# MAR in Croatia

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https://recharge.iah.org/60-years-history-mar

Managed aquifer recharge (MAR) is not discussed often in Croatia since groundwater reserves generally satisfy demand for water. Hence, the need to manage aquifer recharge is not pronounced. Nevertheless, there are some springs used for public water supply which require enhanced recharge during periods of hydrologic drought as well as public wellfields deliberately positioned near rivers in order to, either enhance the capacities of pumping wells through river bank filtration, or diminish wellfield protection zones which in many cases occupy urban areas.

Quaternary alluvial aquifers, typical in the northern part of Croatia which is situated in the southwestern part of the Pannonian basin, are mainly recharged by rivers Sava and Drava. Although river Drava is regulated with hydropower plants (HPP's) on one smaller upper tributary, the majority of the flow of the rivers Sava and Drava is still unregulated with respect to structures such as dams or weirs. Therefore the rivers not only recharge aquifers but also drain them during low flow periods (Posavec *et al*., 2017). Alluvial aquifers, mainly composed of sands and gravels are generally characterized by high hydraulic conductivities, ranging from $10^{-5}$ m/s (~1 m/d) in eastern parts of Croatia to $10^{-2}$ m/s (~1000m/d) in western parts. Such high hydraulic conductivities enable intensive aquifer recharge as well as aquifer discharge. High aquifer discharge potential therefore makes MAR inefficient in many cases. At the same time, high aquifer recharge potential as well as relatively thick alluvial deposits, make positioning of the pumping wells less demanding. Therefore, in many cases there was no need to position the wells near the river in order to utilize river bank filtration.

A study by the Croatian Geological Survey (2009) on assessment of state and risk of groundwater bodies indicates that artificial recharge of aquifers by recharge wells or channels is not present in the Pannonian part of the Republic of Croatia . Nevertheless, some wellfields located in the City of Zagreb, Croatia's capital (population of ~800,000), have been placed knowingly within the proximity of the river Sava with the intention that a proportion of the extracted water would be induced recharge from the river. Further, a structure was built in the river Sava, weir TE-TO. Although the intention of building weir TE-TO was not to increase aquifer recharge, it was one of the consequences which therefore indirectly increased the abstraction potential of some wellfields and the proportion of the water derived from the river. Therefore, this proportion of groundwater pumped at some Zagreb wellfields and derived from the river can be considered as bank filtration (MAR) (Table 1).

Table 1. Estimated volume of Managed Aquifer Recharge (bank filtration) (Million cubic metres/year)

| **Annual MAR volume in the decade centred on date ($Mm^3/y$)** | | | | **Annual Groundwater use (Mm3/y)** |
|---|---|---|---|---|
| **1985** | **1995** | **2005** | **2010-15** | **2010** |
| 42* | 48* | 48* | 46* | 600** |

*derived from measured data on abstraction and estimated percentage of abstracted volume gained from river bank filtration ** based on Zagreb Water Supply and Sewage Company data on abstraction for the City of Zagreb, ~125 Mm3/y (Hidroprojekt-Ing and Sl-Consult, 2014). Extrapolated for the entire region of Croatia.

The hydrogeology of the southern part of Croatia is characterized by karst aquifers and water is supplied mainly from springs. Managed aquifer recharge is generally not a common approach with some exceptions. One such exception and the first attempt in Croatia of managed aquifer recharge in karst aquifers is at the Gradole Spring located in Istria, and used for public water supply. Gradole Spring was artificially recharged from water accumulated in Lake Butoniga and pumped into sinkhole Čiže located in Tinjanska Draga. This resulted in a significant increase of spring discharge (Faculty of Geotechnical Engineering, 2009). From the late 1980's to early 2000's, an average 0.873 $Mm^3/y$ was pumped from Lake Butoniga and discharged into the sinkhole Čiže. The maximum volume was pumped in year 1990 (2.8 Mm3/y) and the minimum was reached in year 1995 (0.1 Mm3/y) (http://www.ivb.hr/naslovna-hidden/30-akumulacija-butoniga). Although this solution was inefficient with respect to energy consumption required to pump water from Lake Butoniga situated at 40 m a.s.l. up to the sinkhole Čiže situated at some 350 m a.s.l., it helped to increase the discharge of the Gradole Spring during summer dry seasons. Later on, a water treatment facility was built at Lake Butoniga, which enabled direct distribution of drinking water to consumers and made further MAR actions unnecessary.

Another attempt of managed aquifer recharge of karst aquifers was done also in the late eighties on the island Krk by building the water storage Ponikve. Although managed aquifer recharge resulted with increase in groundwater quantity available, it also deteriorated the groundwater quality, due to which the concept was abandoned (Faculty of Geotechnical Engineering, 2009). Another aspect of MAR was related to construction of HPP's i.e. accompanying storages. Although detouring of rivers in order to build storages had a negative impact on downstream karst aquifer systems, it also helped in stabilizing the flowrate of some springs (Faculty of Geotechnical Engineering, 2009).

**References**

Croatian Geological Survey (2009): Assessment of state and risk of groundwater bodies in Panonnian part of the Republic of Croatia. Archive of Croatian Waters, Zagreb.

Faculty of geotechnical Engineering (2009): Assessment of state and risk of groundwater bodies in karts area of the Republic of Croatia. Archive of Croatian Waters, Zagreb. http://www.ivb.hr/naslovna-hidden/30-akumulacija-butoniga (accessed 29 November 2017)

Hidroprojekt-Ing and Sl-Consult (2014.): Project Zagreb – development of the water supply and sewage system: Demand analysis. Archive of Water Supply and Sewage Company, Zagreb.

Posavec, K., Vukojević, P., Ratkaj, M. and Bedeniković, T., Cross-correlation Modelling of Surface Water – Groundwater Interaction Using Excel Spreadsheet Application, The Mining-Geology-Petroleum Engineering Bulletin, 32 (2017), 1, 25-32.