WATER REGIME SIMULATION ALONG GABČÍKOVO – TOPOĽNÍKY CHANNEL (VRAKÚŇ JUNCTION) CASE STUDY

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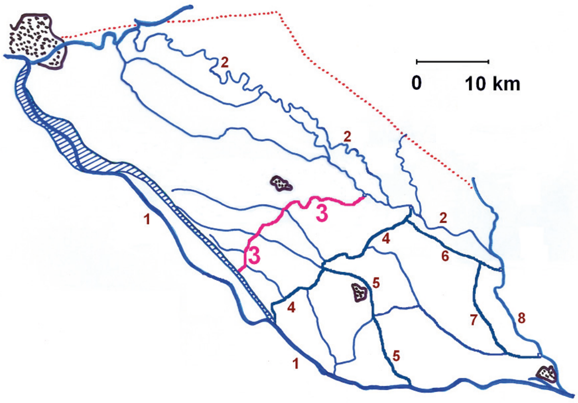
Abstract: Gabčíkovo – Topoľníky channel is one of three main channels in the irrigation and drainage channel network of Žitný ostrov. Žitný ostrov is a lowland area in south – western Slovakia with high degree of agricultural use and thanks to its bed composed mainly of fluvial gravel sediments it is a significant storage of high quality groundwater. The Vrakúň junction location was chosen due to the presence of regulation measures (floodgates) along the boundary of the area of interest and also due to the occurrence of both agricultural and urban areas. The aim of this paper is to evaluate surface water – groundwater interactions between the channel and its surroundings considering the significant increase in volume of silts in the channel over the past years and comparison of the interaction between the current state and state with no aggradation in the channel. The simulation was done using finite – difference groundwater (MODFLOW) (Harbaugh et al., 2000) model in the Aquaveo GMS interface.

Keywords: surface water, groundwater, interaction, groundwater modeling, MODFLOW

Introduction

Žitný ostrov is an important agricultural site and it is also an area with important source of drinking water. Last but not least due to the flat nature of the area and built channel network it is the ideal location for exploring the interaction of surface water and groundwater. The aim of this paper is to evaluate the effect of channel network aggradation on the groundwater regime for different scenarios of sediment thickness and its permeability, using one layer finite – difference groundwater flow model.

Figure 1. Žitný ostrov (1 – Danube, 2 – Small Danube, 8 – Váh), channel network of Žitný ostrov (3 – Gabčíkovo – Topoľníky channel, 4 – Chotárny channel, 5 – Čalovo – Holiare – Kosihy channel, 6 – Aszód – Čergov channel, 7 – Čergov – Komárno channel, 9 – Komárňanský channel) (Velísková, Dulovičová, 2008)



Materials and methods

Žitný ostrov is located in the southwestern part of Slovakia, on the border with Hungary. Located in the Danube Lowland, its boundaries are formed to the south by the river of Danube, in the north by Small Danube and the short section on the east it is bordered by the river Váh (Fig. 1).

The average slope of the lowland is only about $2.54.10^{-4}$ (Velísková, Dulovičová, 2008). The case study area is located in the middle of Žitný ostrov near the city of Dunajská Streda. The total area of the modeled locality is approximately 41 square kilometers. The range of altitude is between 112.3 and 115.5 m a.s.l. The terrain level decreases from west to east. From the geological view the area is characterized by gravel or sandy gravel fluvial sediments of significant thickness, ranging from 350 to 400 m in the case study area (Maglay et al., 2009), covered with layer of sand or sandy loam of average thickness 3 – 5 m, and the top layer is composed by loam with average thickness 1 – 2 m (Gyalokay, 1972). Area of interest falls within the climate zone A1, which is characterized as warm, dry, with mild winters and longer sunshine (Faško, Štastný, 2002). The annual precipitation, according to precipitation measuring station,

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was 519.3 mm in year 2012 and 670 mm in year 2013. The groundwater recharge is affected mainly by precipitation and also by the seepage from the Danube River.

Model boundaries

There are five channels from Žitný ostrov channel network present in this area. On the north boundary there are channels Vojka – Kračany (west) and Boheľov channel (east), on the south boundary there are channels Šulany – Jurová (west) and Jurová – Veľký Meder (east). The main channel Gabčíkovo – Topoľníky flows through the center of the modeled area (rkm 16 - 24). The area boundary on west and east side (red) was set to specified head as a Time – Variant Specified Head (CHD) boundary (Aquaveo, 2013), set to an approximation of a head value in said area. All of the channels were set up as a river boundary using MODFLOW RIV package (Aquaveo, 2013). The area cells set up with river boundary condition are specified by head stage in river (water level), bottom elevation and a conductance value of the bed sediments. The conductance values of bed sediments were adjusted according to field measurements from channel Gabčíkovo – Topoľníky in 2014.

Topography and geology

The topography of the area of interest is specified, as with the whole Žitný ostrov, as a lowland area with low slope and small differences between elevations above sea level. Elevations rage from 112.3 m a.s.l. to 115.5 m a.s.l (Fig. 2). The width of the model area is approximately 8.7 kilometers and the height of the model area is approximately 7.5 kilometers.

The geology of model area is represented mainly by quaternary fluvial sediments. The area is located in a Gabčíkovo depression, where the thickness of the sediments layer is highest from all of Žitný ostrov. The thickness of the quaternary fluvial sediments ranges from 350 to 400 meters and the depth ranges from -237 meters a.s.l. to -288 meters a.sl. (Fig. 3).

The hydraulic conductivity of the one layer model geology is represented by a map of horizontal hydraulic conductivities for said area specified in the geological map of Slovakia (Káčer et al., 2005). Saturated hydraulic conductivity of subsurface geology ranges from $4.2*10^{-3}$ to $8.6*10^{-4}$ m.s^{-1}.

Figure 2. Topography of model area

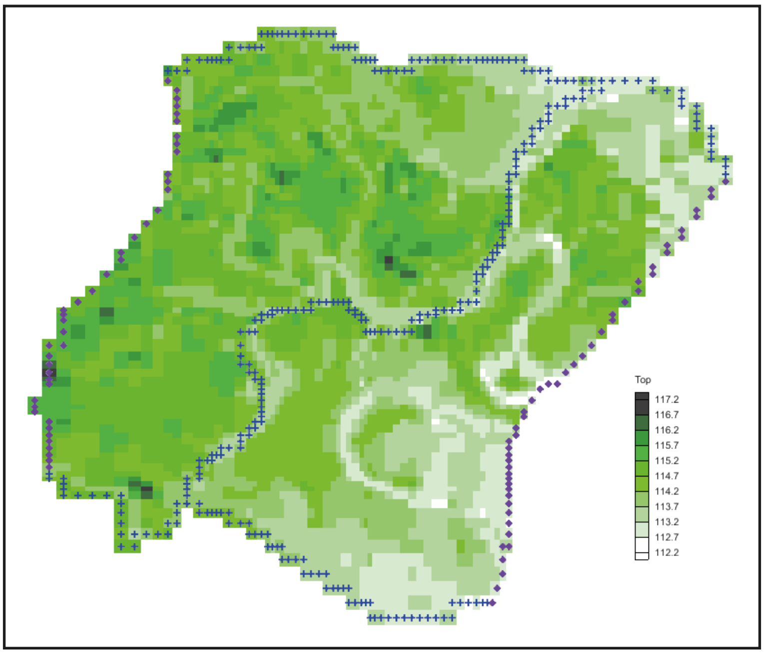

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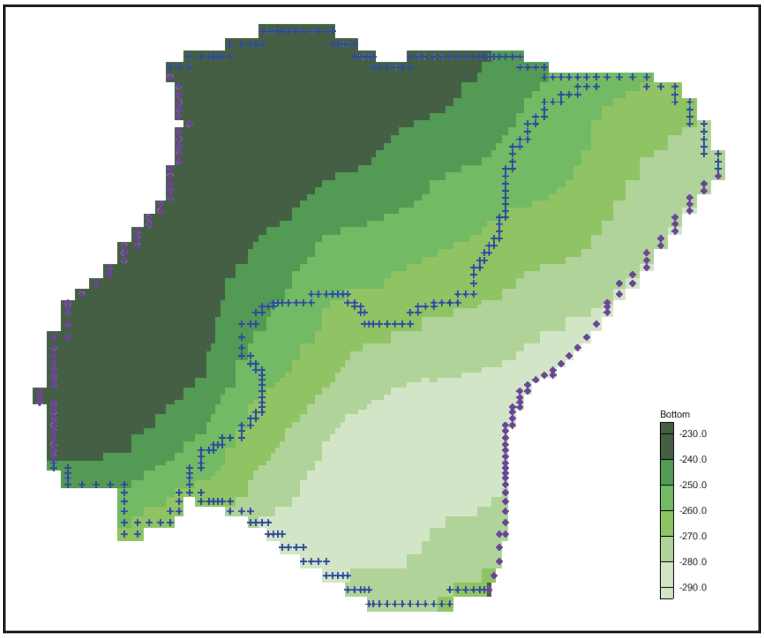
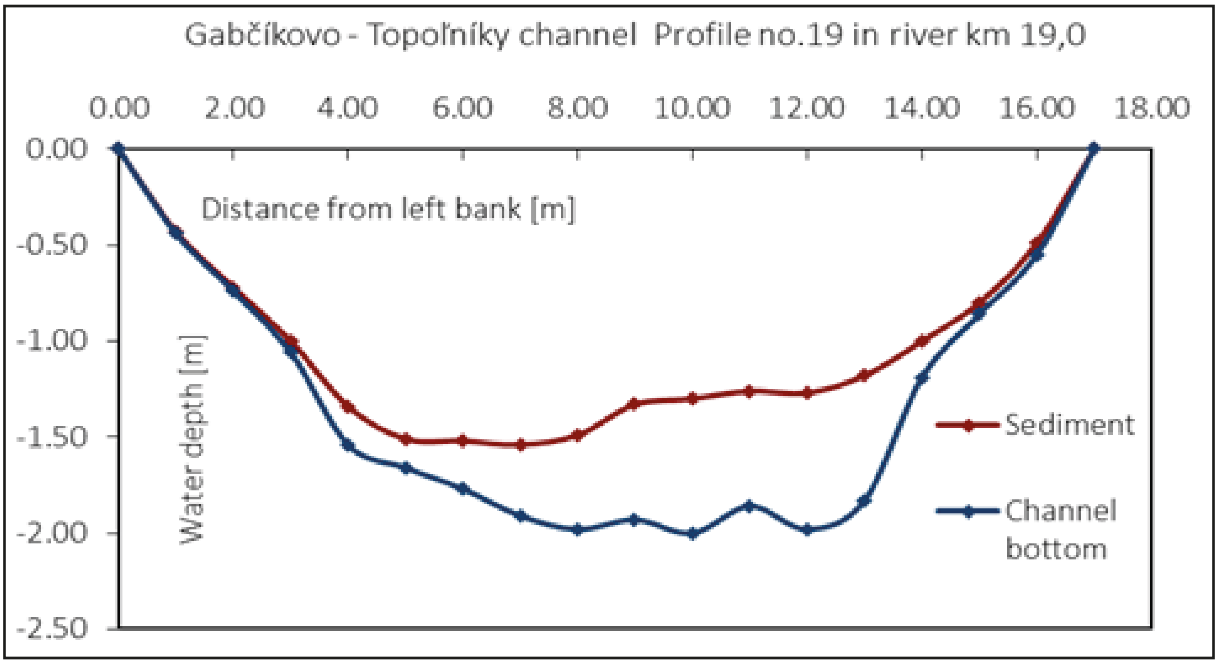
Figure 3. Aquifer bottom depth



Channel aggradation

Complex measurements of Gabčíkovo – Topoľníky channel sediments were completed in May/June 2014 and represent the current state of the channel aggradation. Measurements were done at each river kilometer. Water level and riverbed sediment thickness were measured in each meter across the measured cross-section profile (Fig. 4). If it was possible sediment samples were taken. In this case study we focused on the rkm 16 – 24, which corresponds to the model area. The sediment thickness ranged from 0.09 m to 0.74 m, with an average of 0.43 m. The granular composition of the samples was evaluated and consequently the hydraulic conductivity was calculated using applicable empirical formulas by Bayer – Schweiger and Špaček (Dulovičová and Velísková, 2005).

Figure 4. Example cross section – thickness of riverbed sediments



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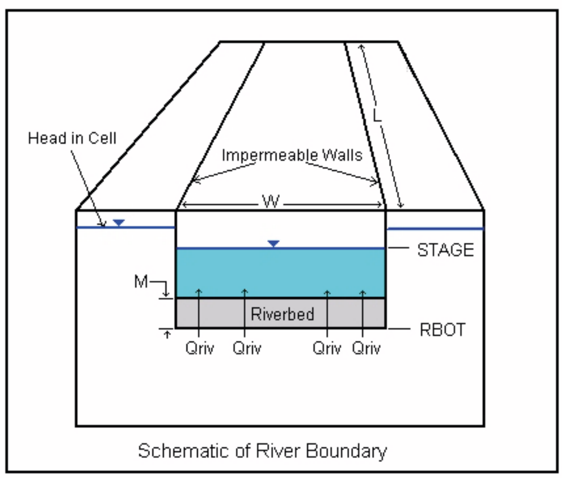
The conductivity values, riverbed thickness and channel width, resp. cross – sectional area were used to calculate conductance, an input parameter of MODFLOW RIV package (Aquaveo, 2013), using following equation:

$$C = \frac{\frac{k}{t} lw}{L}$$

where *k* is hydraulic conductivity, *t* is the thickness of the riverbed sediment, *lw* is the cross – sectional area perpendicular to the flow direction, and L is the length of flow (Fig. 5).

Figure 5. Schematization of MODFLOW river boundary (Aquaveo, 2013)



Surface water model

Water level in rivers, in this case in the channels, is an influential factor regarding the simulation of surface water – groundwater interaction. We used a widely used one dimensional surface water simulation package HEC – RAS (U.S. Army Corps of Engineers, 2013) to determine the surface water table elevations throughout the length of the channels based on discharge data from measurement stations at the lower and upper side of the model at the Gabčíkovo – Topoľníky channel and on the channel morphology data obtained by the measurements on site. The output values of water surface elevations were then used as an input parameter of the river package of the MODFLOW simulation.

Model calibration

Calibration of model was done manually adjusting input parameters of the model (water levels in channels, recharge, hydraulic conductivity) to achieve the best fit of computed and observed head stages in monitoring wells. There are three monitoring wells present in the model area, the observed values were provided by Slovak Hydrometeorological Institute. The model was calibrated to values from May 2014, when the field measurements of riverbed morphology took place on the channel Gabčíkovo – Topoľníky. The maximum difference (error) of simulated vs. observed heads was 0,086 m.

Results and discussion

The first scenario represents the model calibration results (Fig. 6) with current state of sediment deposits. The values of conductance set to each river kilometer ranged from 2.4 to 42.4 $m^2.d^{-1}.m^{-1}$. It shows a W – E groundwater head direction, which corresponds with the general groundwater flow direction at Žitný ostrov. The groundwater heads range from 111.6 m a.s.l on the east to 113.4 m a.s.l on the west. From the direction of the contour lines

Figure 6. Scenario 1 – current state of sediment deposits

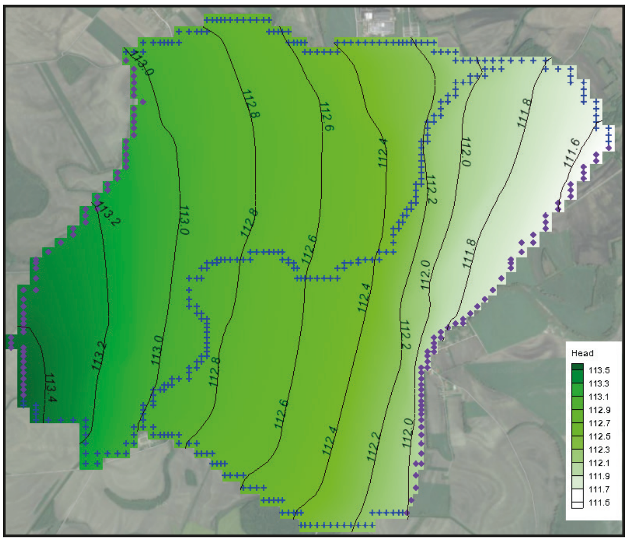


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Figure 7. Scenario 2 – significantly more permeable sediment deposits

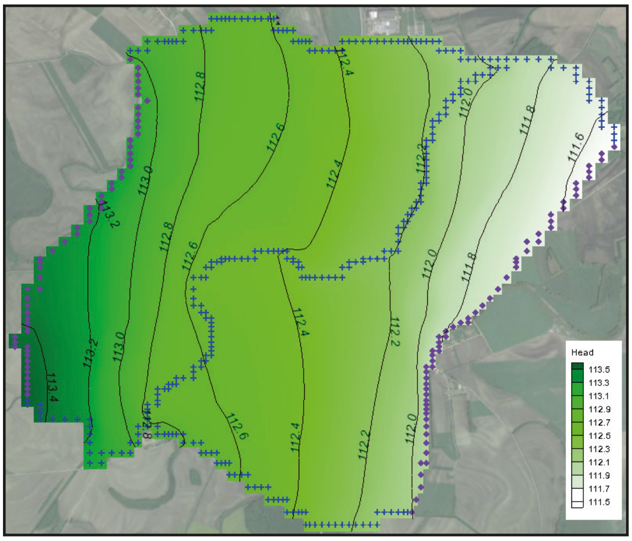
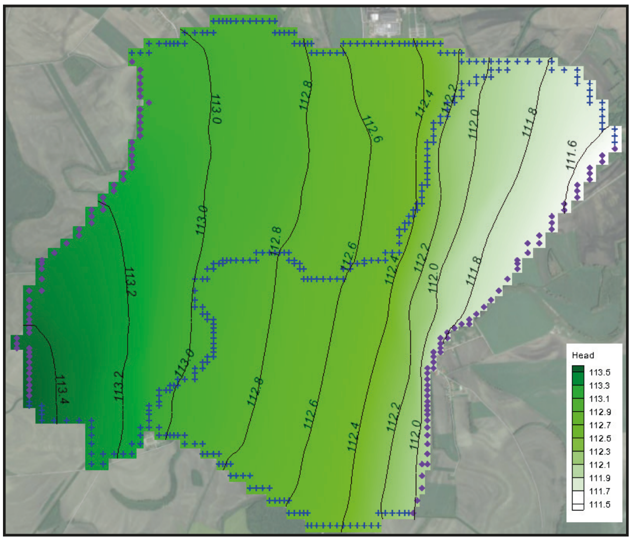


Figure 8. Scenario 3 – less permeable sediment deposits



we can assume that the main channel has less effect on the groundwater level and direction.

The second scenario (Fig. 7) considers all of the channels to be considerably more permeable in terms of bed sediments. All channels were set to a value of conductance of 500 m^2.d^{-1}.m^{-1}. The groundwater level in the main channel area drops by 0.2 – 0.4 m. The contour lines show a more connected main channel, that is affecting the groundwater direction and flow in the aquifer.In the third scenario (Fig. 8) the channels bottom sediments are considered to be even less permeable than those in first scenario. All channels were set to have conductance of 3 m^2.d^1.m^{-1}. The groundwater level raises by additional 0.2 m compared to the first scenario.

Conclusions

The results show that the hydraulic conductivity and thickness of riverbed sediments in lowland area can significantly affect the water regime and especially the groundwater level. The difference in groundwater table elevations between the current state of the volume and distribution of channel bottom sediments and proposed theoretical scenario of channel without bottom sediments is significant, up to 0.4 meters. Therefore it is important to invest to proper maintenance, because channels clogged with sediments are less effective in the ability to drain excessive groundwater from the aquifer, what is one of the main reasons why the channel network was built. In the occurrence of floods the surrounding agricultural areas are prone to flooding and therefore can be damaged.

Acknowledgements

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