Prediction of the interferences of urbanization (including geothermal utilizations) and surface water-groundwater interactions on a large alluvial aquifer, Budapest capital city, Hungary

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HydroPredict 2010, Prague

Aim of our work

- ***to survey*** the present day situation

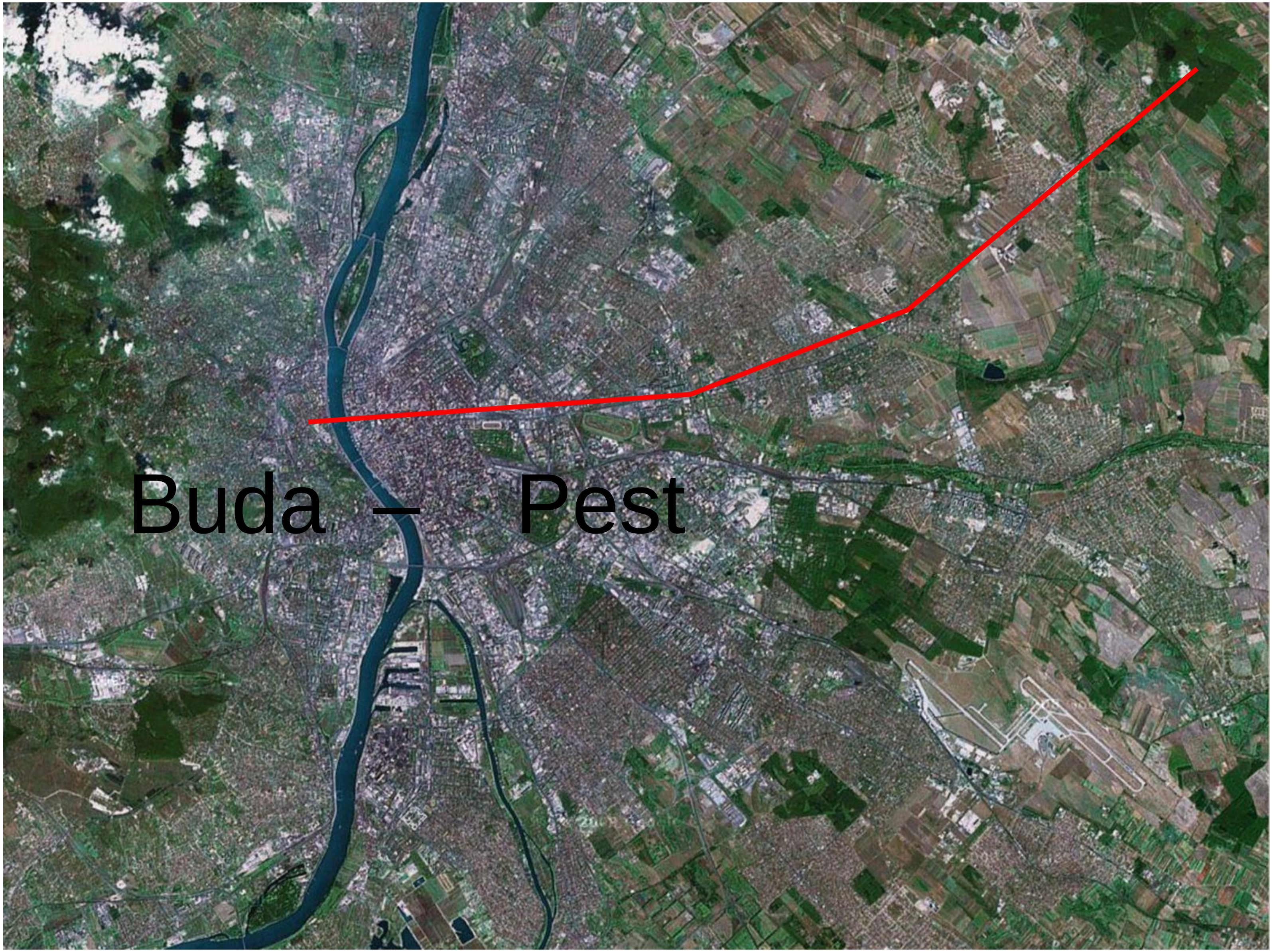
- ***to assess*** the short and long term effects of the changes* in a developing city on its vulnerable groundwater system

  *new buildings, deep underground garages and geothermal heat-pump systems with production-injection well pairs which can dam back part of the groundwater flowing to the river

- ***to determine*** protection zones for ensuring long term sustainable operations

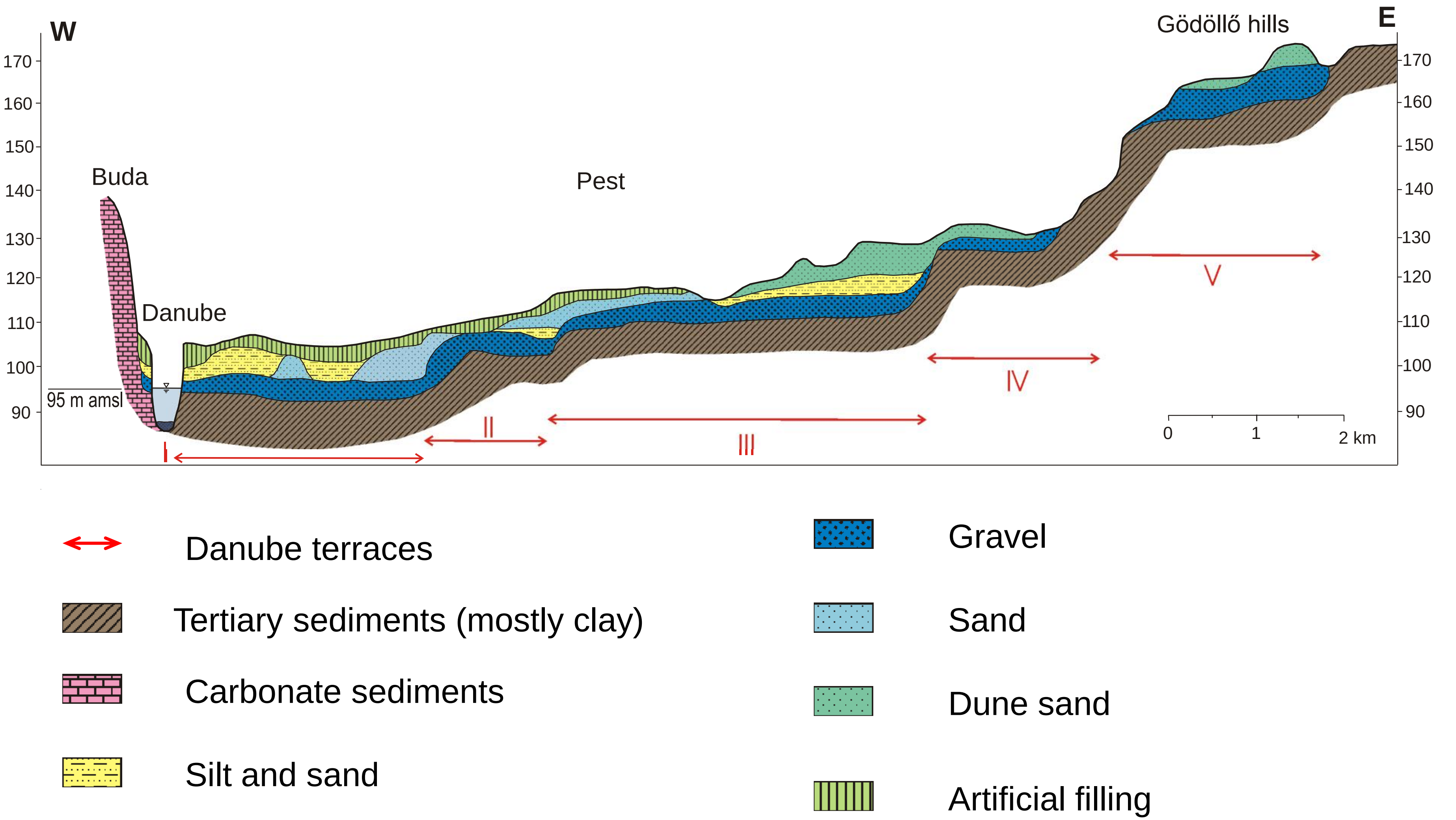
- ***to suggest*** a regional groundwater controlling system for the better groundwater management of the city

City of Budapest



Google map

Geological cross section of the eastern part of Budapest (Pest side)



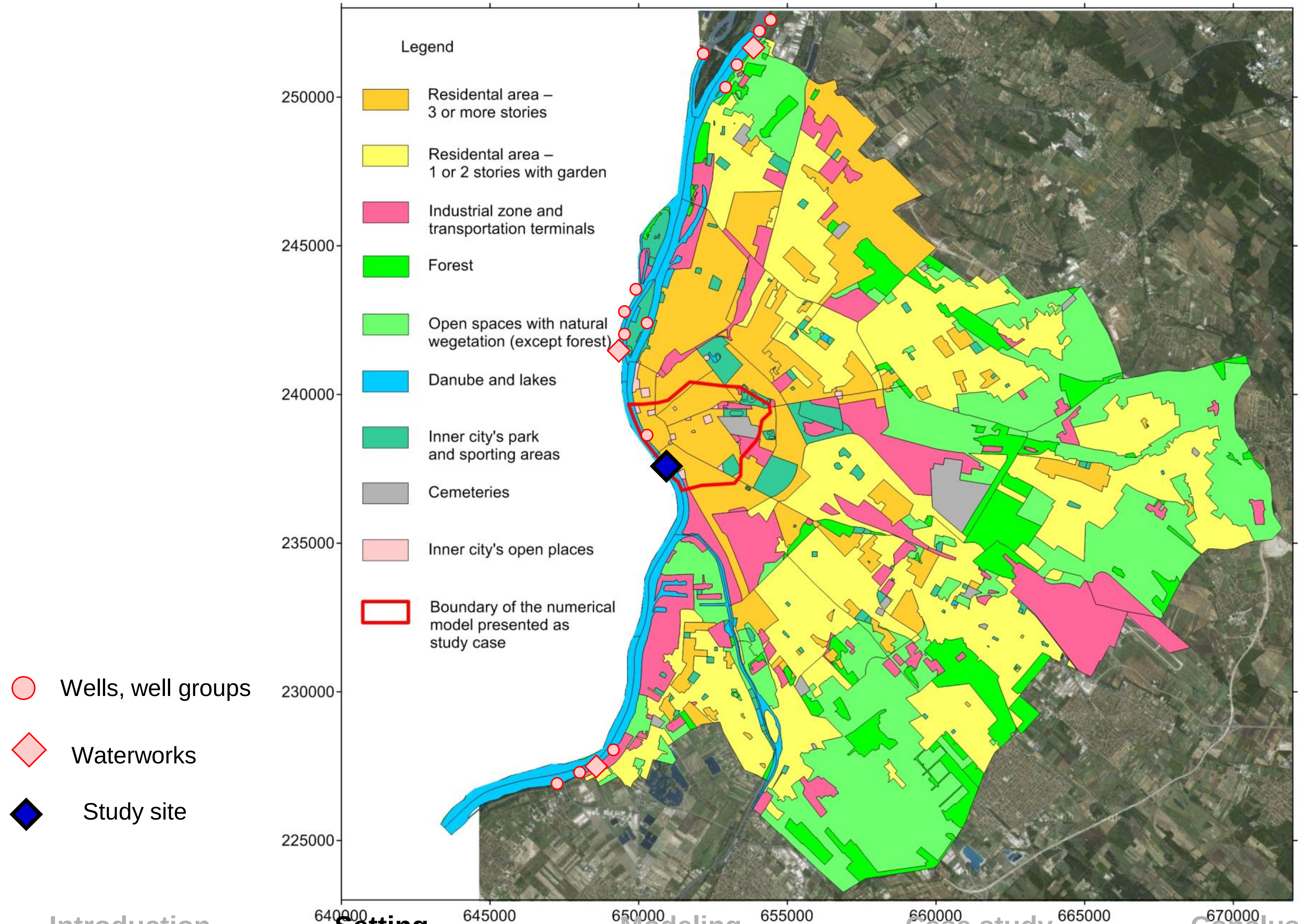
Geology

Danube terrace V
gravel and sand

Filling and man disturbed zone in the city

concrete wall

Land use of the Pest part of the city

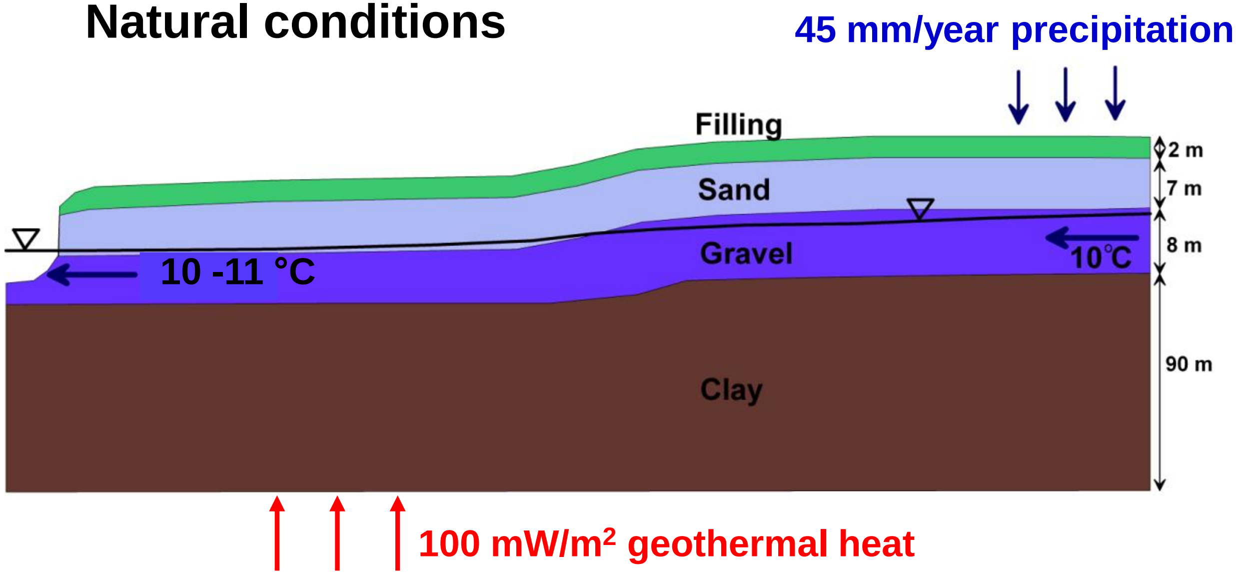


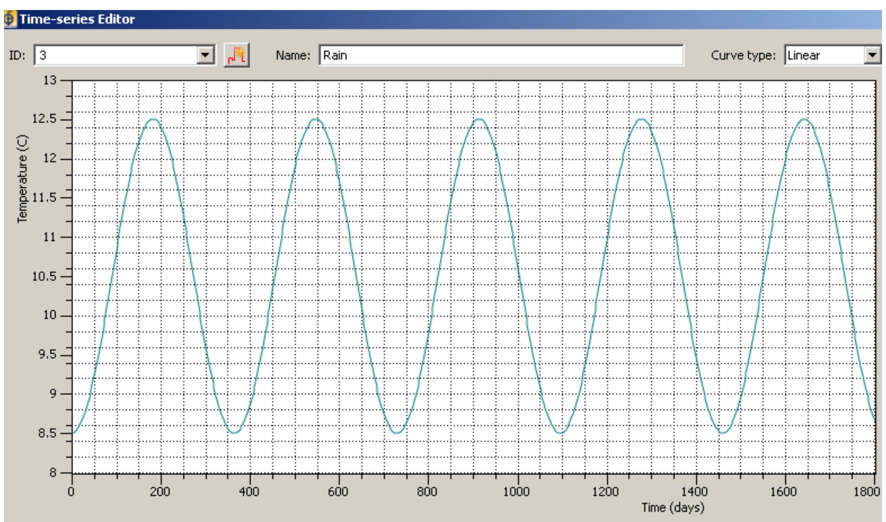
Conceptual model

The system is very variable in time and space due to natural and man induced effects

Natural conditions

Average Danube water level situation



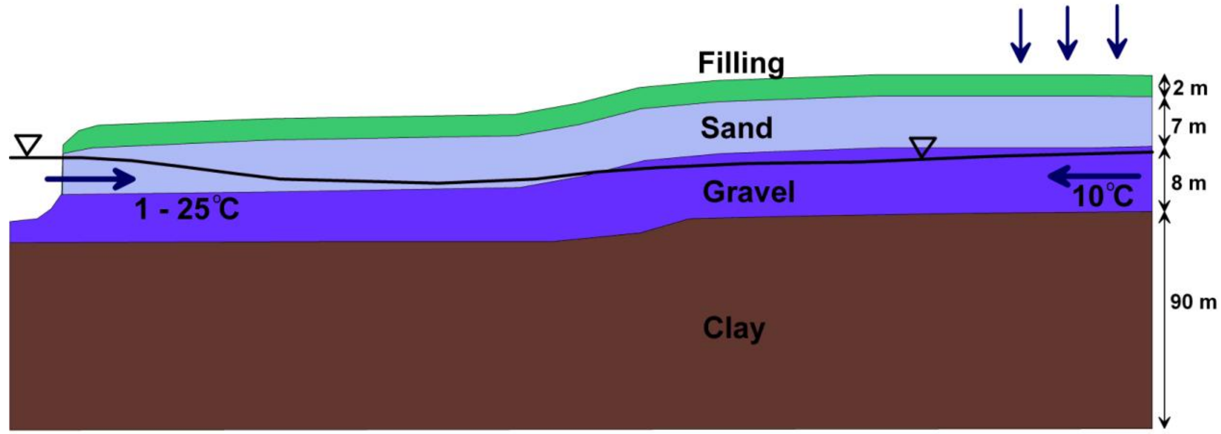


Estimated temperature of the recharged water (8.5 – 12.5 °C), applied in the models

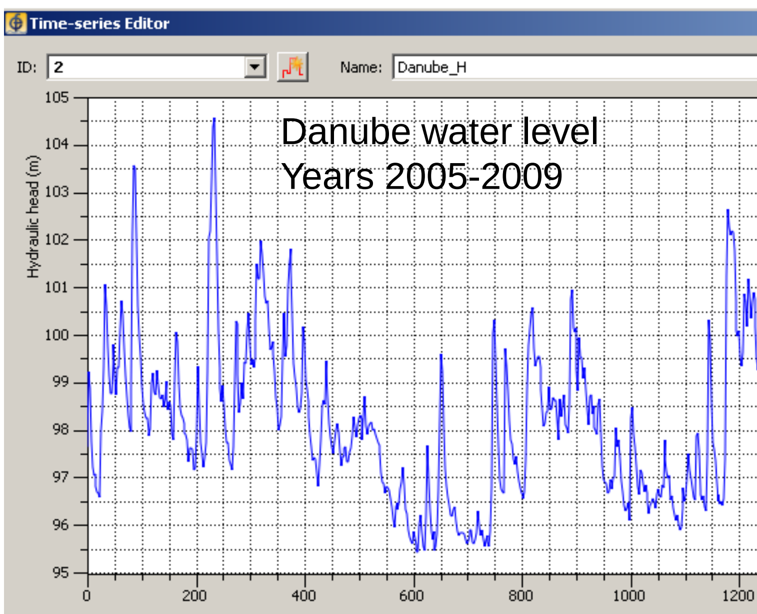
Conceptual model

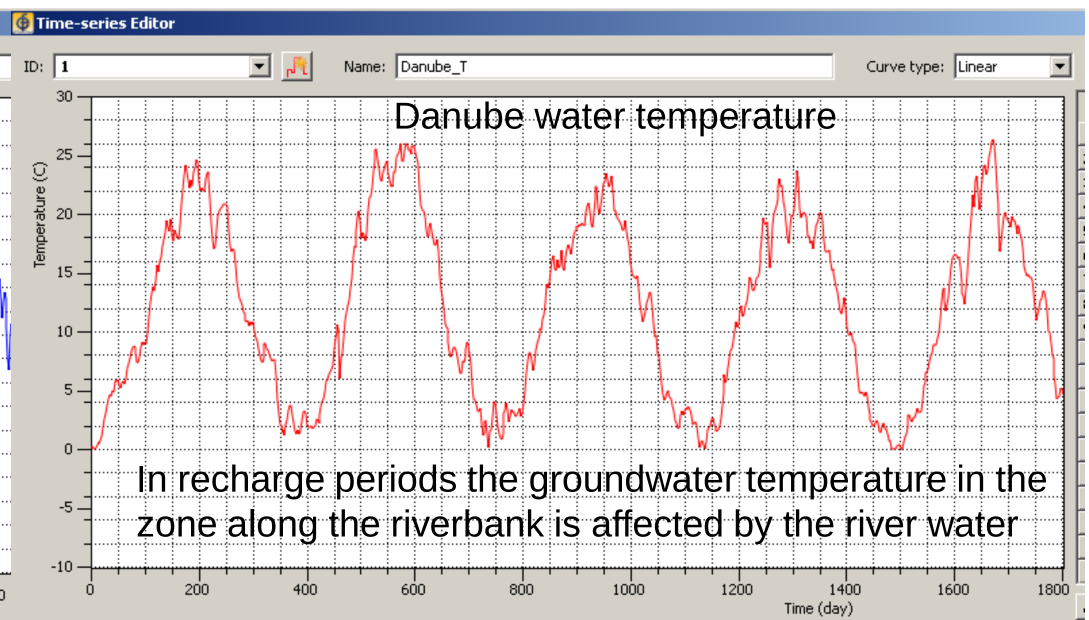
Natural conditions

Danube water during **high** water level periods recharges the groundwater



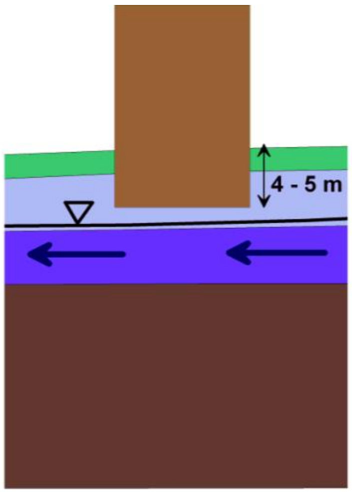
Damming back effect up to 1.5 km





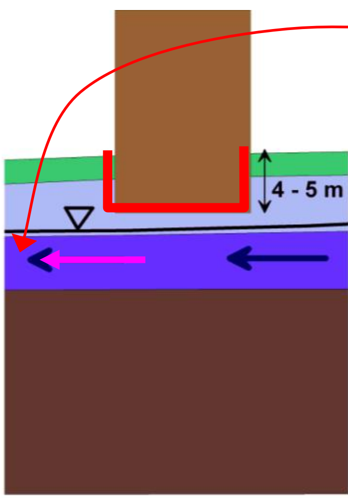
Conceptual model

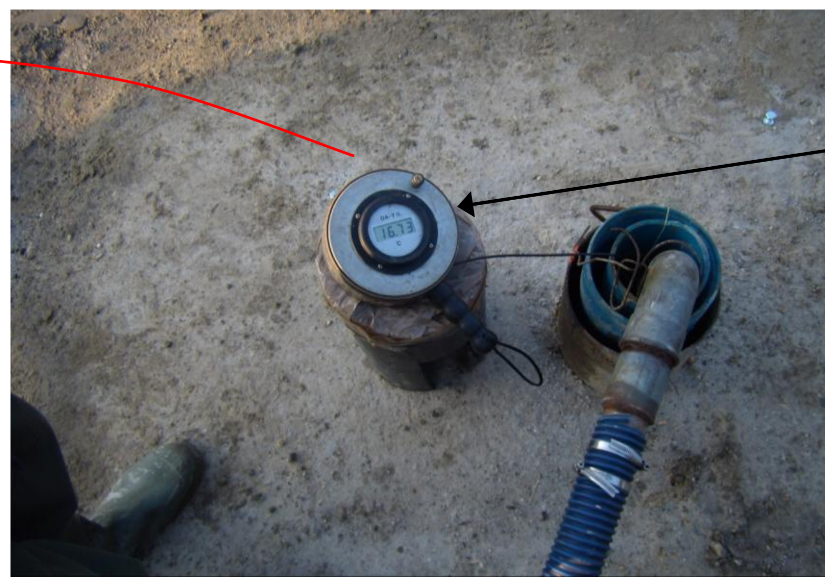
Man induced effects on the groundwater level and temperatures of the city



Buildings constructed before about 1990 don’t reach the groundwater table (average depth of the basement 3 m).

Temperature of cellars varies seasonaly between 15 – 25 °C. They affect the groundwater temperature by advection.

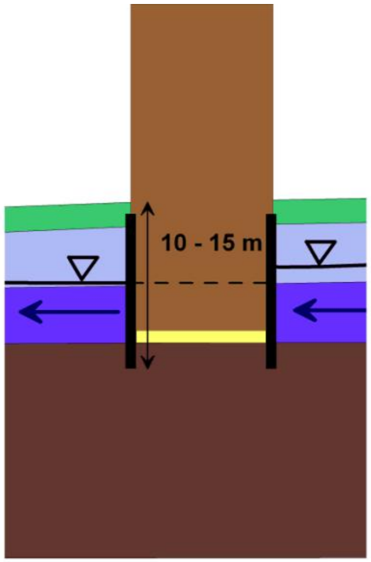




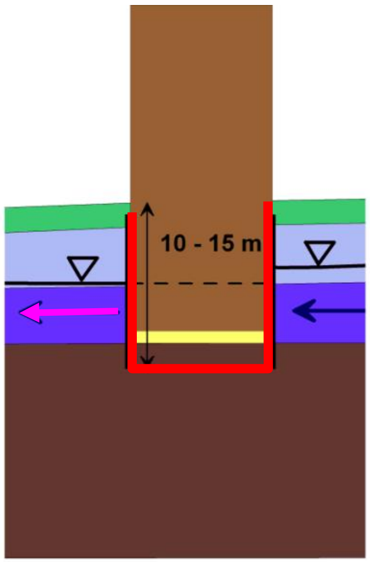
Measurement made at the study case site

Conceptual model

Man induced effects on the groundwater level and temperatures of the city



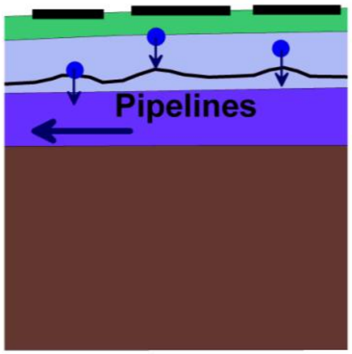
Underground garages, metro stations: damming back effect on groundwater table



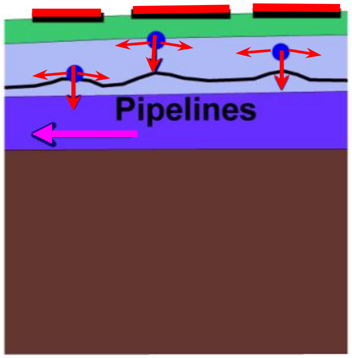
Temperature of deep garages, metro stations varies seasonally between 15 – 25 °C. They affect the groundwater temperature by conduction through the sealed walls. They have more influence, than „simple” cellars.

Conceptual model

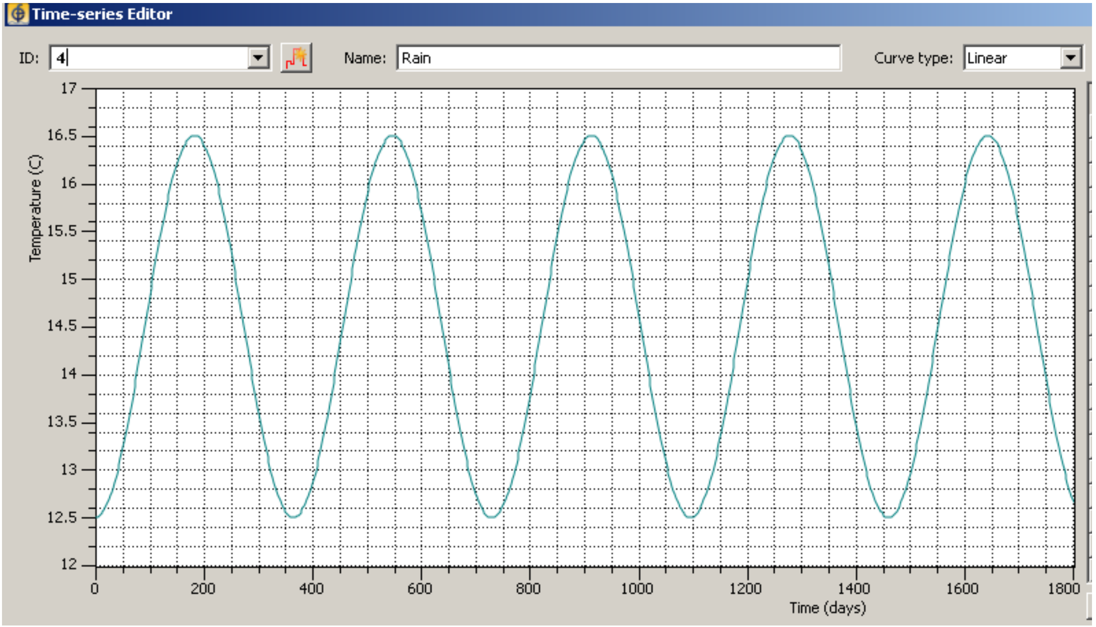
Man induced effects on the groundwater level and temperatures of the city



Land cover with buildings and roads, reduced recharge
Leakages from pipelines, mains (10% of their total yield)

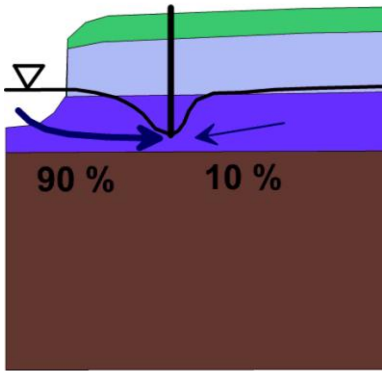


Urban microclimate: infiltrating water's temperature is 4 °C higher as natural („heat island")

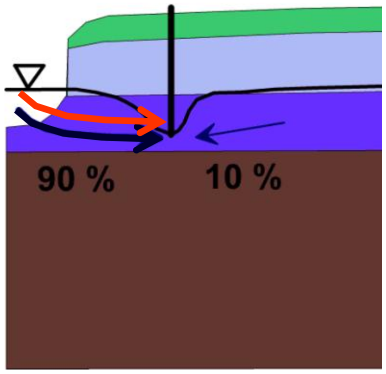


Conceptual model

Man induced effects on the groundwater level and temperatures of the city



Pumping wells – waterworks and pumping wells of the geothermal open loop systems in recent time - along the river for bank filtration systems



In recharge periods the groundwater temperature in the zone along the riverbank is affected by the river water. (In the case of waterworks it lasts all the year round.)

Numerical model

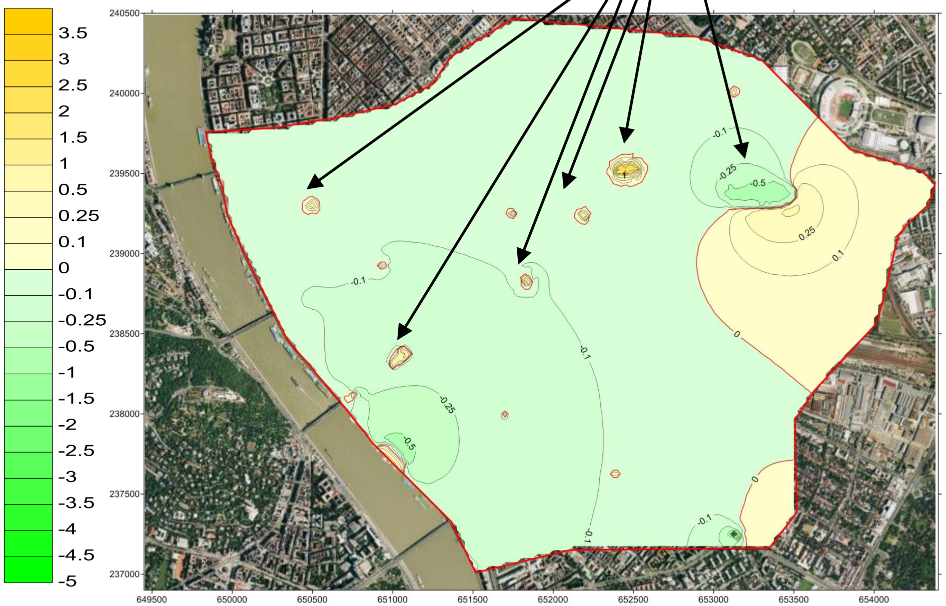
Modeling process is not to construct a single model but series of models:

1. 2D cross sections, 3D models

2. Models with increasing complexity:
   - •Flow only – natural conditions
   - •Flow only – with installations

Metro stations, deep garages

Modeled hydraulic heads without and with the effect of underground garages and metro stations and the depression at high Danube water level situation



Numerical model

3. A model for the whole recharge area and several local ones

Regional model - it gives the time **constant** hydraulic head boundary condition for the:

Local model 1 - it gives the time **dependent** hydraulic head boundary condition for the:

Local model 2: (our model case)

Construction site

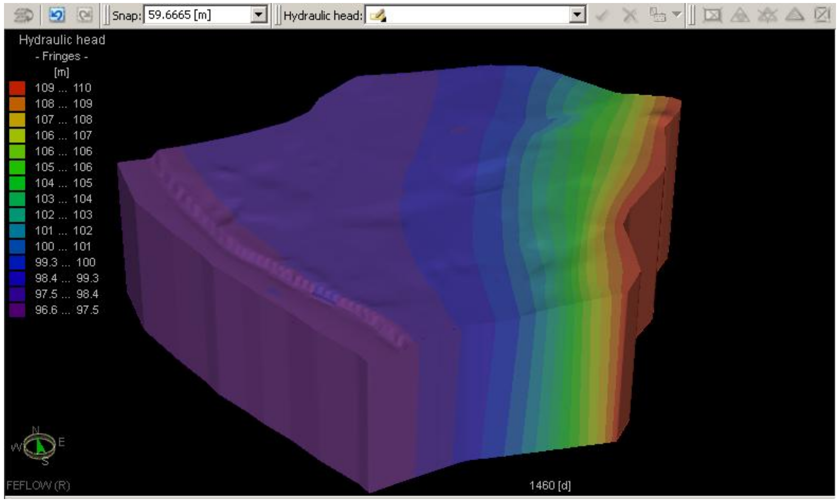
4. The model is continuously developed: it is a „never ending story”

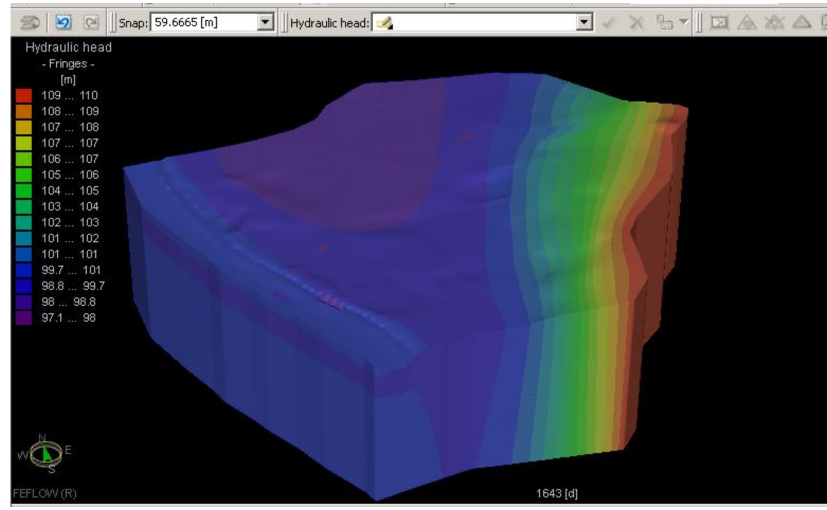
A new cultural centre in the city by the Danube river

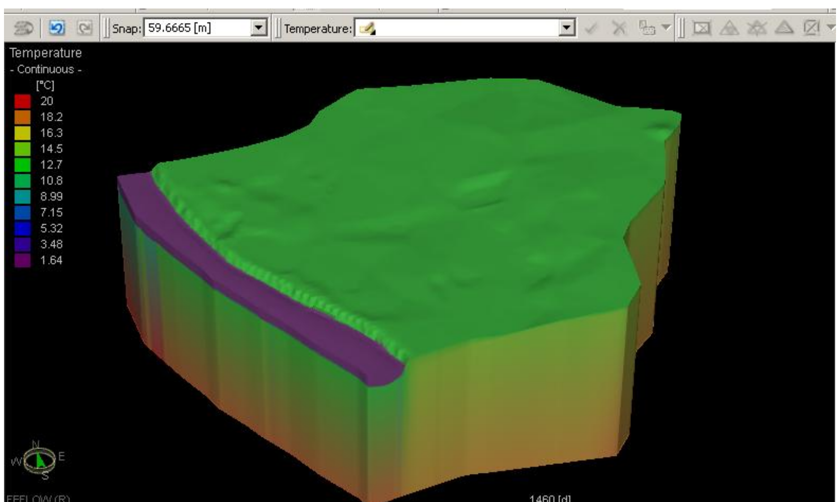
Case study

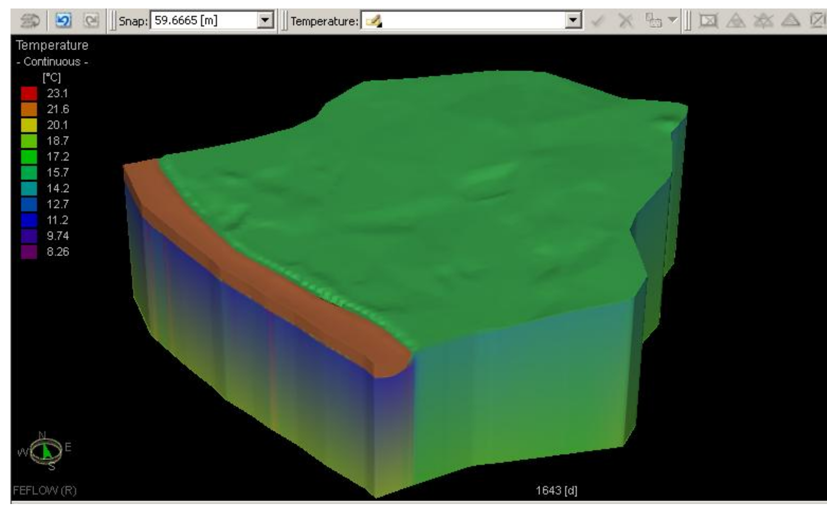
Case study

Hydraulic head and temperature distribution at winter (low water level) and at summer (at high water level at that time) Local model 1



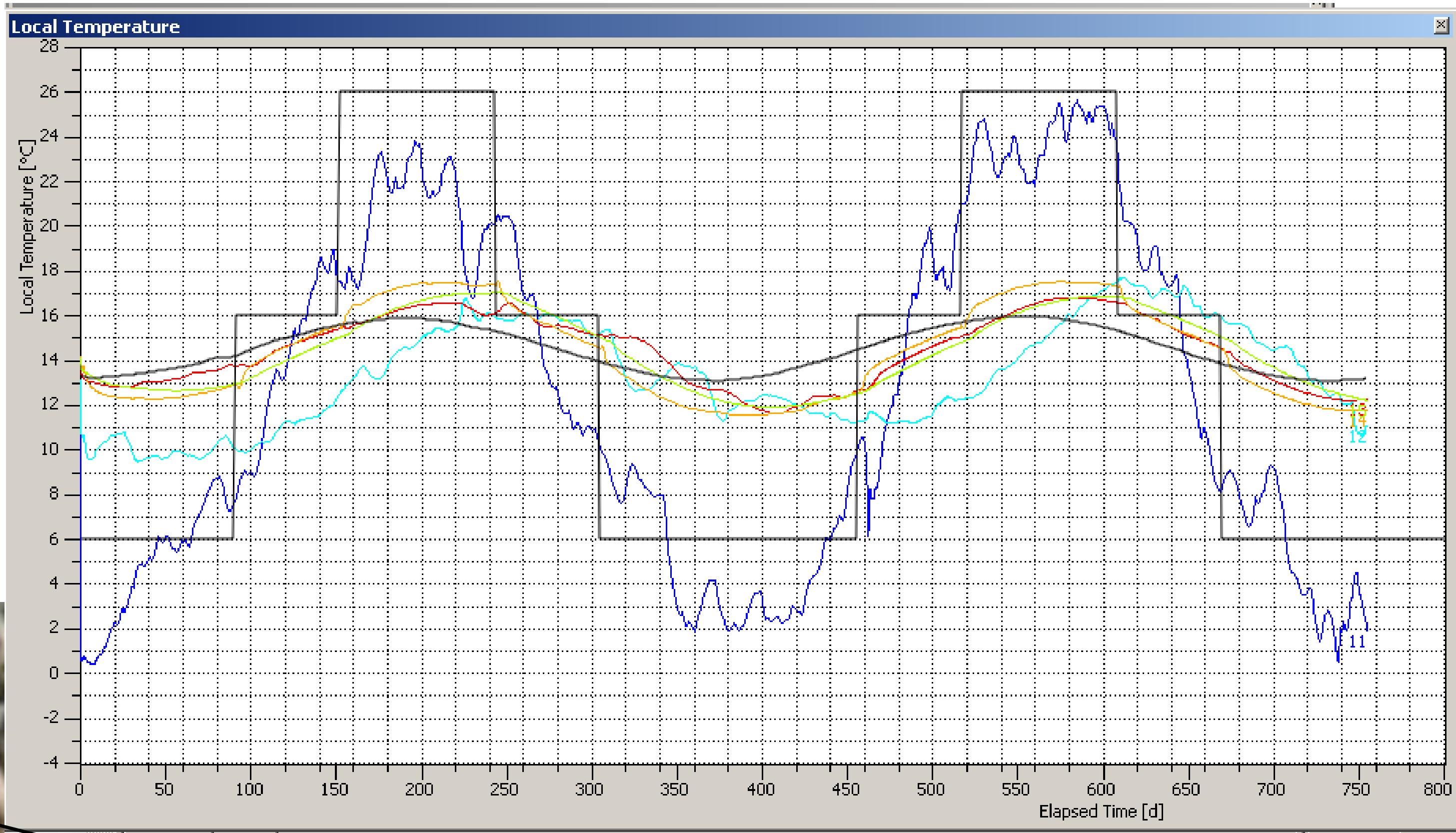


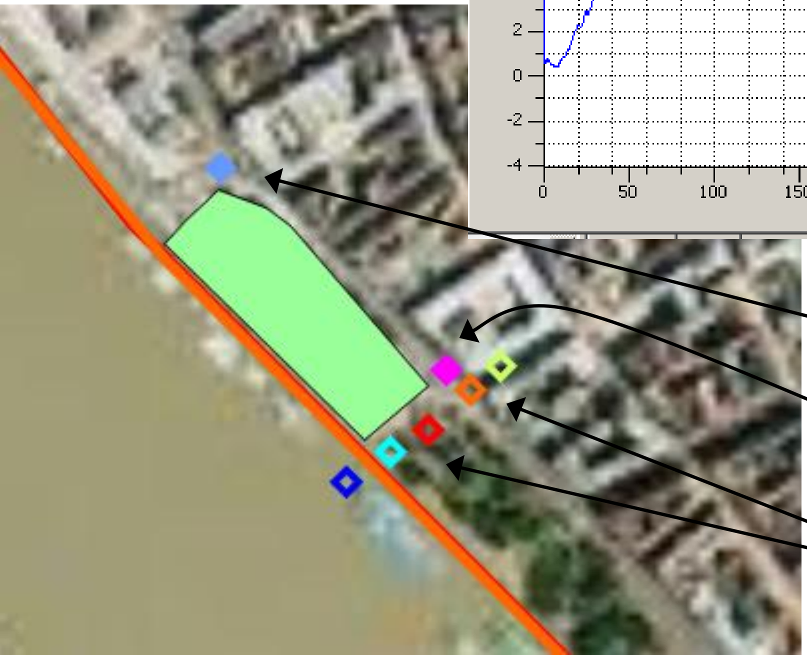




Case study

Water temperature in the pumping and the injection wells and at observation points – local model 2





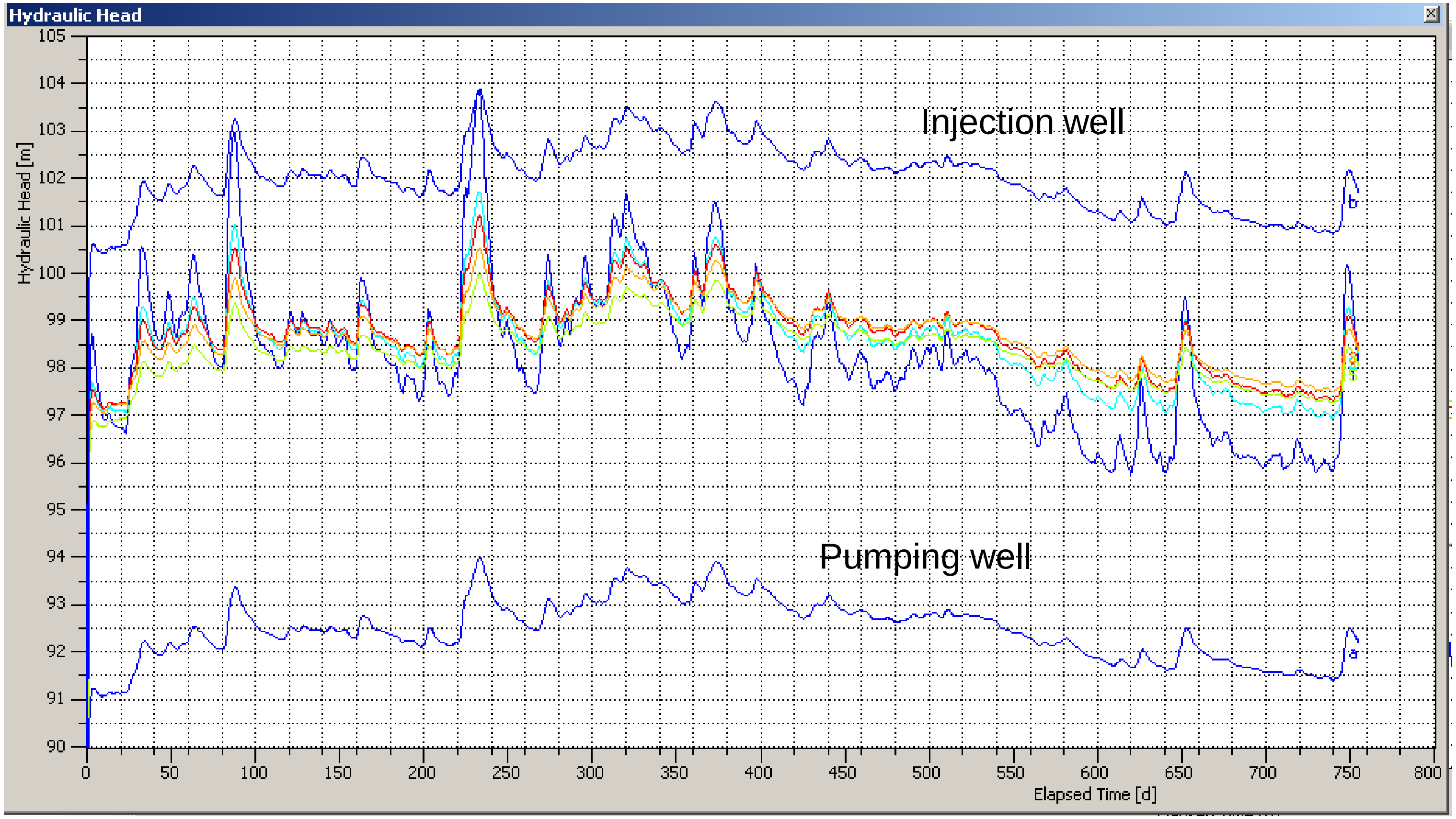
Production well (2000 m3/day)

Injection well (2000 m³/day)

Observation points (Dark blue is the Danube)

Case study

Water temperature in the pumping and the injection wells and at observation points



Conclusions

The coupled flow and heat transport model is able to simulate the complex hydraulic and thermal pressures: it should apply at designing and legislation processes

(today is not the case)

It should be the base for the authorities creating new regulation and giving the permissions of the future investments and the existing operations.

(Now they give permissions on the first come first served basis).

A suitable database is needed for the existing utilizations, application, deep garages, etc to analyze their inferred coupled effect.

For the lower Danube terrace additional monitoring with PTC (pressure, temperature, conductivity) probes are suggested for better calibration and for preparation of the further groundwater management.

Further groundwater management should be centralized, based on better monitoring and coupled models.

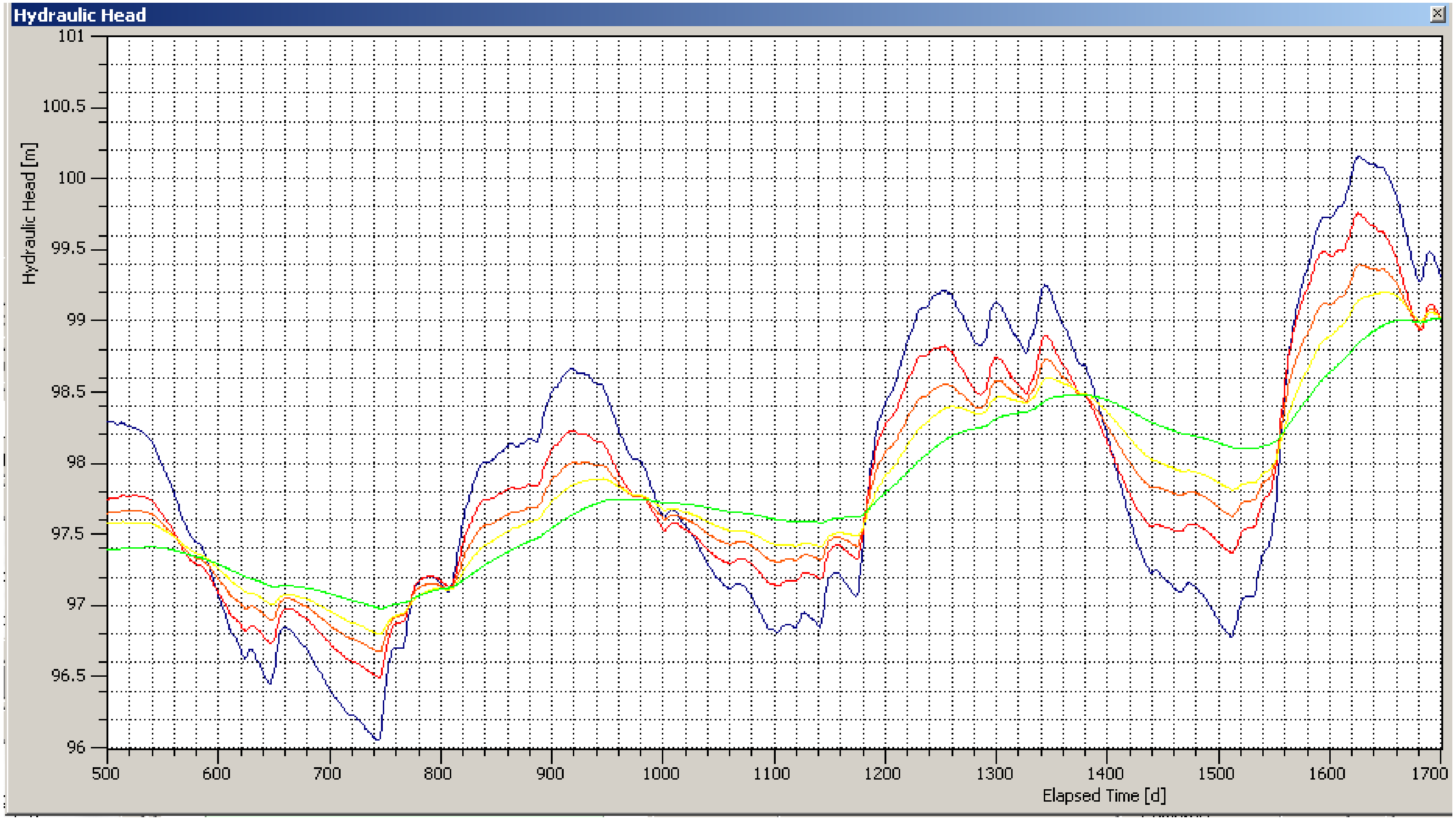
It is the time to construct pumping wells for controlling underground flood events.

Thank you for your attention

Water Work pumping well
just beside the building

Parliament building,
Budapest, Republic of Hungary

Hydraulic heads at increasing distance from the Danube, predictions to improve the monitoring system



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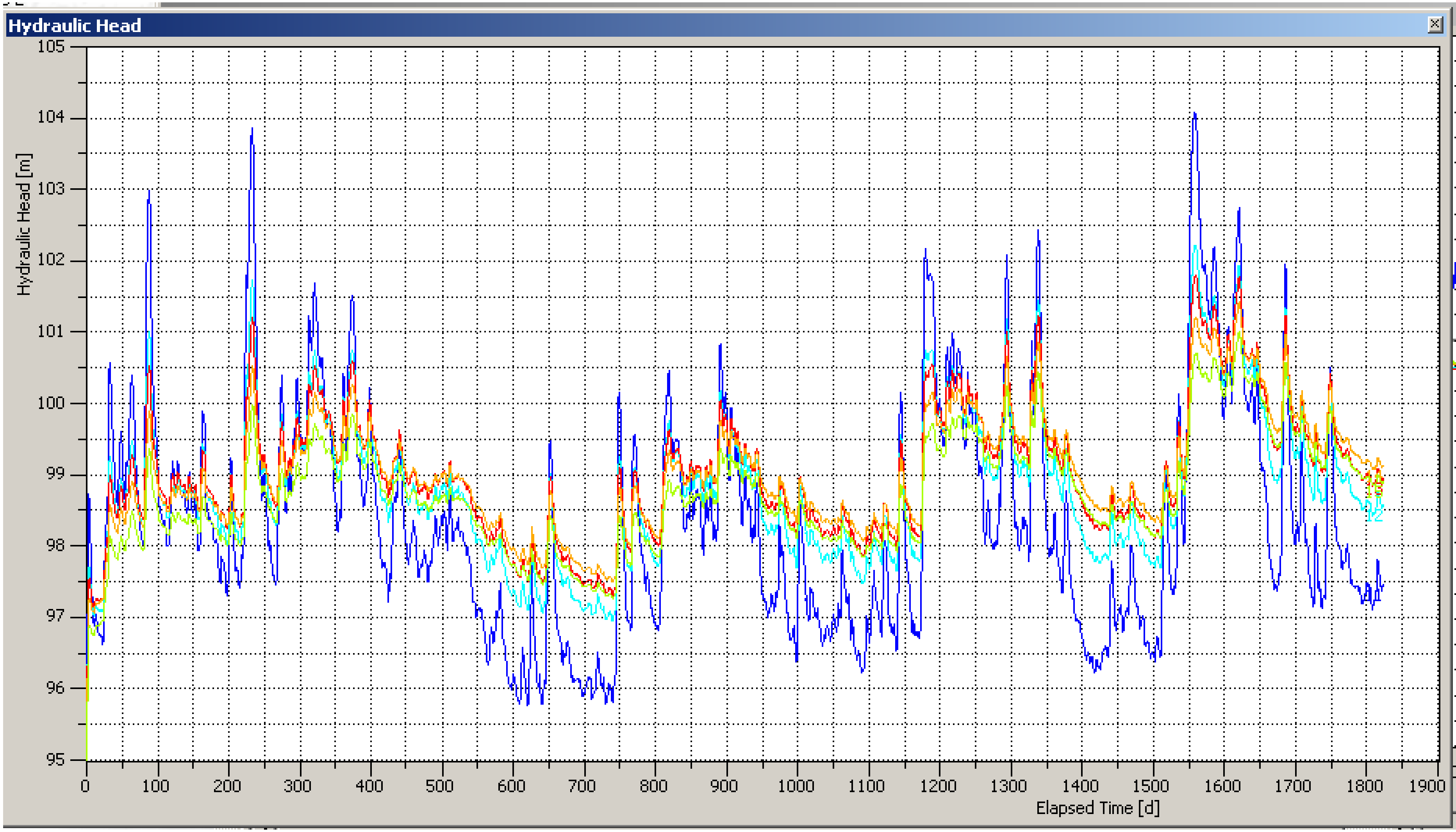
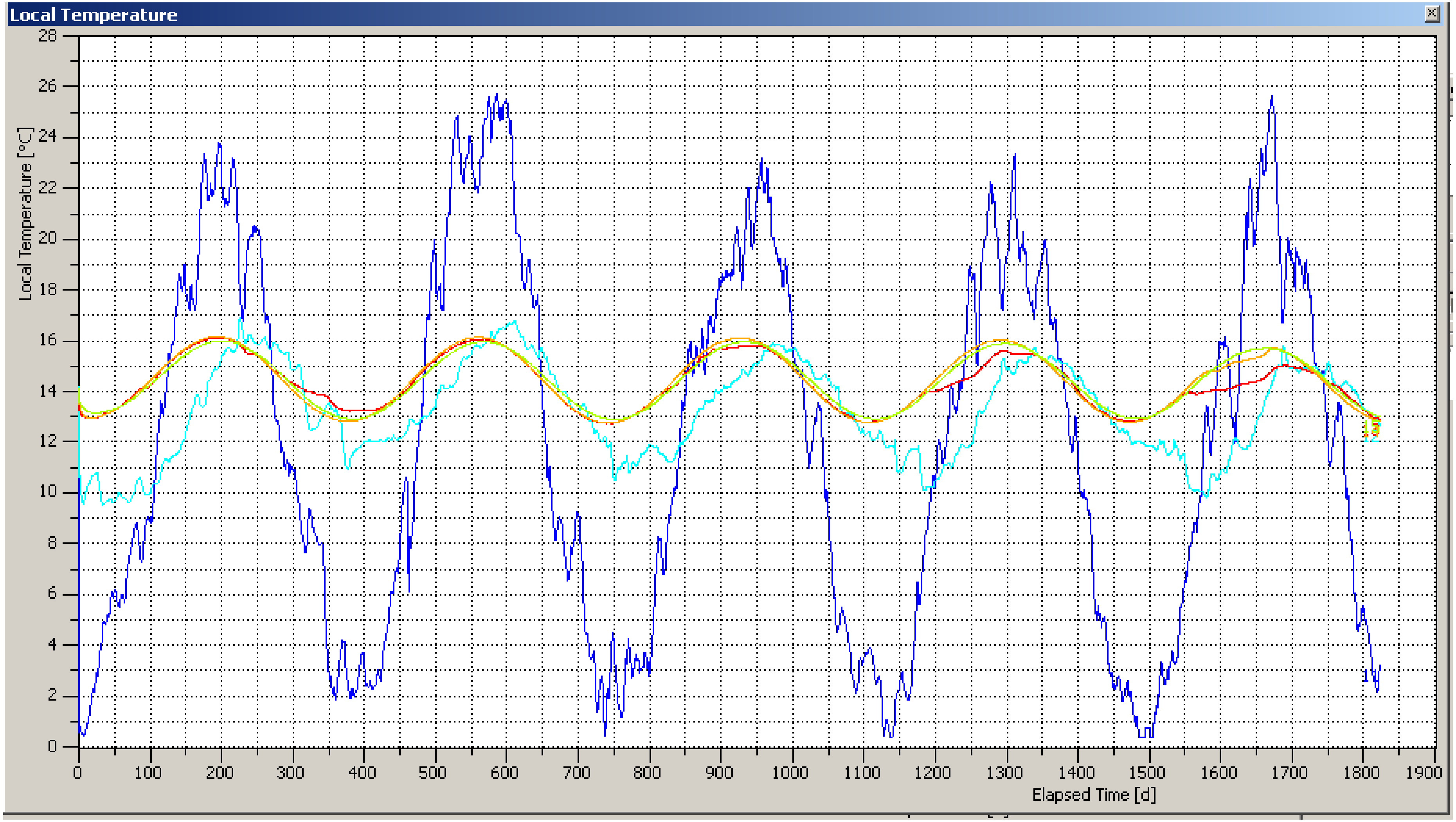
Hydraulic heads from the local model 2



Temperatures from the local model 2



Effects controlling groundwater temperatures in the city

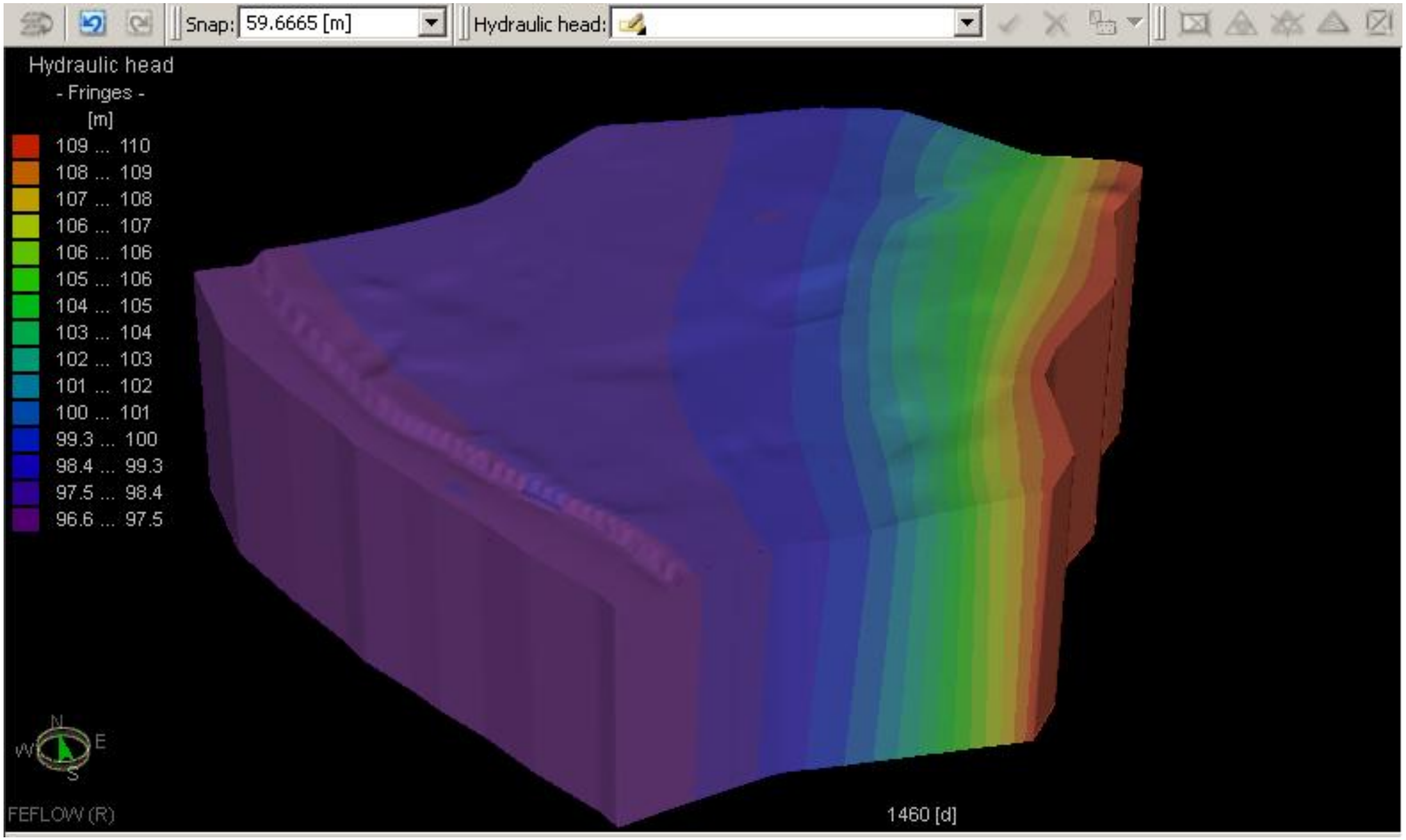
Natural:

- Geothermal heat
- Precipitation infiltrating trough the surface
- The effect of the Danube river water temperature by conduction
- The effect of the river water temperature by advection (during flood events)
- Changes in air temperature.

Man induced effects:

- Reduced recharge from precipitation
- Permanent and occasionally leakages of mains and the sewers
- Irrigation
- Wells, well groups, horizontal wells operated by the Waterwork Company
- During the floods the water remains between the flood protection dykes
- Higher temperature microclimate of the city.

Many of the above also affects the groundwater flow system.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Hydraulic head:
Hydraulic head
- Fringes -
[m]
109 ... 110
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105 ... 106
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101 ... 102
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97.5 ... 98.4
96.6 ... 97.5
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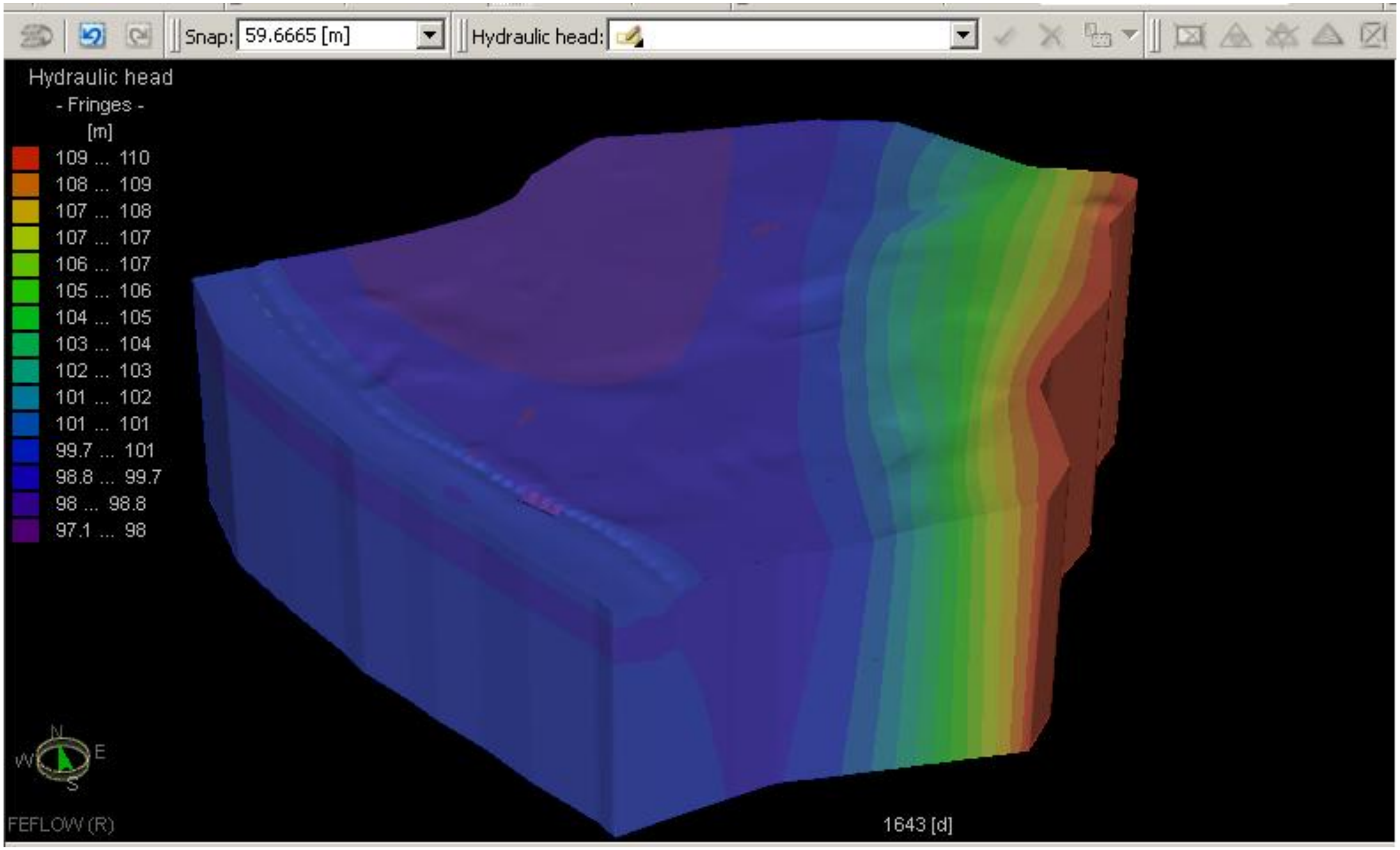
FEFLOW (R)
1460 [d]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99.7 ... 101
98.8 ... 99.7
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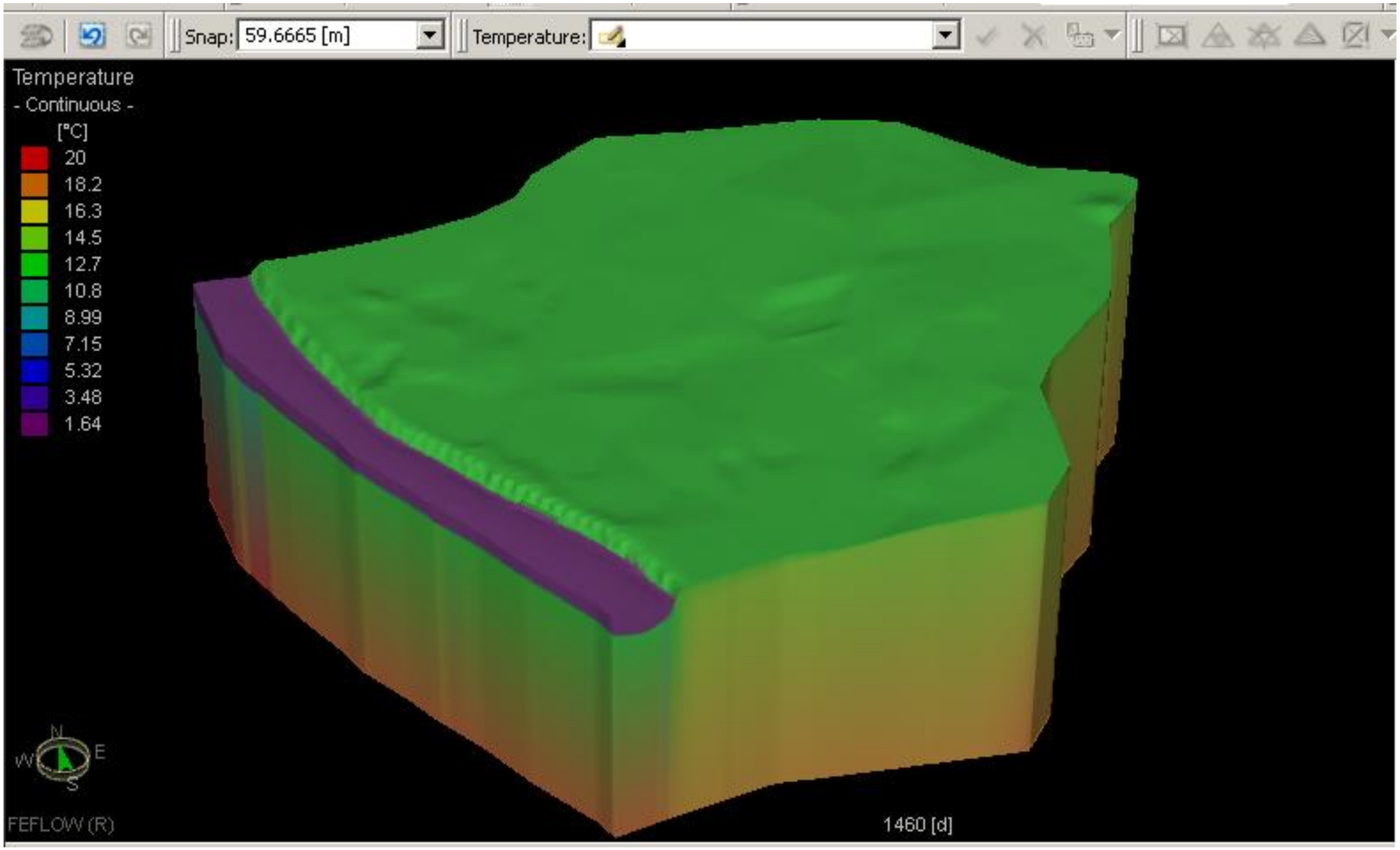
FEFLOW (R)
1643 [d]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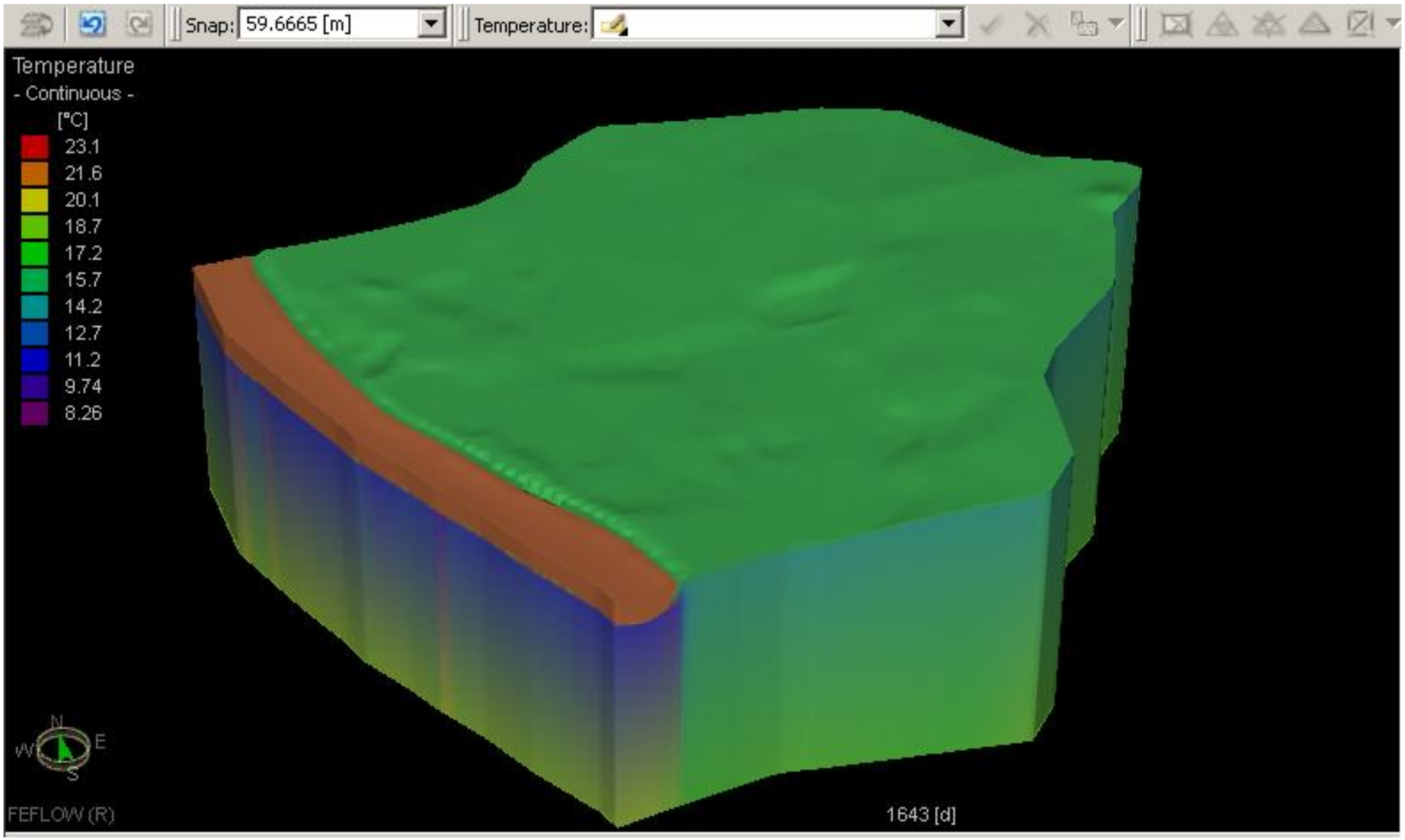
1460 [d]



Snap: 59.6665 [m]
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Temperature
- Continuous -
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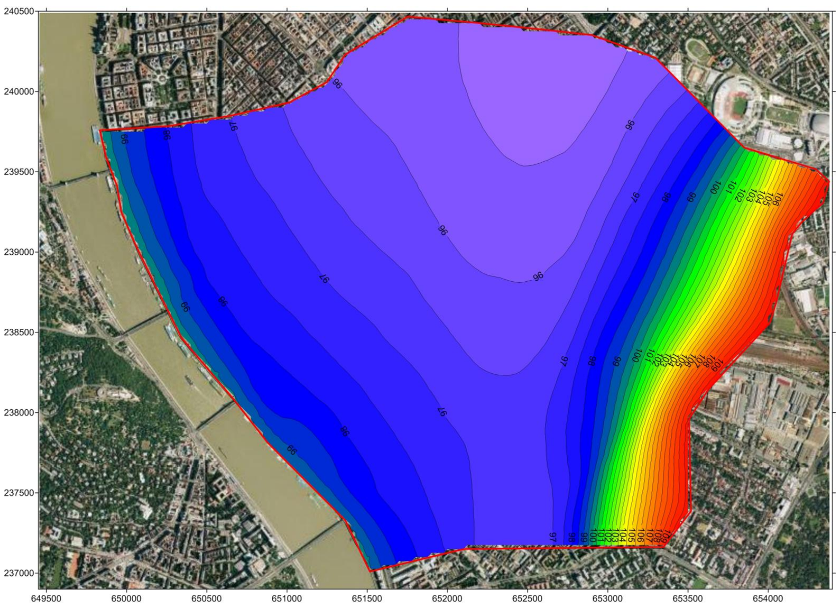
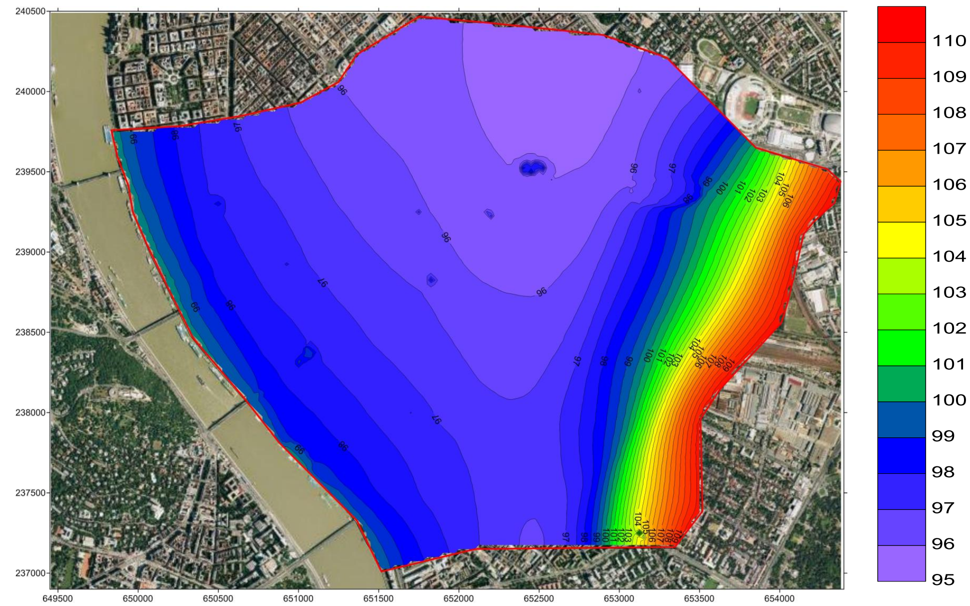
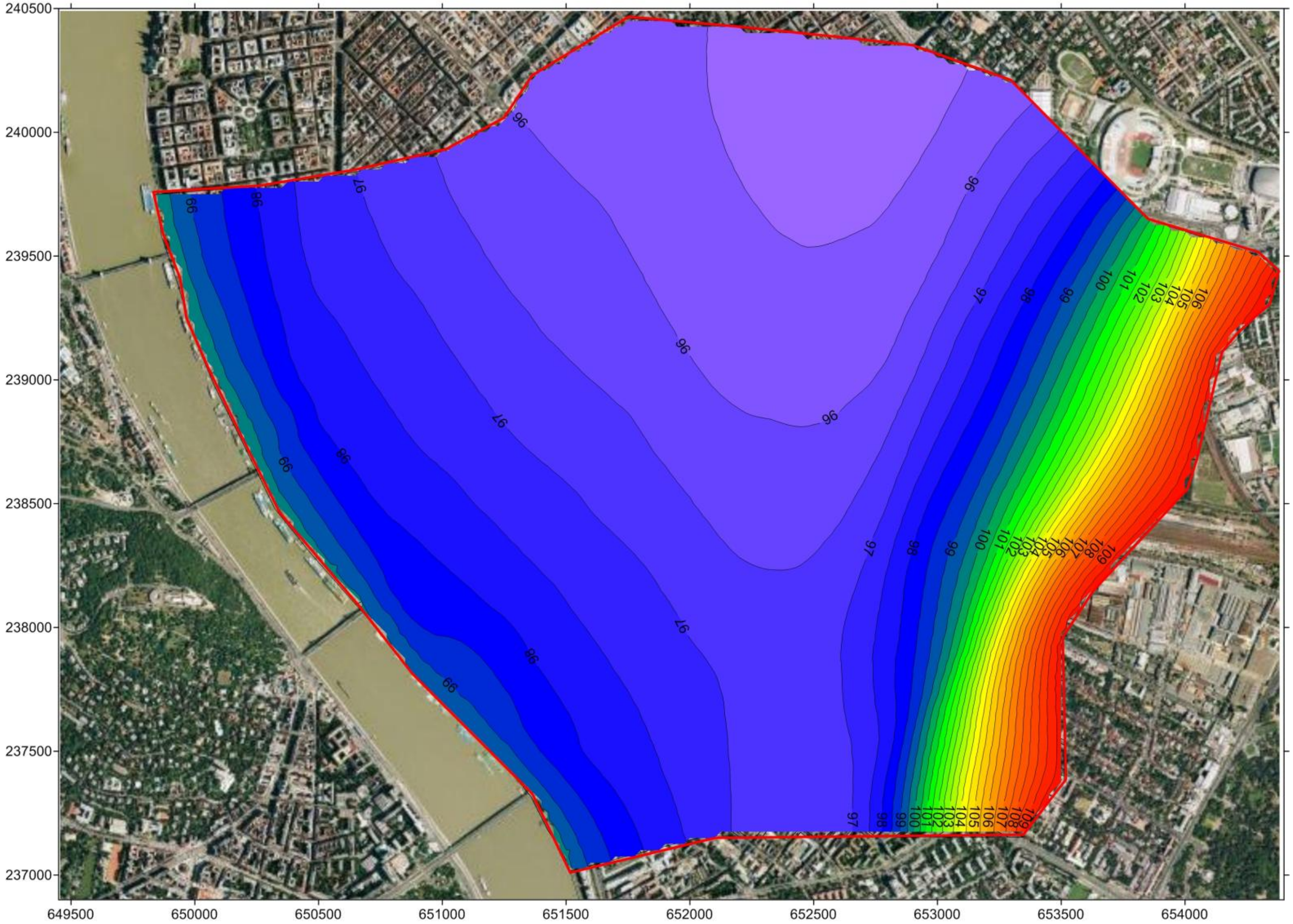
FEFLOW (R)
1643 [d]

Case study





Modeled hydraulic heads without and with the effect of underground garages and metro stations and the depression at high Danube water level situation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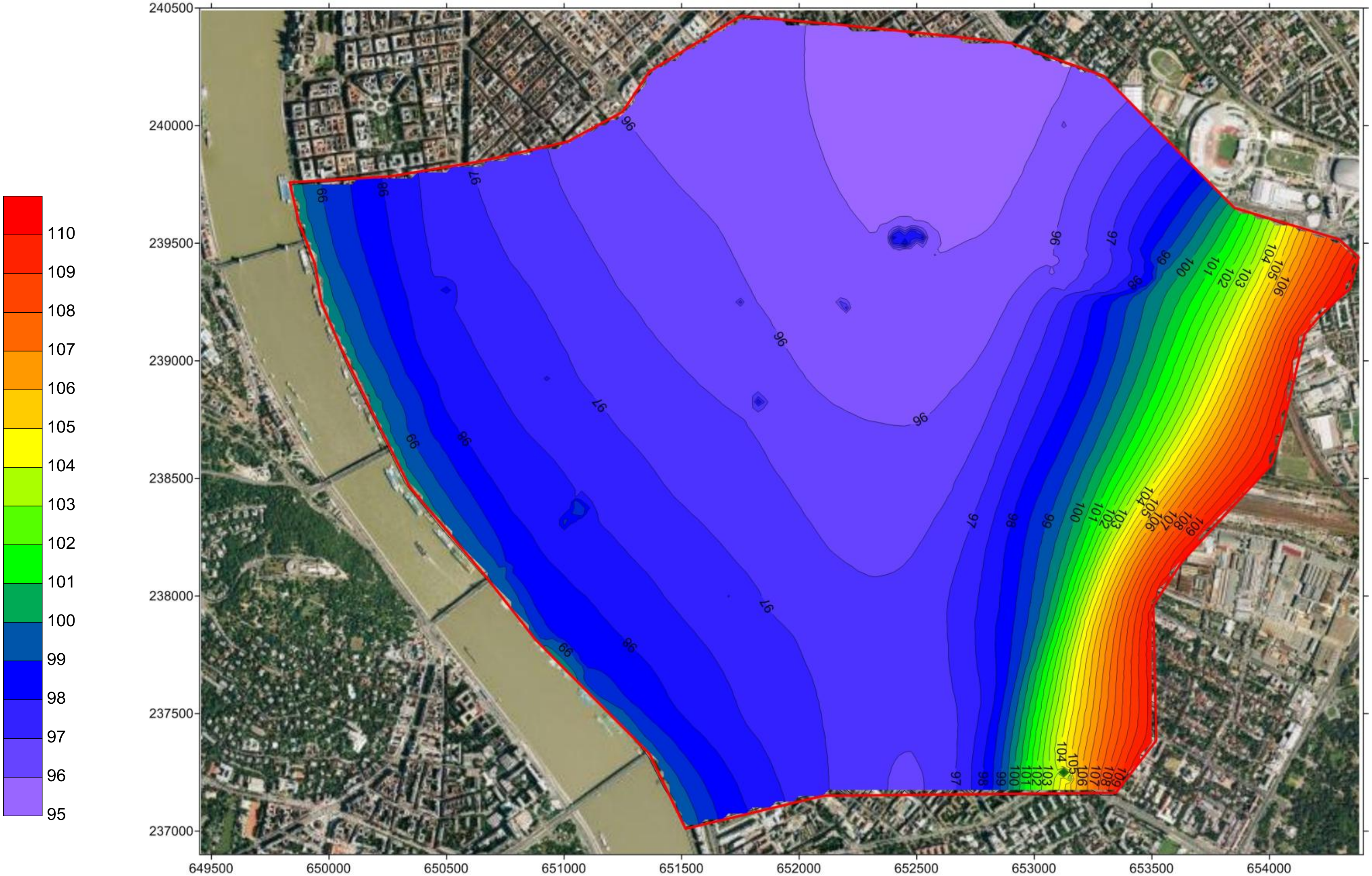

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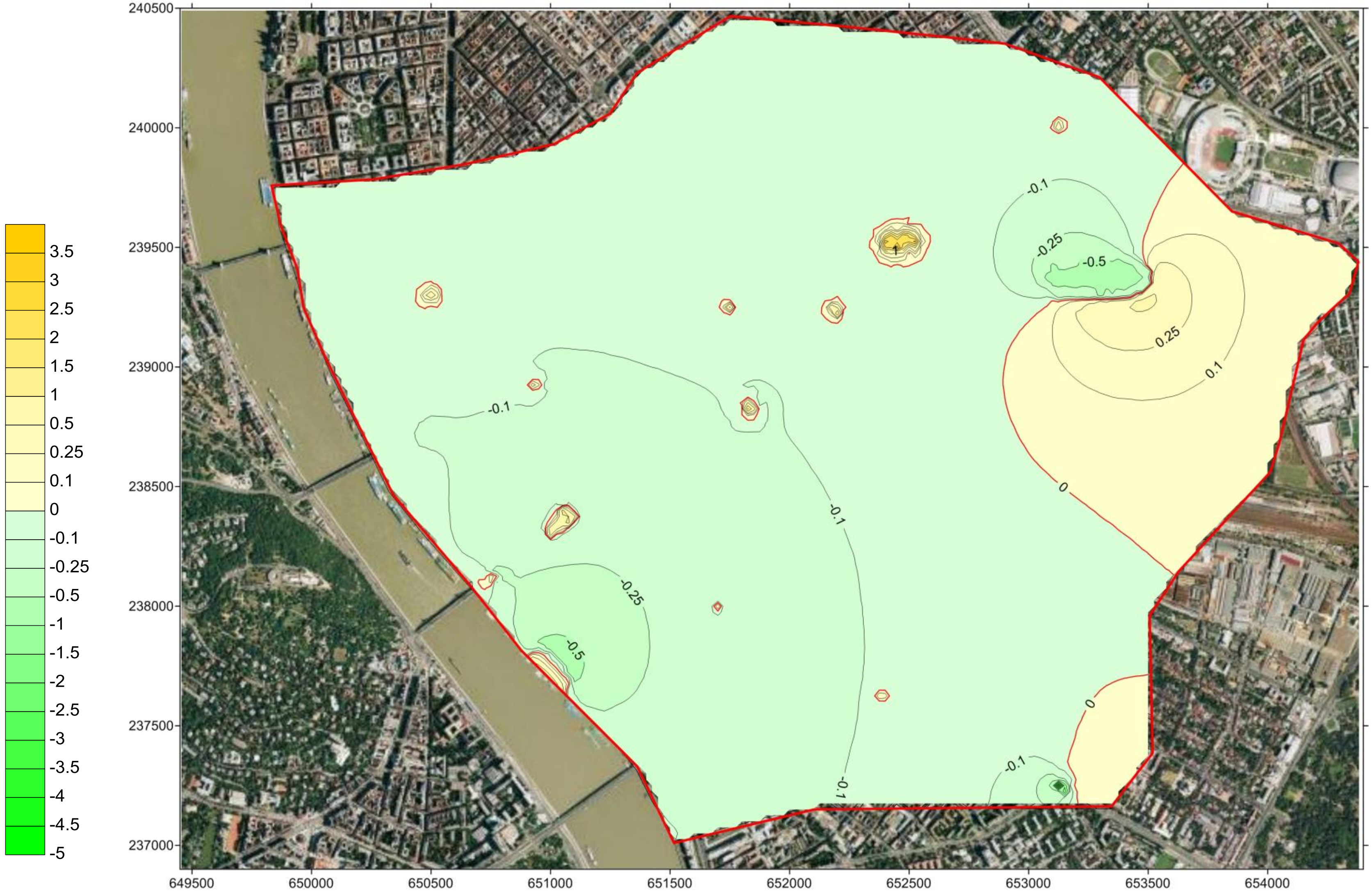
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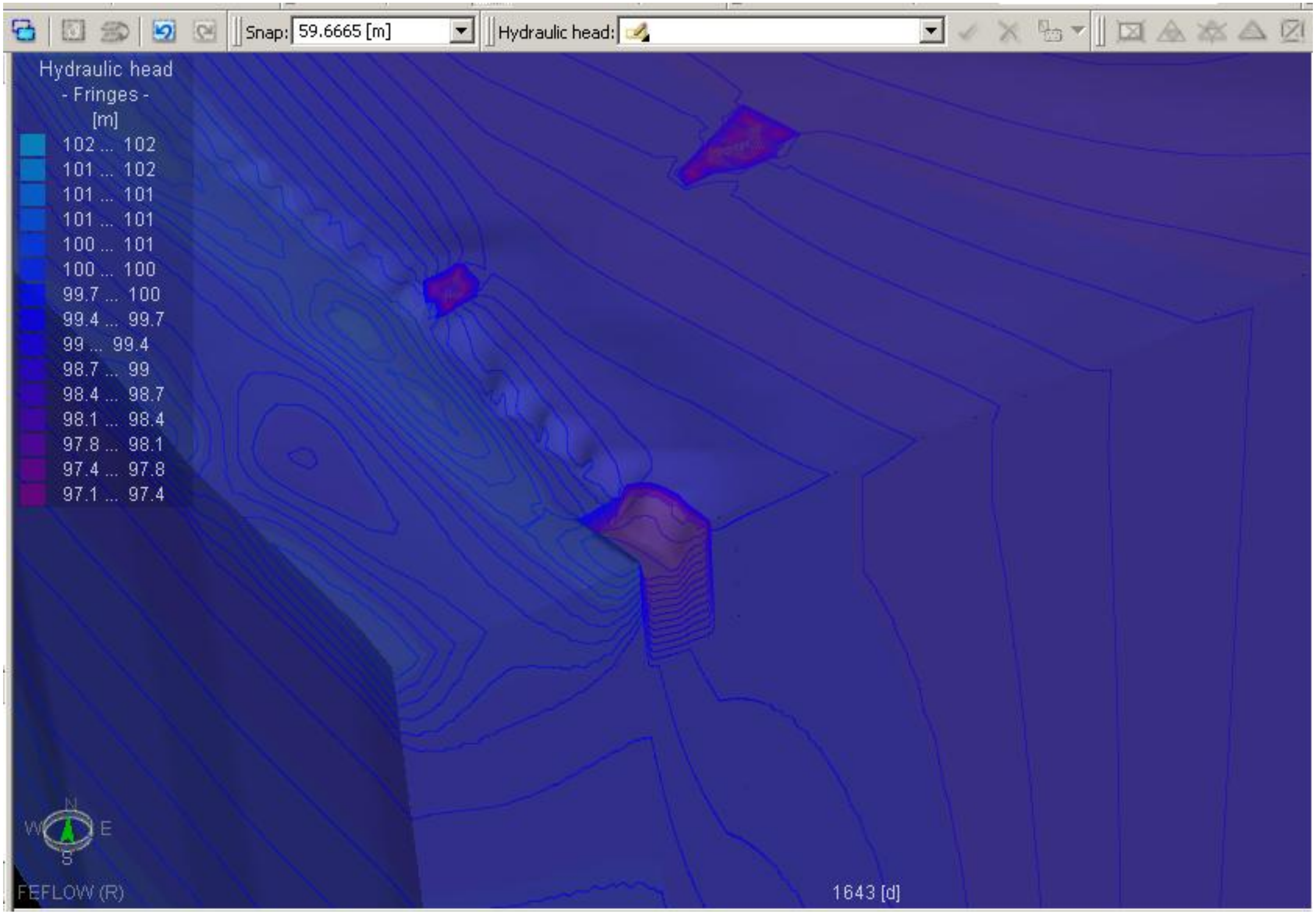
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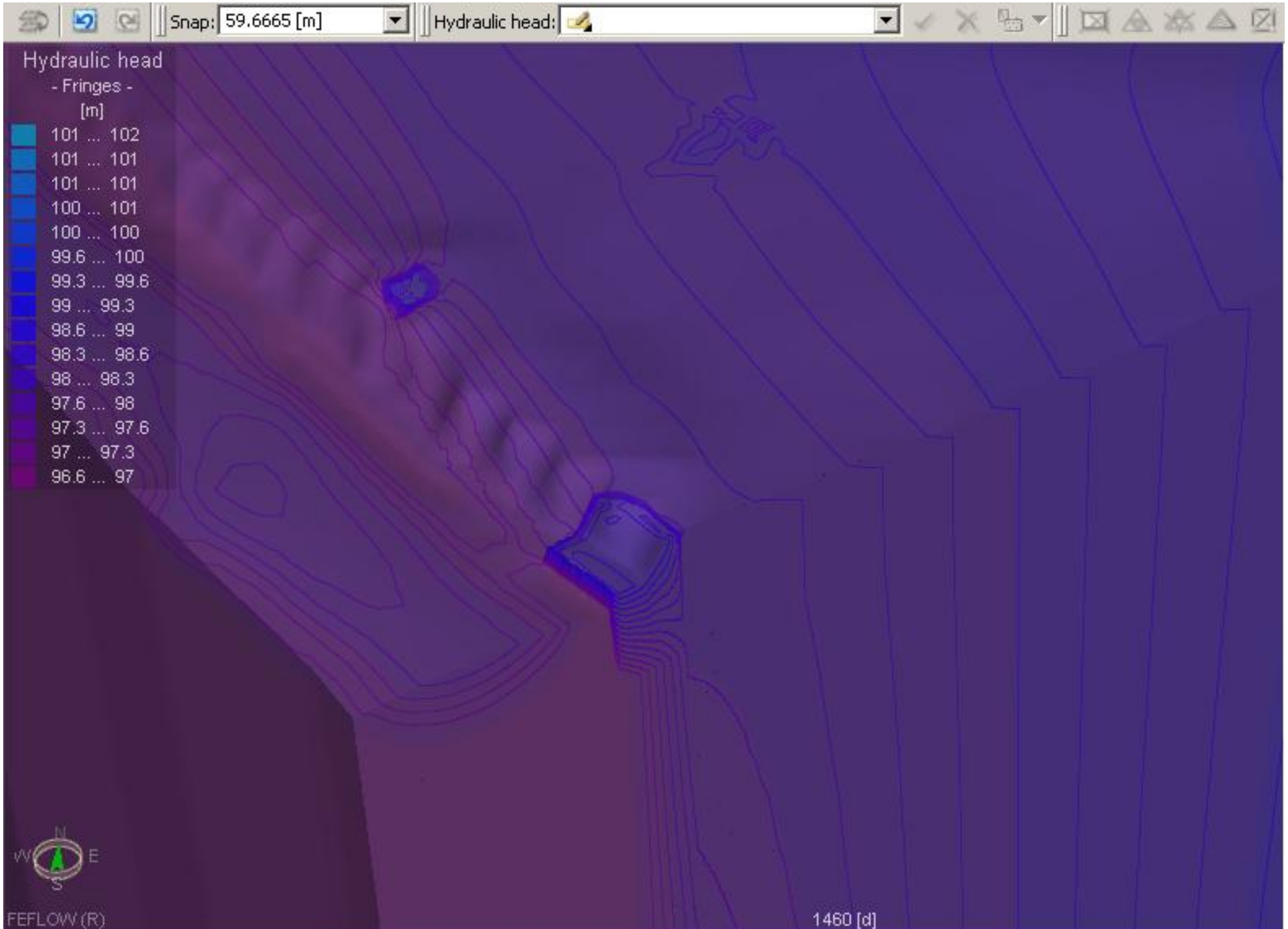
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FEFLOW (R)
1460 [d]

Conclusions

The model can integrate additional installations to make predictions.

Real time modeling

It should be the base for the authorities creating new regulation and giving the permissions of the future investments and the existing operations.

Now they give permissions on the first come first served basis.

Because of the above a database is needed to harmonize the installations inferred coupled effect.

For the lower Danube terrace additional monitoring wells are suggested to observe the still existing garages.

For new sites pumping well are suggested operating in case of high groundwater level caused by floods to lessen the damming back effect.