A Groundwater Recharge Model for the Zagreb Aquifer System (Croatia): Current Status and Proposed Enhancements

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Background and objectives

The Zagreb alluvial aquifer (Fig. 1.) is the largest utilized groundwater source in northern Croatia, supplying drinking and industrial water to the City of Zagreb and surrounding settlements. With the groundwater level declining steadily over the last 50 years, understanding how the aquifer is recharged has become increasingly important. Although the groundwater recharge model for the Zagreb aquifer system exists, there is still a need for a more accurate and detailed determination of groundwater recharge in both spatial and temporal domains. To address these limitations, extensive investigations are planned within the framework of the bilateral Croatian–Slovenian project GWQualityPath2070 (HRZZ: IPS-2024-02-5367).

Study area

Located in southwest of the Pannonian Basin in the Sava Valley in Croatia, the Zagreb alluvial aquifer is composed of Quarternary sediments (Holocene fluvial and Pleistocene lacustrine-marshy deposits). Its thickness varies from 10 m in the western part to up to 100 m in the eastern part of the aquifer (Fig. 2.). The aquifer is unconfined and recharged through both infiltration of precipitation and leakage from the Sava River riverbed. The groundwater level in the aquifer is influenced by the Sava River stage, especially near the riverbed.

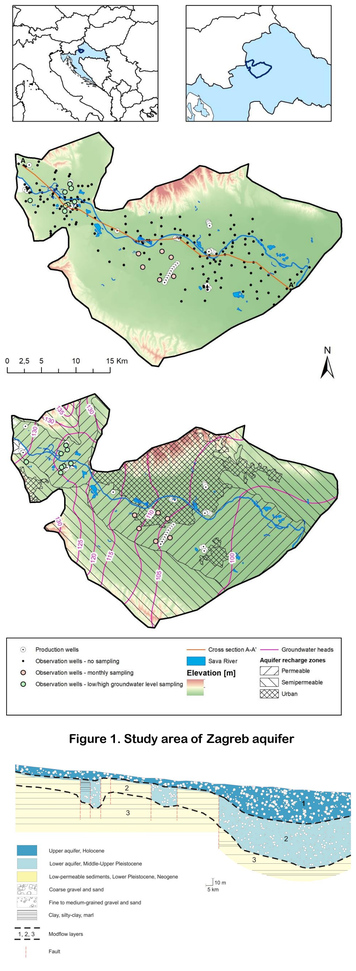


Figure 1. Study area of Zagreb aquifer

Figure 2. Cross section through the Zagreb aquifer (Larva et al., 2022)

Current status

Marković et al. (2013) analysed stable isotopic composition of the groundwater and river water and concluded that the relation between δ^2H and $\delta^{18}O$ in sampled groundwater and Sava River corresponds to the local meteoric water line of the Ljubljana (Fig. 3.). They also concluded that all sampled waters indicate meteoric origin.

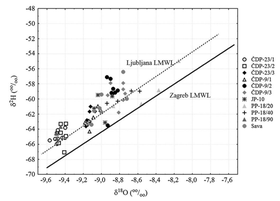


Figure 3. Relation between δ^2H versus $\delta^{18}O$ in the Sava River and groundwater in monitored wells (Marković et al., 2013)

As a result of releasing coolant water from the Nuclear power plant Krško (located upstream) there is occasional higher tritium content in Sava river water and groundwater in the research area. Barešić et al. (2020) successfully used this peak in tritium concentration as a groundwater tracer.

Previous studies have estimated groundwater recharge using groundwater balance calculations, which were subsequently verified by a numerical groundwater flow model. For the purposes of numerical modelling, the alluvial aquifer area was divided into three polygons with different groundwater recharge values: (1) areas with a thin or absent semipermeable covering layer at the top of the aquifer, (2) marginal aquifer areas to the north and south, composed predominantly of fine-grained deposits, and (3) urban areas (Fig. 1.).

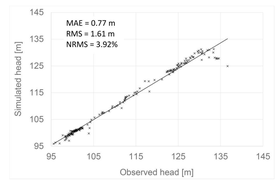


Figure 4. Calibration results (Larva et al., 2022)

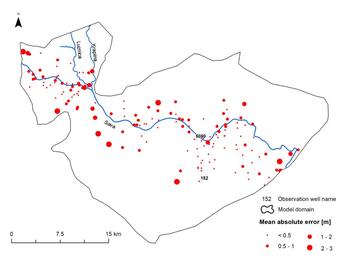


Figure 5. Spatial distribution of the mean absolute error (Larva et al., 2022)

Planned research

- **Groundwater sampling**
  - Monthly sampling (12 months)
  - Sampling during low and high water levels
- **Hydrochemical analysis**
  - Tritium activity
  - Stable isotopes of hydrogen and oxygen in water
  - Stable isotopes of nitrogen and oxygen in nitrates
  - Emerging contaminants
- **Statistical processing**
  - Results of hydrochemical analysis and historical data
- **Numerical modelling**
  - Numerical modelling of groundwater flow
    - ➢Improved groundwater recharge model using:
      1)Tritium analysis results in surface water and groundwater
      2)The SWAT model
- **Statistical analysis**
  - Analysis of the results of numerical modelling and determination of the main sources of uncertainty

Plans for the future

The expected results of the research activities, in general and, in particular, those related to the groundwater recharge model, will provide a solid basis for further research.

Primarily focused on analyses of climate change impacts on the quantitative and qualitative status of groundwater, future studies will contribute to the assessment of the risk of nitrogen pollution and enable the assessment of long-term trends in groundwater quality, as well as the effects of different agricultural practices and land use on groundwater quality. This research will support further development and wider adoption of sustainable agricultural practices in the sensitive aquifer. The results of the research will enable water protection agencies to develop better water management plans. In addition, valuable information will be provided for future research into other potential groundwater pollutants.

References

- Barešić, J., Parlov, J., Kovač, Z. & Sironić, A. (2020): Use of nuclear power plant released tritium as a groundwater tracer. Rudarsko-geološko-naftni zbornik, 35 (1), 25-34. https://doi.org/10.17794/rgn.2020.1.3
- Larva, O., Brkić, Ž., Briški, M., Karlsson Seidenfaden, I., Koch, J., Stisen, S. & Refsgaard, J. C. (2022): An ensemble approach for predicting future groundwater levels in the Zagreb aquifer impacted by both local recharge and upstream river flow. Journal of Hydrology, Volume 613, Part B, 128433, ISSN 0022-1694, https://doi.org/10.1016/j.jhydrol.2022.128433.
- Marković, T., Brkić, Ž., & Larva, O. (2013): Using hydrochemical data and modelling to enhance the knowledge of groundwater flow and quality in an alluvial aquifer of Zagreb, Croatia. Science of The Total Environment, Volumes 458–460, Pages 508-516, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2013.04.013.

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