

Modelling of the groundwater flow in Baltic Artesian Basin

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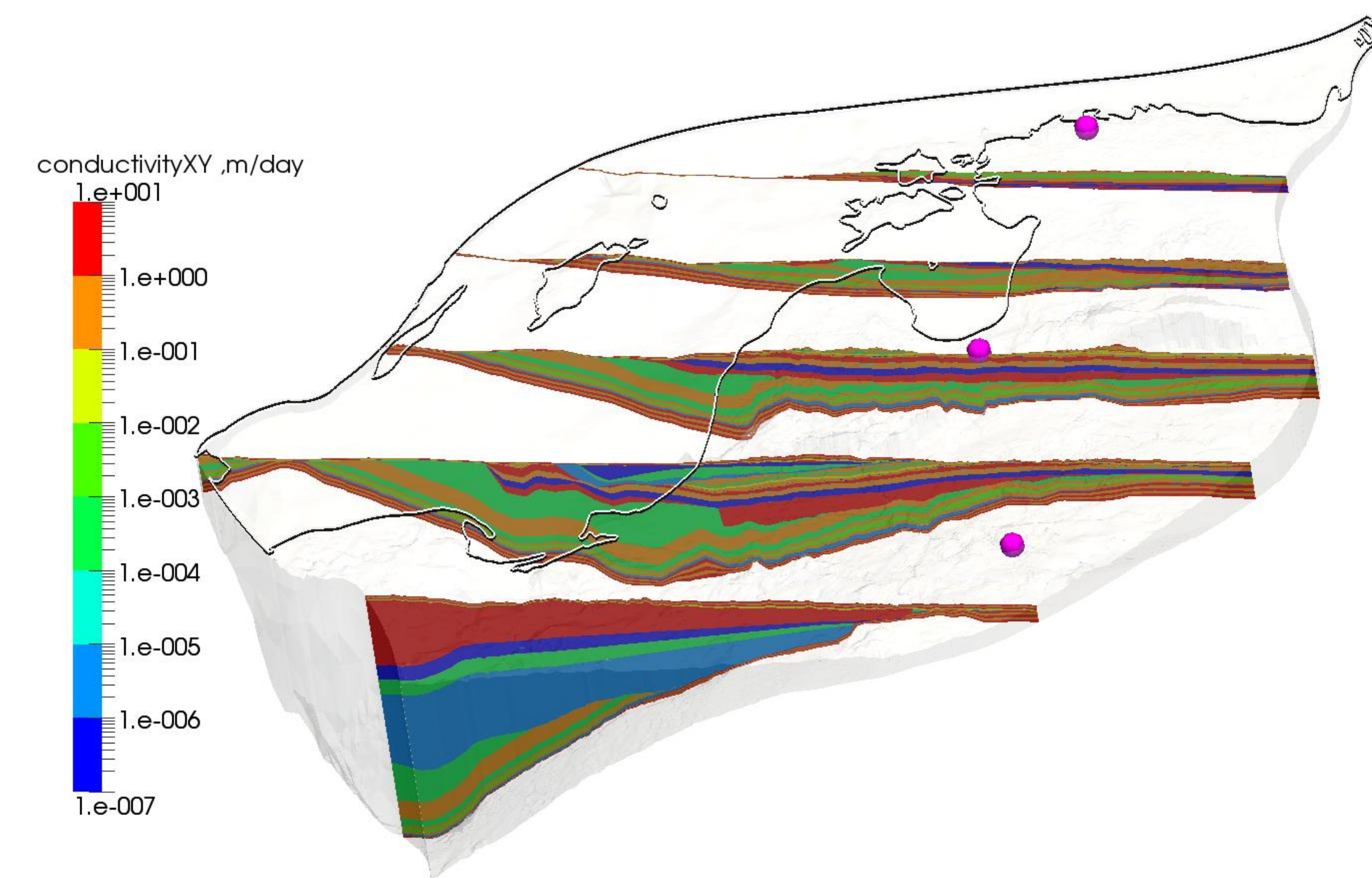
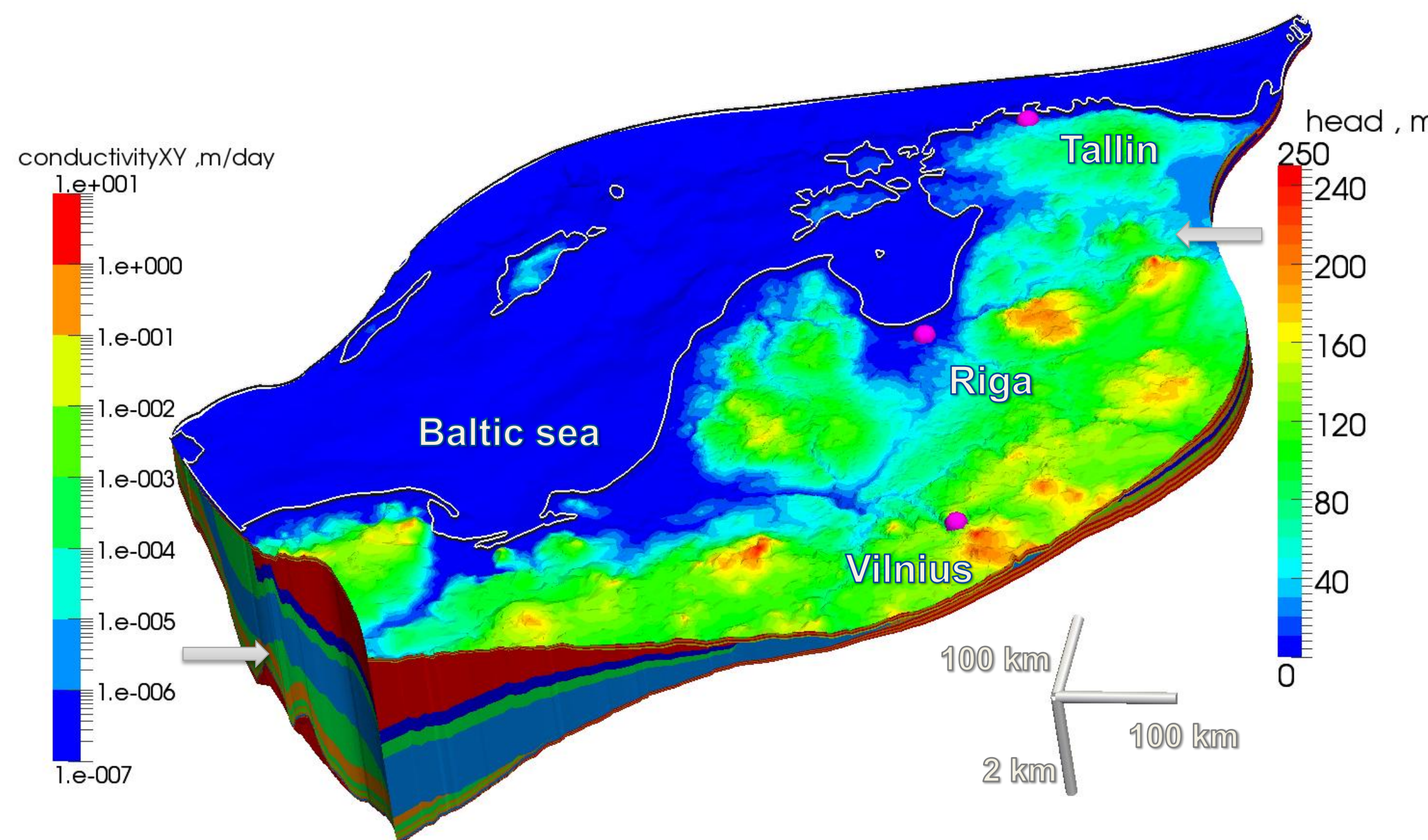
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Abstract

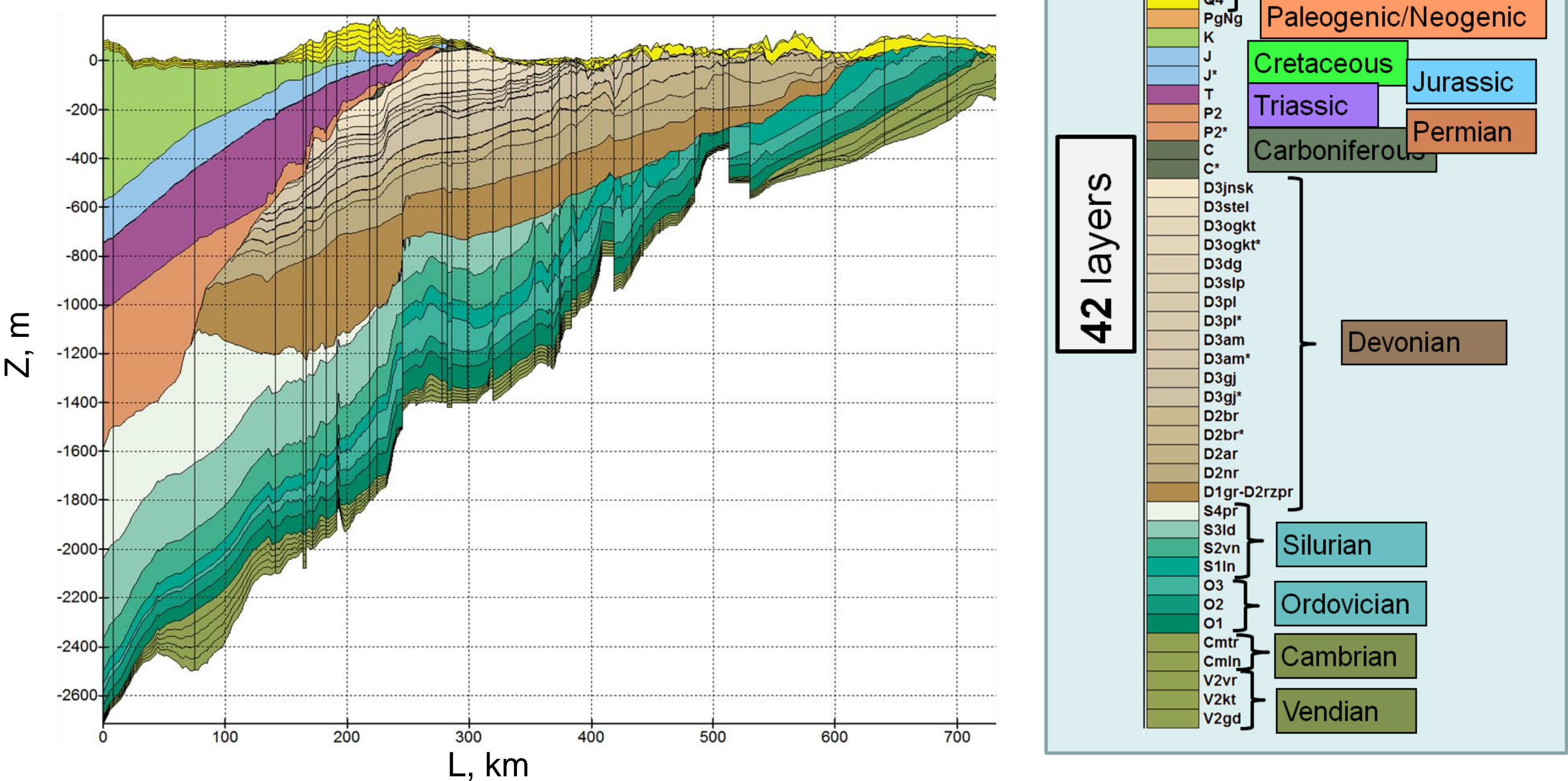
The finite element method was employed for the calculation of the 3D groundwater flow with free surface in Baltic Artesian Basin (BAB). The distribution of piezometric heads, principal flows and integral parameters inside BAB was analyzed based on the model results. A transient model was used to investigate the influence of water abstraction on piezometric heads.

1. Geometric model of Baltic Artesian Basin

BAB is a multi-layered complex hydrogeological system underlying about 480'000 km² in the territory of Latvia, Lithuania, Estonia, Poland, Russia, Belarus and the Baltic Sea. The model of the geological structure contains 42 layers including aquifers and aquitards from Cambrian up to the Quaternary deposits.



Layers in S-N cross-section



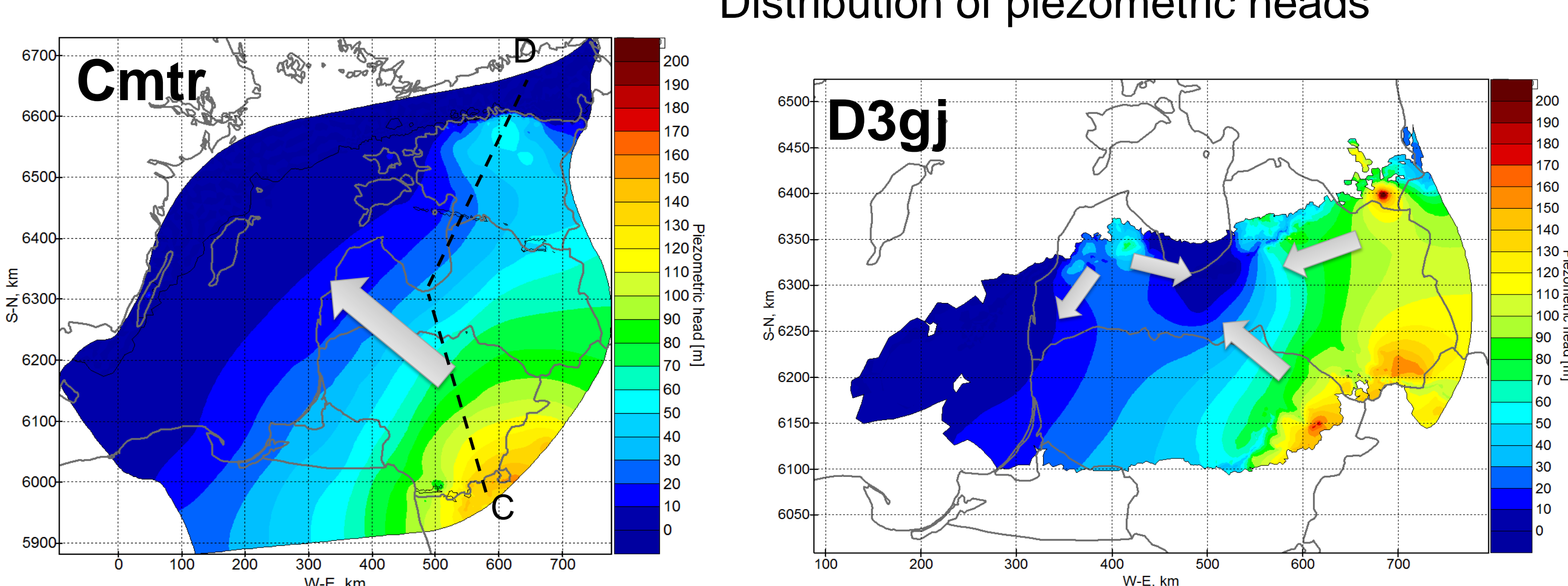
2. Hydrogeological model

3D Darcy flow with free-surface and anisotropic conductivity is assumed for the steady-state solution:

$$\frac{\partial}{\partial x} \left(K_h \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_h \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_v \frac{\partial h}{\partial z} \right) + Q = 0$$

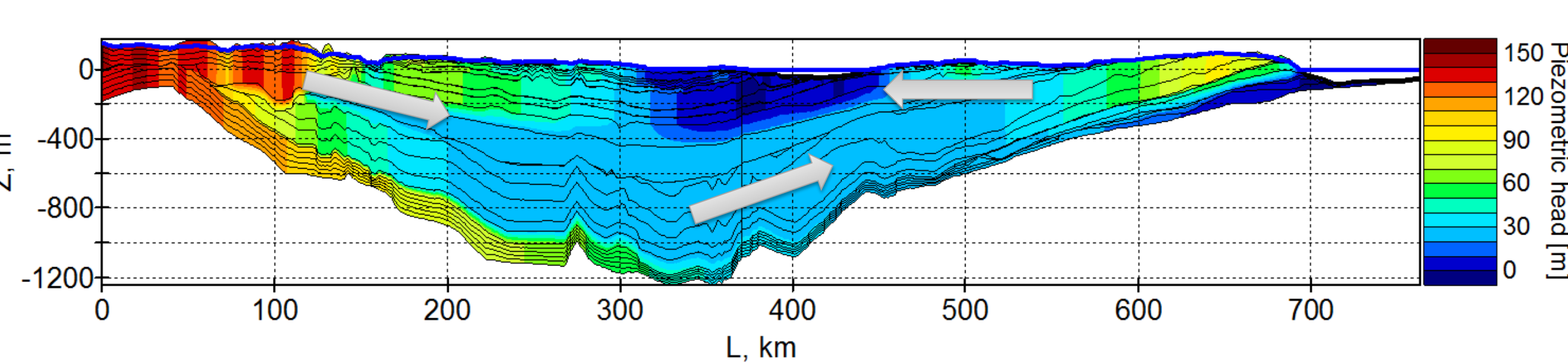
- Finite Element method with Galerkin weighted residuals is used.
- Boundary conditions: impermeable basement, zero flux on side boundaries.
- Earth surface: Infiltration from regional climate model; fixed head on waterbodies.
- Model is calibrated on the statistically weighted borehole water level measurements.
- Direct solver used, 3 Mio elements, 5 min on i7 PC.

3. Results



The flow is directed from southeast to northwest, but the more shallow aquifers show strong influence from local topography.

Vertical section C-D from south to north



Water budget

Surface, in/out ,m³/day

Quaternary: 5.4e8
Sub-quaternary: 4.8e7
Cambrian-Vendian: 8.5e5

Budget from land to
the Baltic sea: 2.6e7 m³/day

Flow budget, 10³ m³/day

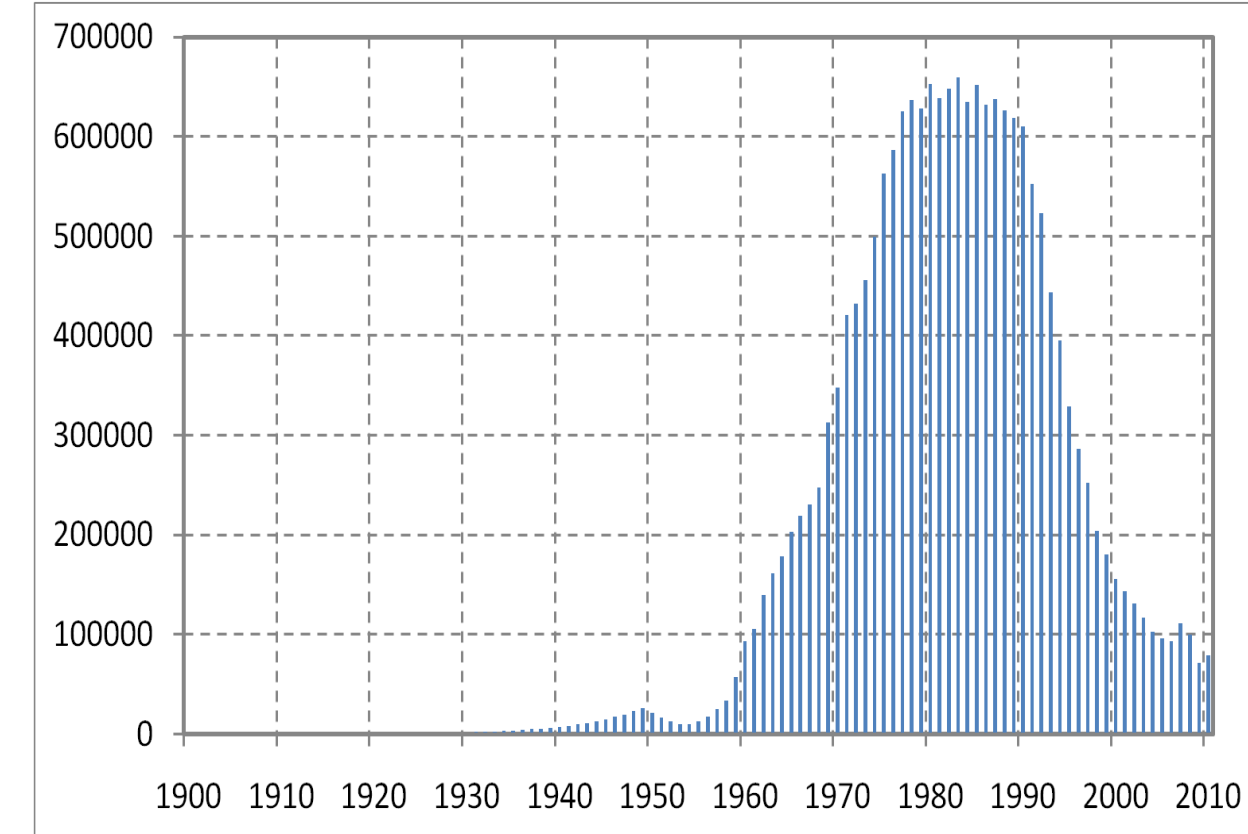
from> to	Q	K-C	D23	D2Nr	D12	S-O	Cm-V
Q	X	126	216	-105	-76	129	-27
K-C	-126	X	62	0	14	37	9
D23	-216	-62	X	116	-4	0	0
D2Nr	105	0	-116	X	5	4	0
D12	76	-14	4	-5	X	-61	0
S-O	-129	-37	0	-4	61	X	56
Cm-V	27	-9	0	0	0	-56	X

4. Transient modelling – influence of water abstraction

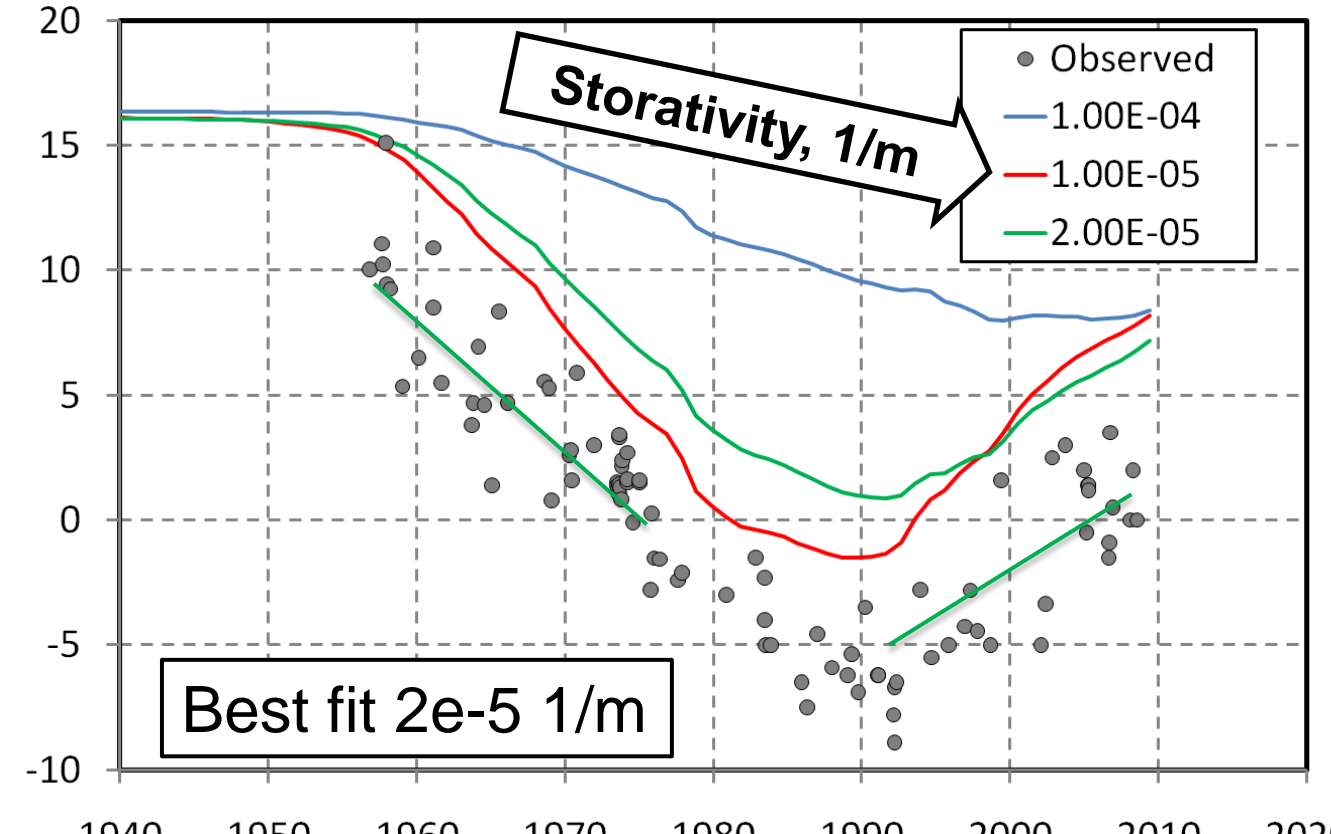
For the model of transient flow an additional parameter storativity S_s is introduced.

$$S_s \frac{\partial h}{\partial t} = \frac{\partial}{\partial x} \left(K_h \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_h \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_v \frac{\partial h}{\partial z} \right) + Q(t)$$

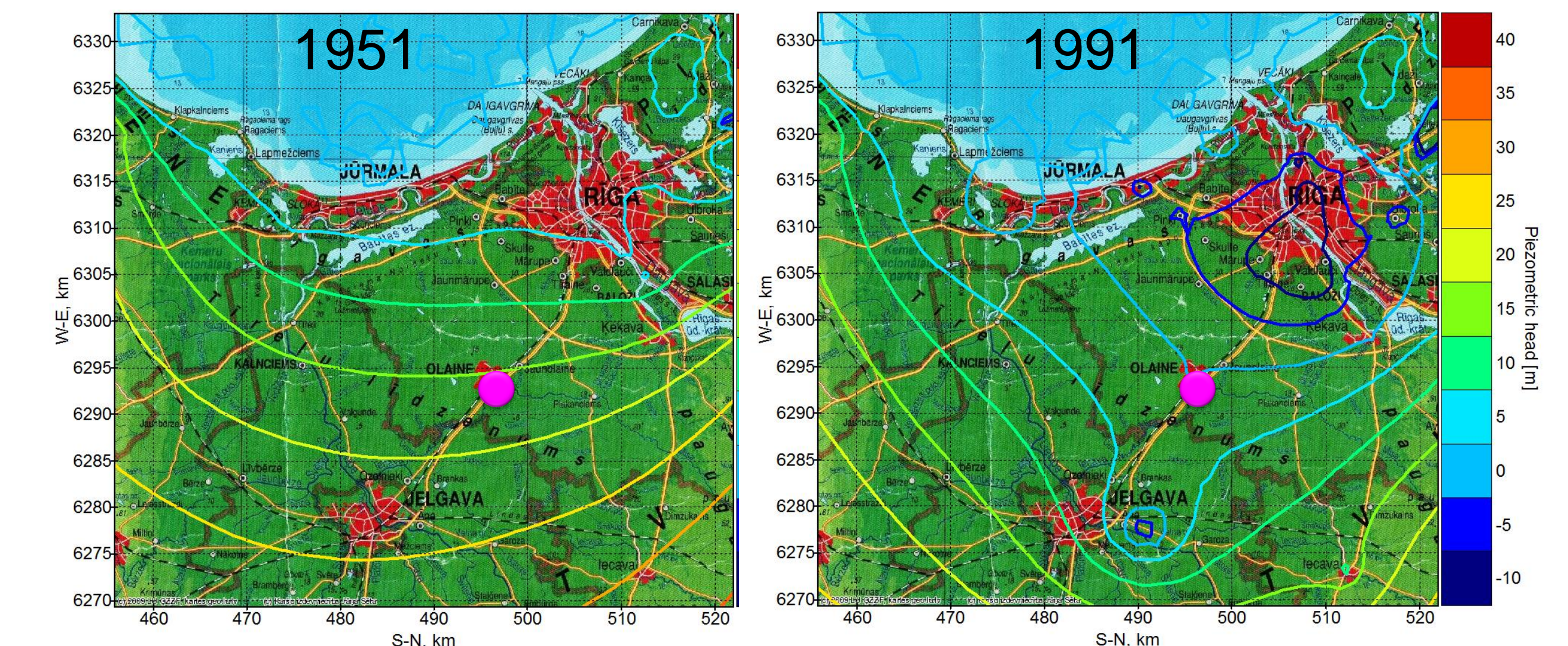
Water abstraction in Latvia, m³/day



Head [m] in D3gj near Olaine



Storativity is calibrated using observed heads



Noticeable reduction and restoration of water heads in central Latvia due to water abstraction.

5. Conclusions

- Generally the flow is directed from southeast to northwest.
- Local topography strongly influences the flow in shallow aquifers.
- Water budget of BAB is calculated.
- Calibrated transient model shows noticeable changes in water heads due to water abstraction.