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Effects of Karst and geological structure on groundwater flow: The case of Yarqon-Taninim Aquifer, Israel

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SUMMARY

This study demonstrates the significant influences of the geological structure (especially folding and lithology) and the karst system on groundwater flow regime. Folds divert groundwater flow from the general hydraulic gradient; marly layers sustain several perched sub-aquifers above the regional aquifer; and karstification increases the hydraulic conductivity by several orders of magnitude. These phenomena are quantitatively demonstrated within the Yarqon-Taninim (YT) basin, Israel, which is a complex groundwater system, combining several (extremely) opposite characteristics: humid and arid recharge zones, phreatic and confined parts, shallow and deep sub-aquifers, stratified and relatively-homogeneous sub-basins, saline and fresh water bodies, as well as stagnant and fast-flowing groundwater regions.

We have introduced a 3D geological-based grid for the basin (for the first time). It was implemented into a numerical code (FEFLOW), which was used thereafter to analyze quantitatively the flow regime, the groundwater mass balance, and the aquifer hydraulic properties. We present up to date conceptual understanding and numerical modeling of the YT flow field, especially at its mountainous parts.

Based on the calibration procedure and the sensitivity analyses, we obtained the best-fitted hydraulic conductivity values for the aquifer mesh. The general phenomenon observed is that as groundwater flow quantity increases, the hydraulic conductivity also increases. We interpret this result by the karstification mechanism (including paleo-karst). Thus, where groundwater flow-lines converge and where groundwater discharge amount increases, the karstification process intensifies and permeability increases. Consequently, at the mountainous region, along the syncline axes, where groundwater flow-lines converge, higher conductivities are found.

Modeling results also exhibit that at the lowland confined area, the geological structure does not play a major role in directing groundwater flow. Rather, the flow field is controlled by the well-developed karst system and the relatively homogenous carbonate section. It is hypothesizes that the extensive karstification took place at the Messinian Salinity Crises, ~5.5 Ma, during which groundwater heads as well as sea level were lowered by several 100 m.

1. Introduction

1.1. The Yarqon-Taninim basin

The YT basin is one of Israel's most important resources of fresh water, providing ~25% of the countries fresh water (Hydrological service, 2007). It stretches from the foothills of Mount Carmel in the north to the northern Negev and Sinai anticlines in the south, and from the central mountain range in the east to the Mediterranean coastline in the west, over about 10,500 km^2 (Fig. 1) (Goldshtoff and Shachnai, 1980; Shachnai, 1980). The basin is named after its two natural outlets: the Yarqon Springs, located at the central part of the basin, 15 km north-east of Tel-Aviv (altitude +18 m asl), and the Taninim Springs, located at the northern tip of the basin (+3 m asl).

The YT comprises of a western confined part and an eastern, mountainous phreatic part, where replenishment occurs. Climate in the replenishment area is of a Mediterranean one, with an average precipitation of 550–600 mm/year, during the winter. The estimated recharge ranges between 330 and 360 million cubic meters per year (MCM/year), which accounts for 30–33% of the annual precipitation on the average (Guttman and Zukerman, 1995). In addition, 3–5 MCM/year of deep-seated saline water, having a salinity of seawater, enters to the bottom of the aquifer, at the northern edge of the basin, producing the brackish groundwater at the northern Taninim outlets (Paster et al., 2005). Groundwater heads at the mountainous area reach 660 m in Hebron, 500 m in Jerusalem and 300 m in Samaria. At the lowland it gently drops

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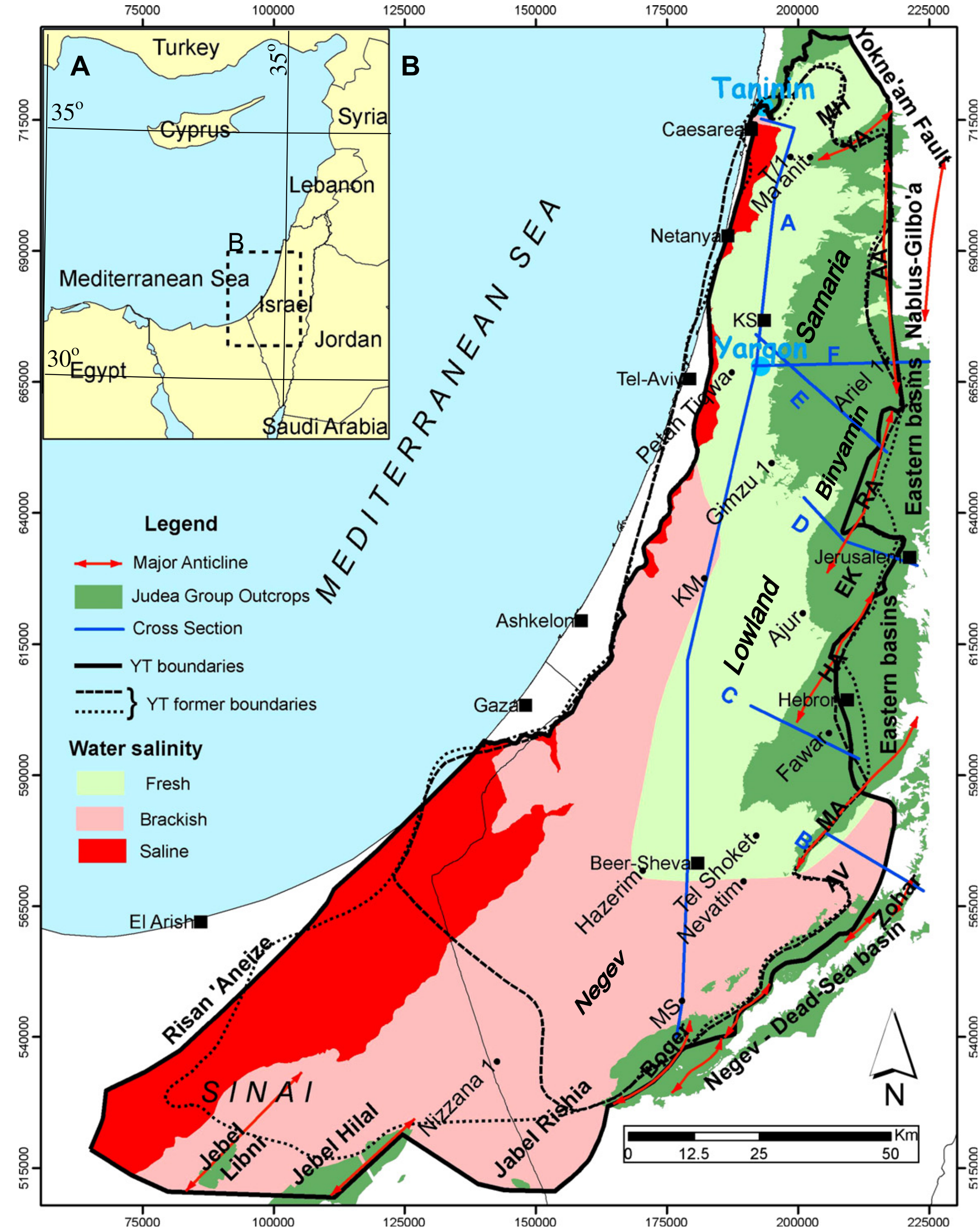

Fig. 1. Location maps. The indicated cross-sections are shown in Fig. 3. Abbreviations (from south to north): MS – Mash'abey-Sade, AV – Arad Valley, MA – Ma'on anticline, HA – Hebron anticline, EK – En Karem basin, KM – Kefar Menahem well, RA – Ram'alla anticline, KS – Kefar Saba, AA – Anabta anticline, T/1 – Menashe T/1 well, YA – Yiron anticline, MH – Menashe Height.

from south to north: at the 1930s, referred here as the 'historical period', before pumping had started, heads dropped from 27 m near Beer-Sheva at the south to 16 m in the Meanashe Heights at the north.

At the historical period, the YT groundwater drained toward the two major springs and additional minor outlets near the Taninim Springs (Table 1). Since the 1950s, the basin is exploited intensively by hundred of wells for domestic and agriculture purposes. During the last decade, the YT supplied about 405 MCM/year on the average, of which 20–30 MCM/year through the Taninim Springs (~25% of its original discharge) and the rest through wells (Hydrological service, 2007). Due to the overexploitation water levels at the confined part of the aquifer dropped by 15–10 m and the Yarqon Springs totally dried since 1962.

1.2. Geological settings

The YT groundwater flows within the Judea Group Aquifer (JGA). The Late Cretaceous Judea Group is mostly composed of karstic, permeable limestone and dolomite interbedded with thin ter-