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INDUCED RIVERBANK FILTRATION FOR MANAGED ARTIFICIAL GROUNDWATER RECHARGE AT APAČE FIELD

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KEY POINTS

- *Managed artificial groundwater recharge (MAR) with induced riverbank infiltration (IRBF)*
- *Numerical groundwater flow model for better understanding of the MAR system*
- *Analysis of the effectiveness of the MAR system using FREEWAT*
- *Methodology for assessing groundwater recharge and nitrate rinsing using hydrotopes*

1 INTRODUCTION

Apače field is a plane in the statistical region of Pomurje (northeastern part of Slovenia) with an area of 44,78 km^2. The plain extends between Konjisce in the northwest and Gornja Radgona in the east. The plain is bordered with river Mura in the north, which also represents the state border with Austria, and with the hills of Slovenske gorice in the south.

Unlike most of the groundwater aquifers and water resources in Slovenia, which are high in Carbonate hardness from dolomite and limestone rocks, the groundwater body of Pomurje has a lower carbonate hardness, with a more or less aggressive CO2 and with a content of iron and manganese. Due to the shallowness and thinner roof layers, intensive agriculture and settlements, the aquifer of Apače field is also among the most vulnerable and exposed aquifers in Slovenia.

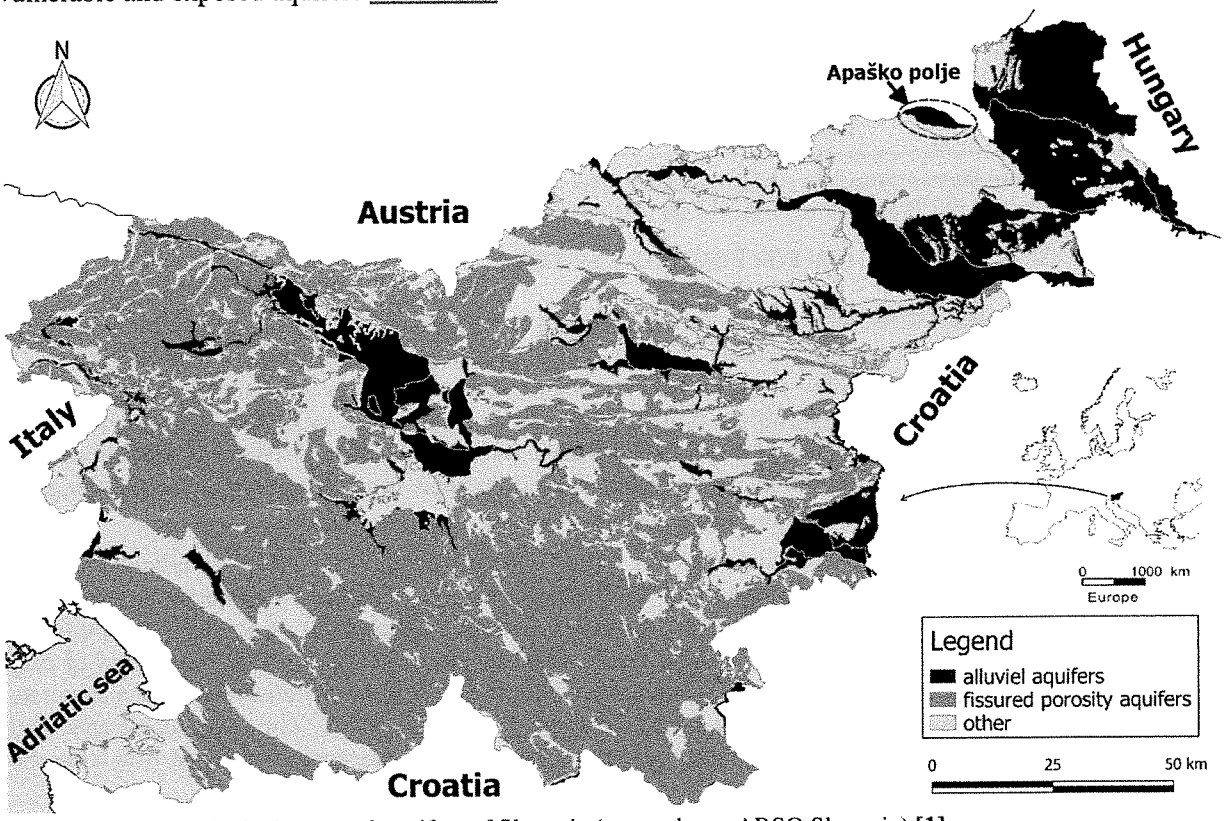

Figure 1: Hydrogeological map and aquifers of Slovenia (source base: ARSO Slovenia) [1]

2 GENERAL INFORMATION OF THE APAŠKO FIELD AQUIFER

The Aquifer of Apače field is a very shallow aquifer with its thickness ranging from 4 to 12 meters. The groundwater regime depends heavily on the amount of water in river Mura, as the aquifer of Apasko polje is mainly recharged from river Mura. Other sources of water include precipitation and infiltration of the Mlinski, Bizjak and Plitvice stream that inflow from the nearby hills of Slovenske gorice. The aquifer reserves range around 190 l/s. The water resource is very sensitive to climate change, even a slight decline in the groundwater level can have a significant impact on the aquifer and its yield. The climate change affects the river stage, the annual rainfall and the daily temperature, which all contribute to lower water tables.

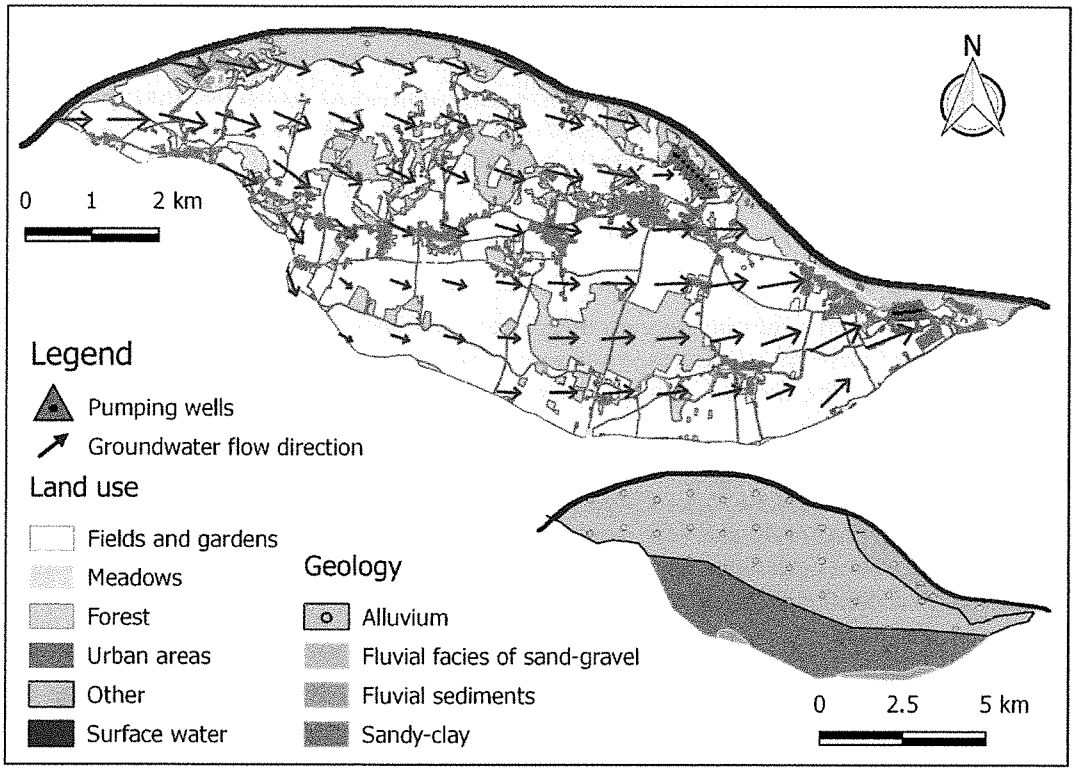

Figure 2: Land use map (base source: http://RKG.gov.si/GERK) of Apaško polje with the groundwater flow direction (after Kopač and Vremec, 2017) and the geological map (base source: ARSO) [1]

3 PUBLIC WATER SUPPLY SYSTEM FOR POMURJE – SISTEM C

At the aquifer of Apeče field, we have two groundwater pumping stations (Podgrad and Segovci), which are the main drinking water supply stations for the water supply network System C, which covers 8 municipalities with 27,000 inhabitants. To protect the two main pumping stations (pumping stations for water supply system, named System C) from nitrate polluted hinterland water and to prevent water scarcity in the summer period, a new managed artificial groundwater recharge system with induced riverbank infiltration was established. For a functional operation of the system, a well-planned monitoring system with equipped observing wells (total 49) and one meteorological lysimeter station was constructed.

The source for the groundwater recharge system are 14 wells located in the Mura riverbank near the pumping station Segovci and 14 wells located near the Podgrad pumping station. The extracted groundwater from the wells is first infiltrated into an injection drainage, which is situated 50 m south of the pumping drainage. The drainage is divided into two chambers, 40 m in length, divided by a 2 m wide area of clay material. The recharge system operates in a way, that every second well extracts groundwater with a flow rate of 10 l/s and every second well recharges the water with a flow rate of 2.68 l/s. The water is pumped and returned in the aquifer to saturate it with gaseous oxygen in order to separate manganese and iron from the drinking water.

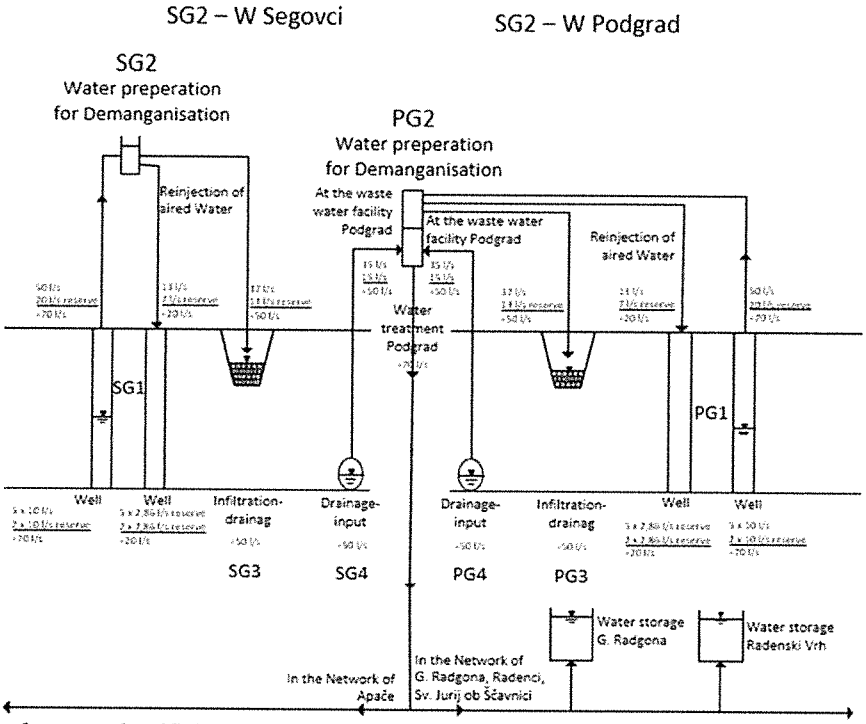

Figure 3: Scheme of managed artificial recharge system at the pumping stations Podgrad and Segovci [1]

4 IMPLEMENTATION OF A GROUNDWATER FLOW MODEL

Within the project GEOHIDRO (Vremec et. al., 2017) a steady-state groundwater flow model was established to analyze the efficiency of the artificial groundwater recharge system in the area of the Apasko polje aquifer. For the groundwater flow model, we decided for one model layer with unconsolidated gravel, sand, and silt and for the next water management scenarios:

- activated groundwater recharge system with average pumping quantities and average yearly data for precipitation and evaporation.
- deactivated groundwater recharge system with activated pumping wells with yearly average pumping quantities, and average yearly data from precipitation and evaporation.
- activated groundwater recharge system with "summer" pumping quantities and "summer" data for precipitation and evaporation.

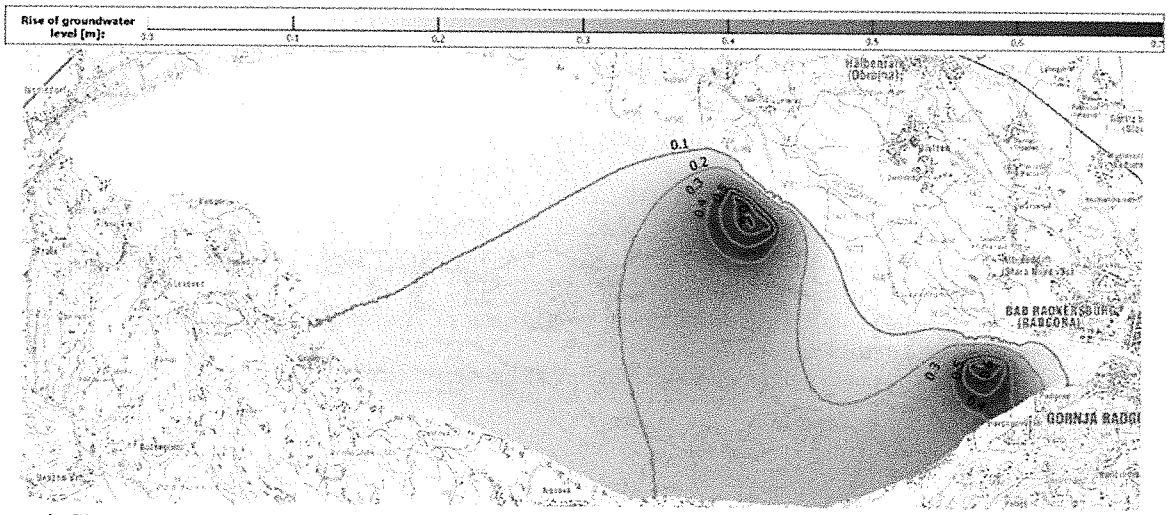

Figure 4: Simulated results of the rise of groundwater after the construction of MAR (Vremec et al., 2017)

In the master's thesis (Kolar, 2018), an additional analysis was done using a group of small lakes in the north-western part of the aquifer (used for fishing) as a source of possible contamination of groundwater. A flow direction analyze was done to inspect if the contaminated groundwater from the lakes will flow towards the artificial groundwater recharge system in Segovci or towards the river Mura. For our purpose, we observed the flow of contaminated groundwater with the MODPATH particle tracking method in 2 different scenarios:

1. Scenario (high water level): increased precipitation values, increased level of river Mura by 2 meters, increased flow of hinterland water from Slovenske gorice.
2. Scenario (low water level): decreased precipitation values, decreased level of river Mura by 2 meters, decreased flow of hinterland water from Slovenske gorice

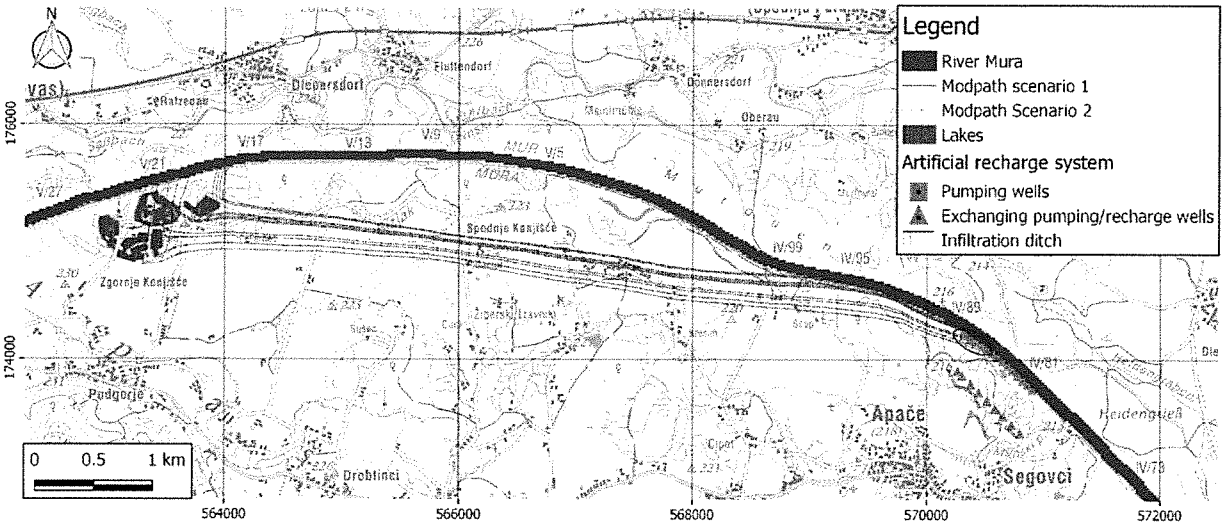

Figure 5: Results of Modpath particle tracking for the simulation of Scenario 1 and 2 (Kolar, 2018)

5 CONCLUSION

Managed artificial groundwater recharge systems (MAR) coupled with induced riverbank filtration (IRBF) have proven itself as an irreplaceable contributor in the protection of the pumping stations Segovci and Podgrad, which supply drinking water for the municipalities of Apače, Ljutomer, Sveti Jurij ob Ščavnici, Križevci, Gornja Radgona, Radenci, Veržej and Razkrižje (supply to more than 26.000 inhabitants). The MAR system in Segovci and Podgrad is constructed to prevent possible contamination of nitrates and recharge the aquifer in the summer months. The use of water resource management tools like FREEWAT has shown a significant role in the establishment, maintenance and optimization of an efficient MAR system with IRBF. The numerical models produced inside the FREEWAT hydrogeological environment can be used to analyze the MAR systems impact on the groundwater level, the change in the groundwater flow direction, the efficiency of the system against possible contamination and also for optimization of the MAR system in order to reduce the operating costs related to water pumps. In the project, an additional analysis was done to assess groundwater recharge and nitrate rinsing using hydrotopes.

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