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Numerical model as a predictive analysis tool for rehabilitation and conservation of the Israeli Coastal Aquifer: example of the SHAFDAN Sewage Reclamation project

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Abstract

This study is part of a large-scale project aimed at rehabilitation of the Israeli Coastal Aquifer. Development of a regional 3-D, transient flow and transport model of the hydrological system in the vicinity of the Dan Region Sewage Reclamation Project (SHAFDAN) is presented.

The SHAFDAN facilities include five infiltration ponds to which high-quality treated effluent is sent for soil aquifer treatment (SAT). The ponds are surrounded by recovery wells that abstract the treated water and prevent it from spread to fresh water pumping zones.

The model is used for estimating the spread of SHAFDAN water and testing operational scenarios. A 30-year forecast run showed that significant spread in the aquifer from the southern ponds is expected. The model examined two possible solutions for reducing spread: (1) increased pumpage in existing recovery wells; (2) additional wells on the eastern side of the ponds.

The results show that the first solution reduced spread more effectively, but also led to rapid seawater intrusion from the west. The study demonstrates how changes in pumping regime affect spread. The model is, therefore, an appropriate tool for evaluating SHAFDAN operation in addition to its role in planning rehabilitation of the aquifer as a whole.

Keywords: Aquifer; Numerical model; Rehabilitation; Salinization; Sewage; SHAFDAN

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1. Introduction

Water resources in Israel are scarce and are subject to overexploitation and severe salinization. The declining water levels and increasing salinity are of special concern in the Coastal Aquifer, which provides about 20% of the water consumed annually in Israel and serves as a seasonal and long-term fresh water reservoir [1–3].

This study is part of a large-scale project aimed at rehabilitation and conservation of the Coastal Aquifer, financed by the Israel Water Authority. The rehabilitation program comprises construction of a large GIS-based database, development of hydrological models, and prediction of flow regimes, water levels and salinity for several operational alternatives. A specific section of the regional model is presented here in order to demonstrate the use of hydrological–numerical models as a predictive analysis tool for an aquifer management system. The example focuses on the hydrological system in the vicinity of the Dan Region Sewage Reclamation Project (commonly known in Israel as the SHAFDAN). Part of the SHAFDAN project includes groundwater artificial recharge by treated wastewater for secondary use – a method used in many sites around the world for many years [4–6 and many others].

The SHAFDAN collects and treats wastewater from towns in the Tel Aviv Metropolitan Area for further use as irrigation water. The plant was established in the 1970s and since then has supplied a considerable part of the water needed for agriculture in the northern Negev region. The SHAFDAN system, located above the Israeli Coastal Aquifer, includes two percolation ponds in the northern part of the Dan Region (N-1 and N-2 Soreq sites) and four in the southern part (S-1, S-2, S-3, and S-4 Yavne sites) (Fig. 1).

In its present format the treatment method applied is SAT (soil aquifer treatment). Water that has undergone high secondary treatment is sent to the percolation ponds, where it infiltrates the sandy layers, reaches the aquifer and is later pumped for irrigation by means of 130 surrounding boreholes. The long retention time, exceeding 180 days, as well as adsorption processes, initially in the unsaturated sandy profile and subsequently in the aquifer, bring the water to a quality that is suitable for the irrigation of agricultural crops.

The first purpose of this paper is to study the interrelations between two water bodies in the aquifer – recharged and natural – in the SHAFDAN area. Its importance derives from the development plans drawn up recently for the Yavne S-3 and S-4 sites and from the need to estimate the amount of abstraction required in coming years with the continued development of artificial recharge. The second purpose of the study is to examine the extent of SHAFDAN water (to be defined here as "labelled water") dispersion at the various SHAFDAN sites, as well as the possibility of reducing the areas of influence in places where the labelled water has spread beyond the planned limits.

2. Study area

The Coastal Aquifer of Israel is composed of Pliocene–Pleistocene predominately calcareous sandstone sequence, and intercalations of clay, silt and loam of different origin. Its thickness varies from 200 m near the coastline in the west, to only a few meters in the east. The aquifer overlies thick (up to 2000 m) and impermeable units of Saqiye group. In the west, the aquifer is subdivided into four sub-aquifers: two main subaquifers and secondary division into sub-units (TAHAL, Shachnai, unpublished cross sections and maps). The subdivision is created, invariably, by the above mentioned intercalations. This system of intermediate impervious to semi-impervious horizons dissipates gradually eastwards. In the east, the aquifer is uniform and undivided, and overlies the Eocene (Shefela Group) aquitard [2,7,8]. The aquifer is undergoing salinization processes resulting from infiltration of water from