EFFECT OF BURIED VALLEYS ON GROUNDWATER FLOW: CASE STUDY IN VENTSPILS VICINITY

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INTRODUCTION

Buried subglacial valleys are common feature of the Quaternary sedimentary cover. These narrow, elongated and deep formations could be filled with various, mainly Pleistocene sediments – either till of different ages or sand and gravel or interbedding of both above mentioned. The filling material of the valleys influences groundwater flow in the confined aquifers cut by the valleys. It is supposed that glacial till filled valleys serves as a barrier to groundwater flow and as a recharge conduit when filled with sand and gravel deposits.

AIM

To study effect of the buried valleys on groundwater flow in a confined aquifer (Middle Devonian Arukila aquifer, D_2ar) applying numerical modelling.

STUDY AREA

The vicinity of Ventspils, near wellfield Ogsils was chosen, as there were number of the buried valleys with different depth and filling, and sufficient amount of geological and hydrogeological data for the model development.

Geological structure and hydrogeological conditions of the area

The study area is situated on Piejūra lowland Rinda plain, where thin layer of Quaternary sediments are exposed, thickness varies form 10 to 20 meters, Prequaternary sediments are exposed at some places .

Quaternary deposits consist of Weichelian glacial till with rare sand and gravel lenses and interlayers, partially covered by the Baltic Ice Lake sand deposits (Fig. 1). The depth of the buried subglacial valleys are various, in the surrounding of the wellfield Ogsils it is about 25-60 meters, but a bit further to the West it reaches even 100-120 meters depth. These valleys are filled with Quaternary sediments of different origin – both glacial till loam and sand with gravel (Fig. 1).

Deposits of the Middle Devonian Arukila and Burtnieki formations are found on the sub-Quaternary surface, and Narva Formation deposits are present there within the buried valleys (Fig. 2).

The groundwater is mainly bound to deposits of Arukila formation – sandstone and siltstone interbedding. The groundwater flow in the confined Arukila aquifer is to the West, towards the Baltic Sea. Groundwater level in the area is 10-20 m amsl.

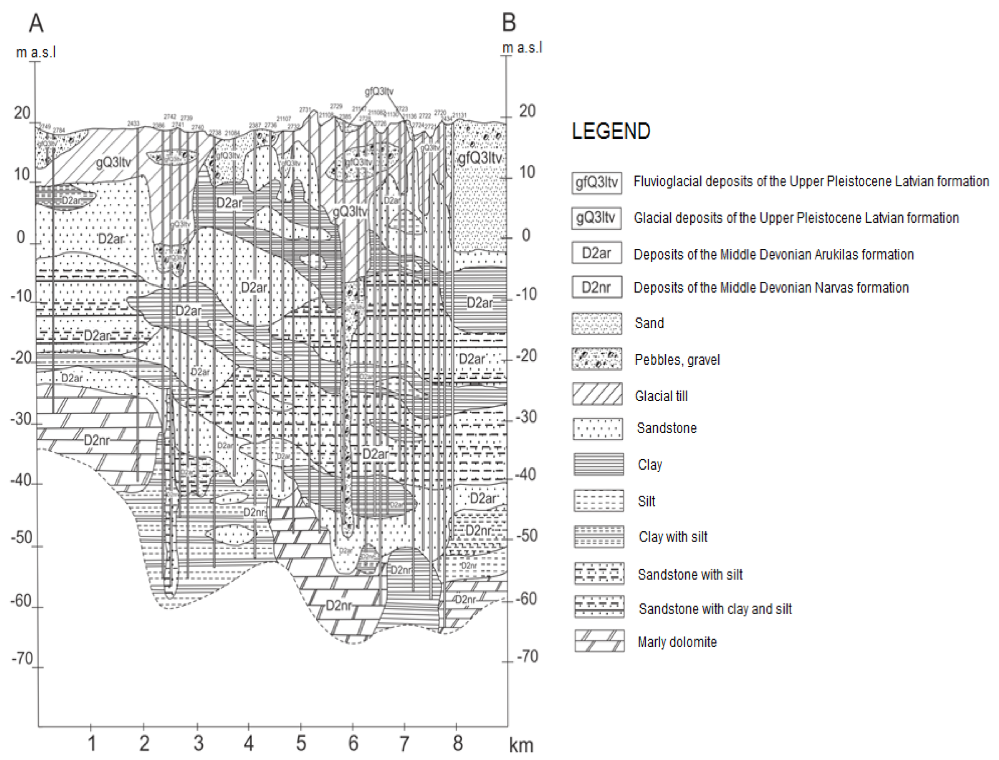

Fig. 2. Generalised geolocigal cross-section along line A-B (Dūdiņa 2014)

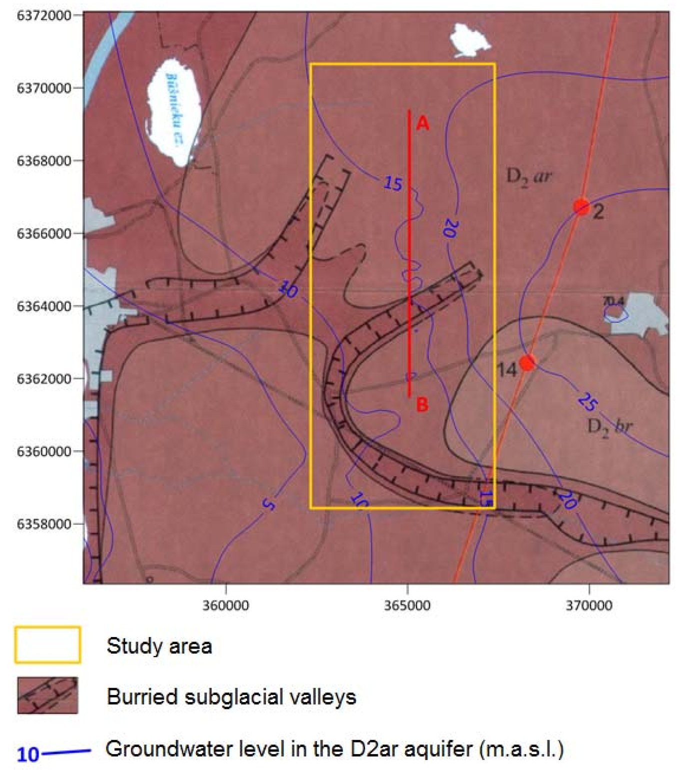

Fig. 3. Map of subquaternary deposits of the study area (Mūrnieks 1998) and groundwater level of D_2ar confined aquifer (based on data from LVGMC)

MATERIALS

Geological and hydrogeological data for compilation of numerical model (geological structure, aquifer properties, boundary conditions) were obtained from data base of Latvian Environmental, Geological and Meteorological centre (LVGMC) and archive data of company «Udeka» managing wellfield Ogsils.

MODEL SETUP

Numerical model was built within MOSYS modelling system (Virbulis et al. 2012) using finite element triangular mesh. A 3D Darcy flow with free-surfaces and anisotropic conductivity (Table 1) is assumed for the steady-state solution. As boundary conditions, water level of largest rivers, lakes and sea were defined as tophead (Fig. 3) with slightly variable recharge of 1.4-1.5 e-5 m/day in uppermost layer. Numerical model covers territory of 45x30km, including buffer zone 5 km around the interest area.

Table 1. Hydraulic conductivity values in the model

Model layer	Kxy, m/day	Kz, m/day
m,lgQ3-4	8	8
gQ3	0.0005	0.0005
D3gj	6	6
D2br*	0.0001	0.0001
D2br	6.2	6.2
D2ar*	0.0001	0.0001
D2ar	8	6
D2nr*	1.8e-9	1.8e-9
D2pr	4	4
Valleys (gravel)	15	10
Valleys (till loam)	0.0005	0.0005

Modeling approach involved building of several structures where different hydraulic conductivity values were applied for the valleys filling afterwards. The main structure for calculations included buried valleys, and the structure without valleys was created a reference one. Hydraulic conductivity values of sediments of the buried valleys were changed in the calculation stage, so that one solution represents valleys filled with highly permeable sediments (k=10-15 m/day) and another one – valleys filled with low permeable sediments (k=0,0005-0,001 m/day).

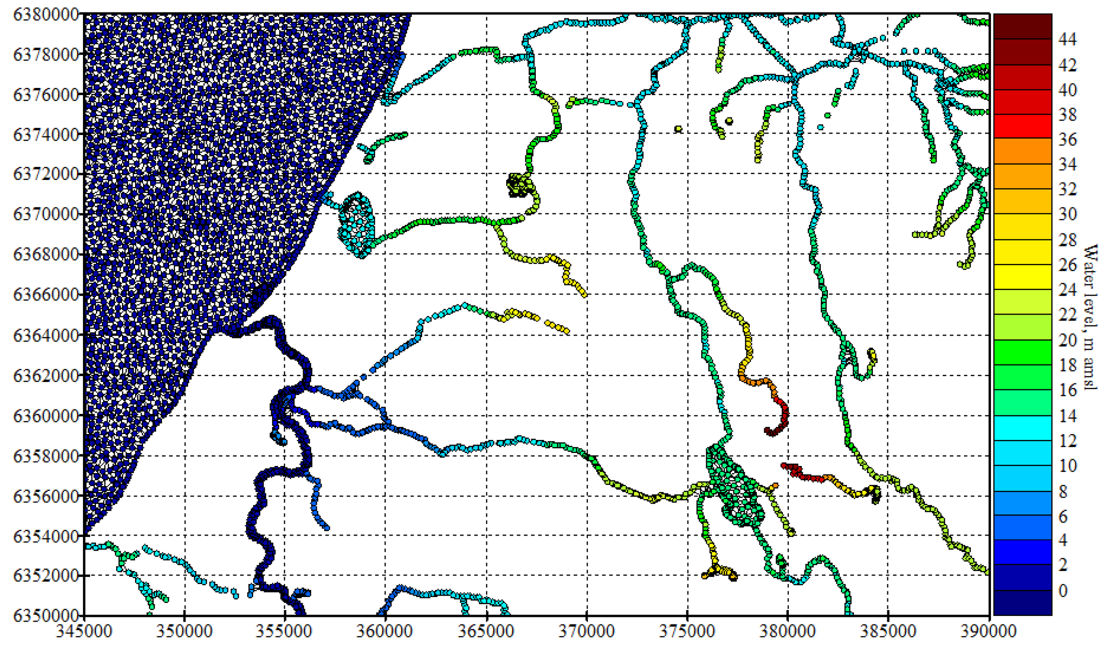

Fig. 3. Boundary condition values at the earth's surface

MODEL CALIBRATION

Model was calibrated using observed water level data before and after wellfield construction. Measured and modelled levels were compared (Fig. 4), and afterwards aquifer properties and recharge conditions were modified to achieve the best correspondence between observed and modelled groundwater level values. Although modelling results after the calibration were improved in most locations (head difference 1-2 m), there were some areas, where most likely other factors influence groundwater level rather than just above mentioned, because there difference between the measured and observed values was high, reaching 8-10 m.

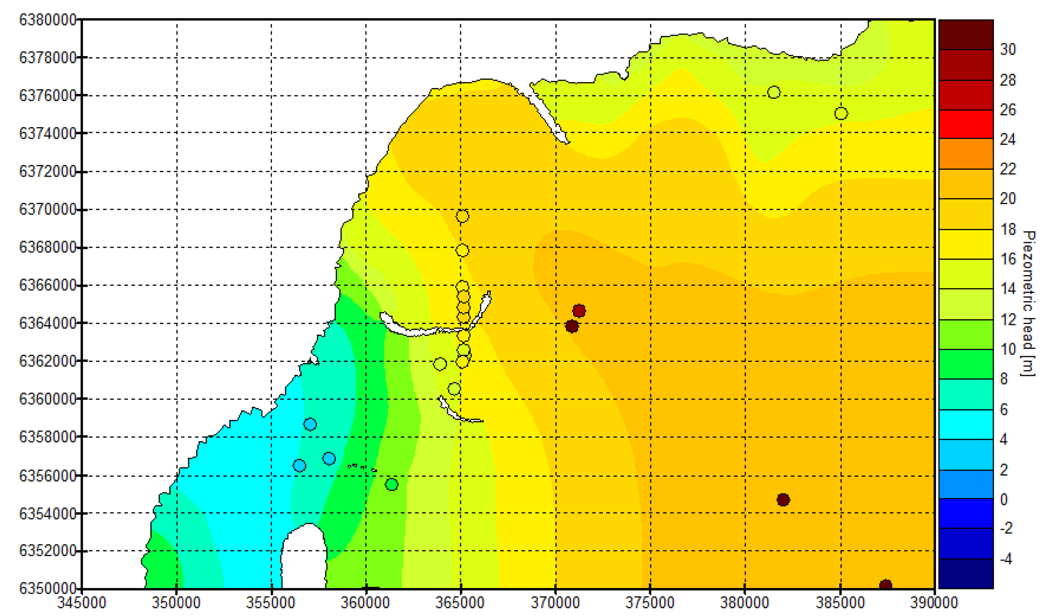

Fig. 4. Modelled (fill) and observed (dots) groundwater level values in D2ar aquifer after calibration

RESULTS

Permeable valleys serve as continuation of cut aquifer and no disruptions in piezometric head distribution in the particular aquifer are observed. They serve as recharge areas for the aquifer as well (Figs. 5A and 6). Low permeable valleys do not facilitate aquifer recharge and disturb groundwater flow within the aquifer which is shown by the disturbances in piezometric head distribution near valleys (Figs. 1B and 3).

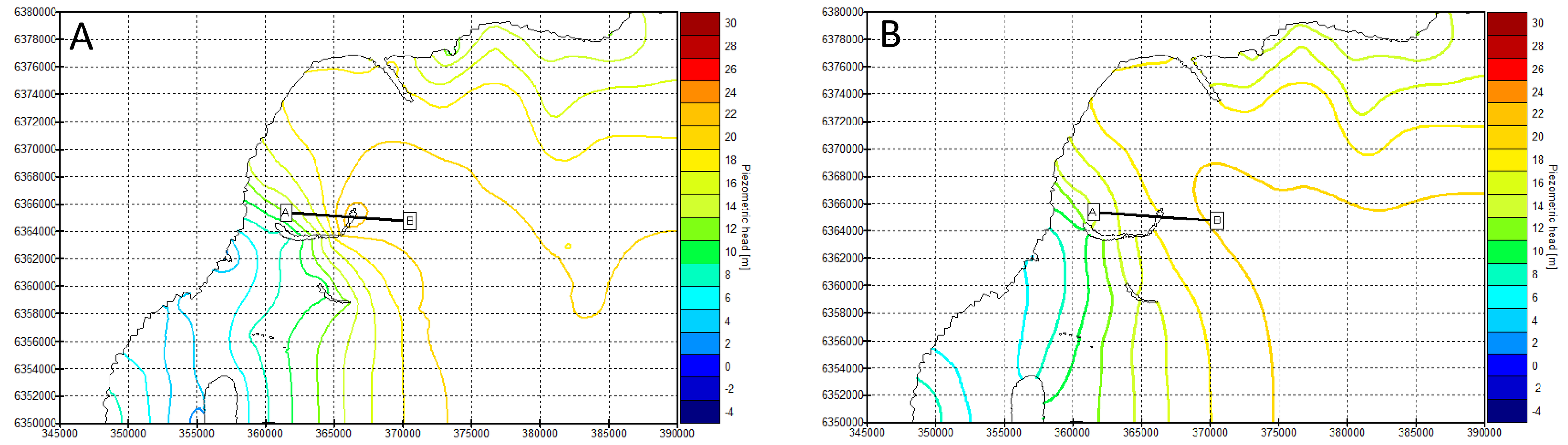

Fig. 5. Modelled piezometric heads in the Arukila confined aquifer: A. Buried valleys filled with sand and gravel sediments, B. Buried valleys filled with till sediments. Thin black lines – aquifer distribution border, thick black line shows location of cross-sections of Figs. 6 and 7.

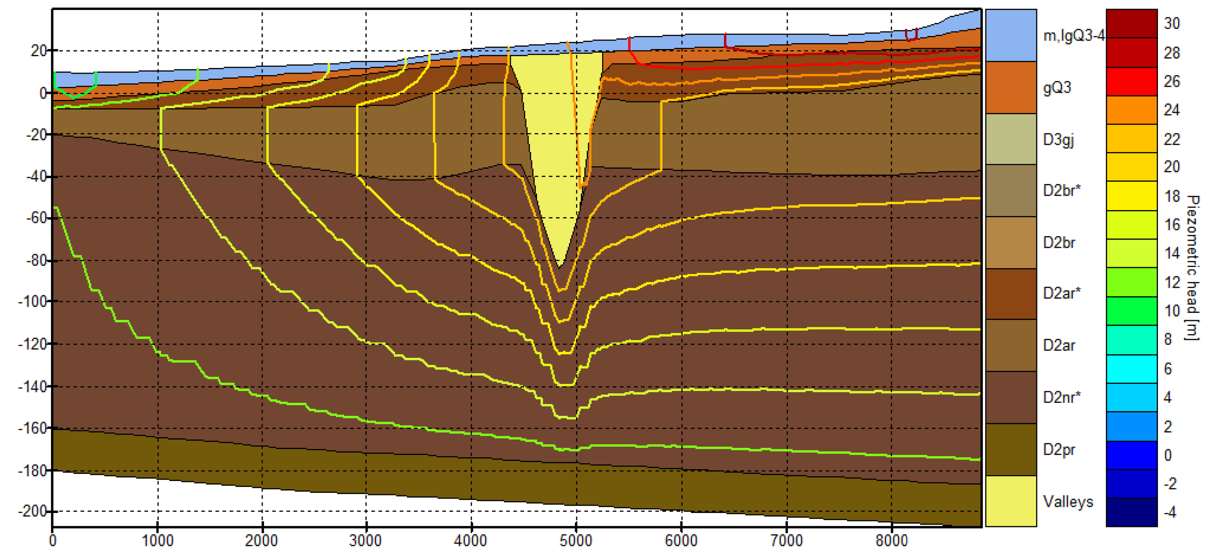

Fig. 6. Modelled piezometric head distribution near buried valley filled with sand and gravel sediments.

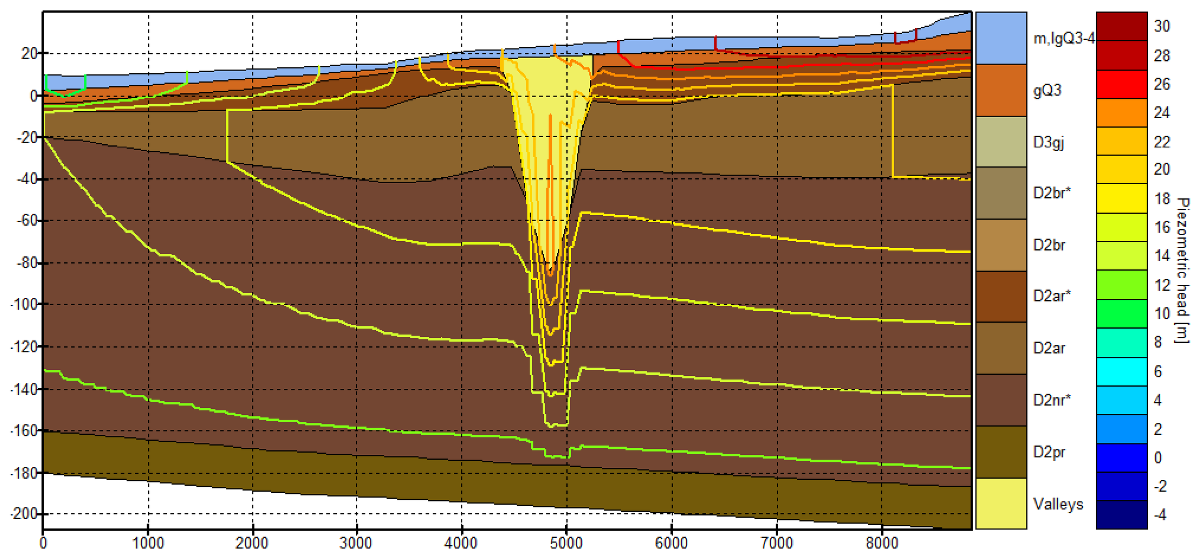

Fig. 7. Modelled piezometric head distribution near buried valley filled with till sediments.

SUMMARY

The results approve initial suggestions that buried valleys filled with till sediments and cutting into confined aquifer serves as a barrier in groundwater flow, causing sharp drop of piezometric head and downward flow within whole valley area (Fig. 3). And on contrary, valleys filled with sand and gravel sediments have minimal influence on piezometric head distribution (Fig, 2), but facilitate recharge from shallower aquifers and groundwater exchange within the valley. The study shows that piezometric head distribution disturbances within the structure with buried valleys are spatially limited next to the valleys comparing to the structure without valleys.

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ERAF EIROPAS REGIONĀLĀS ATTĪSTĪBAS FONDS

IEGULDĪJUMS TAVĀ NĀKOTNĒ

EIROPAS SAVIENĪBA