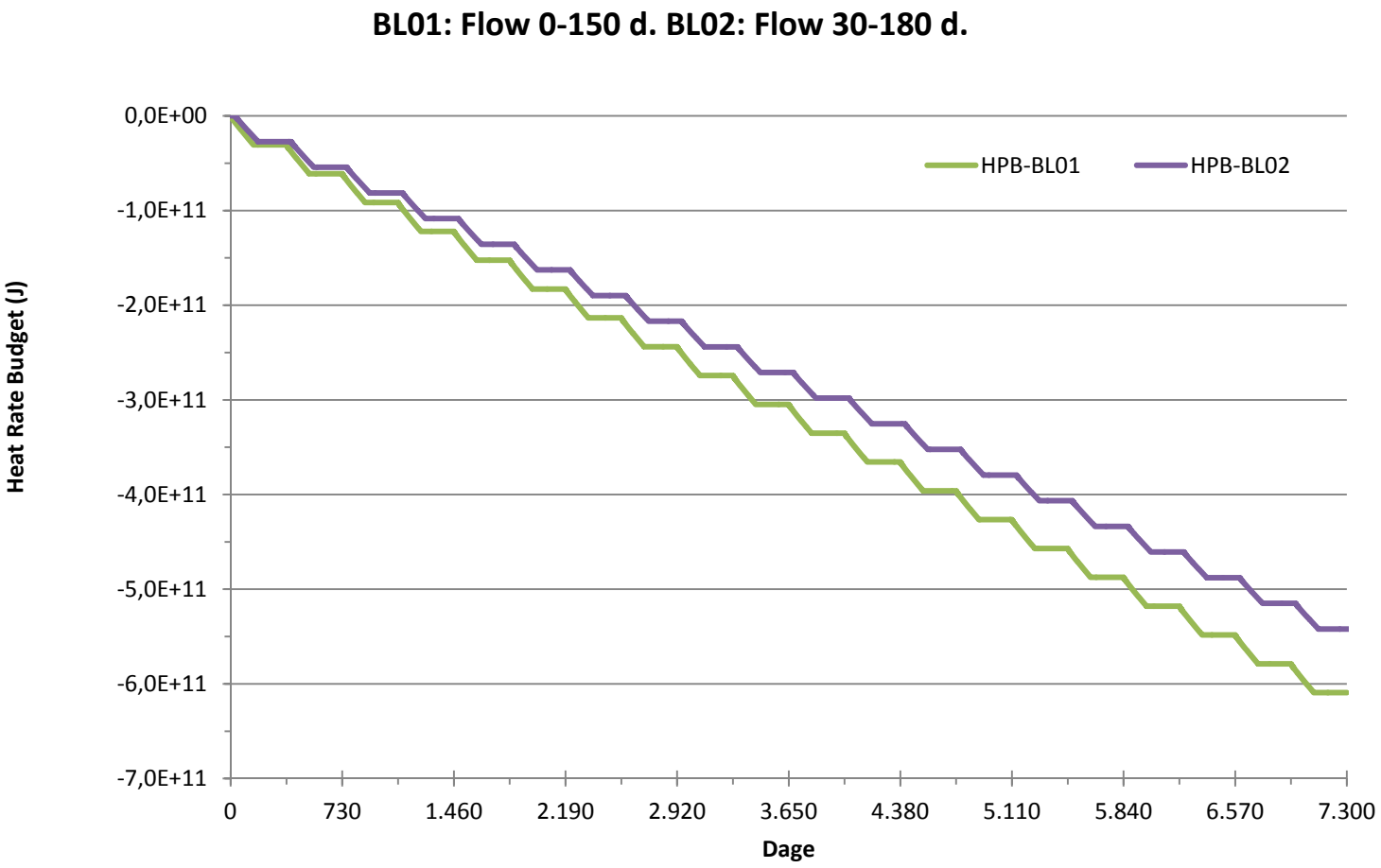


Eksempler på model output (6)





Udestående udfordringer



Det videre arbejde

GeoEnergi Følsomhedsanalyse				
Variable	enhed	Baseline	Ændringer i følsomhedsanalyse	antal simuleringer
Aquifer				
x	m	200	-	
y	m	200	-	
z	m	138	-	
Sand				
Hor. hydraulic conductivity (Kx=Ky)	m/s	1,00E-04	Varierer jf. geologiske typologier fra CDI	10
Vertical hydraulic conductivity (Kz)	m/s	1,00E-05	1/10 af Kx	
Porosity	-	0,3	Konstant	
Longitudinal dispersivity	m	0,2	0.6; 1.8; 5.4	4
Transverse dispersivity	m	0,02	1/10 af longitudinal	
Volumetric heat capacity	J/m3/K	2,640E+06	Varierer jf. geologiske typologier fra CDI	
Thermal conductivity	J/m/s/K	2,4	Varierer jf. geologiske typologier fra CDI	
Anisotropy?	-	1	Konstant	
Vand				
Volumetric heat capacity	J/m3/K	4,20E+06	Konstant	
Thermal conductivity	J/m/s/K	0,65	Konstant	
Temperature	C	8,69	Konstant	
Rand				
Gradient, grundvandsstrømning	promille	3	0; 1; 2; 5	5
Temperatur gradient	C/100m	3	Flux top/bund og gradient i dybden	1
Temperatur rand, top (3C/100m)	C	8,69		
Temperatur rand, bund (3C/100m)	C	12,83		
Borehole				
Depth	m	100	50; 75	3
Diameter	m	0,15	Konstant	
Volumetric heat capacity of grout	J/m3/K	2,190E+06	Konstant	
Grout volume thermal conductivity	J/m/s/K	2,3	?	4
Pipes				
Outer diameter	m	0,04	0,03	2
Pipe wall thickness	m	0,0037	0,029	
Pipe distance (center to center)	m	0,06	0,04; 0,08; 0,10	4
Thermal conductivity of pipe walls	J/m/s/K	0,38	Konstant	
Brine				
Volumetric heat capacity	J/m3/K	3,403E+06	Konstant	
Thermal conductivity	J/m/s/K	0,6405	?	4
Dynamic viscosity	kg/m/s	5,4741E-04	?	4
Mass density	kg/m3	9,2225E+02	?	4
Operation				
Inlet T	C	0	Konstant	
Discharge	m3/d	30	10; 30; 40	4
Flow duration	d	150	50, 75, 100, 125	5
Total time	year	20	Konstant	
Number of runs with individual parameters				54
Combinations of geologi/heat parameters, groundwater gradient and flow durations				249
Total number of runs				**303**

Sammenfatning

- Afklaring af Feflow problemer
- Følsomhedskørsler for udvalgte parametre
- Scenarier for forskellige geologier
- Udarbejdelse af ‘lookup table’