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Seasonal and Temporal Variation of the Piezometric Level in the Alluvial Aquifer of Loutraki (Korinthia), with the Use of GIS Mapping Techniques

K. Pyrgaki[1], P. Krassakis[1], V. Gemeni[1], N. Koukouzas[1], A. Argyraki[2], K. Voudouris[3]

(1) Centre for Research and Technology, Hellas (CERTH), 52 Egialias St., 15125 Maroussi, Athens, pyrgaki@certh.gr.
(2) Department of Geology and Geoenvironment, National University of Athens, Panepistimioupolis, Ano Ilissia, Athens, Greece.
(3) Lab of Engineering Geology & Hydrogeology, Dept. of Geology, Aristotle University of Thessaloniki, Greece.

According to the European groundwater directive (2006/118/EC), groundwater bodies must be protected from qualitative and quantitative degradation. According to the 1st revision of the National Water Management Plan for the River Basin District of Attica, the groundwater body of Loutraki is characterised by a good qualitative and quantitative status. The water demand (mainly for drinking purposes) of Loutraki is covered exclusively by the alluvial aquifer located at the southern part of the basin. It is estimated that the annual groundwater abstractions from the alluvial aquifer are approximately 2.5 million m^3. During the summer, the groundwater abstractions are doubled as Loutraki is a popular touristic resort and this causes an additional pressure on the aquifer. Within such a framework, the scope of the present study is to assess the variation of groundwater level between the wet and dry season as well as to compare the present and the past piezometric level for the studied part of the aquifer by using Geographical Information Systems. Several researchers have used GIS techniques for the assessment of groundwater-level fluctuation (Tiwari *et al*., 2017).

Loutraki basin is located at the south-east part of Korinthiakos Gulf in the North-east Peloponnese (Fig. 1) and covers an area of approximately 53.3 km^2. The maximum elevation in the basin is 1368 m a.s.l., while the mean elevation is 470 m a.s.l. The climate is temperate with a dry summer and rainy winter and a mean annual temperature of 18.2ºC. The alluvial aquifer covers an area of 7.45 km^2 with a maximum water level depth of 150 m (Kounis and Vitoriou-Georgouli, 2003). The delineation of the groundwater body of Loutraki is depicted in Fig. 1. The thickness of the unsaturated zone increases gradually from the western to the eastern part of the aquifer and ranges from zero to 125 m while the maximum thickness of the saturated zone is approximately 200 m. Hydraulic conductivity ranges from 2×10^{-4} to 5.2×10^{-5} m/s and the transmissivity from 1.6×10^{-2} to 4.3×10^{-3} m^2/s (Stamatis and Voudouris, 2000).

The present study assembles new data (2017) and existing unpublished data (2009), which were acquired by the Municipal Directorate for Water and Sewage of Loutraki – Agioi Theodoroi on groundwater level/piezometric head of the alluvial aquifer. The groundwater level depth in 14 boreholes was recorded during the wet season in April 2017 and the dry season in September 2017 (Fig. 1). The delimitation of the study area was performed based on the geographical distribution of the boreholes and it is estimated at 6.4 km^2 (Fig. 2) covering only a small part (12%) of the basin. The borehole depths range from 20 to 220 metres with a gradual depth increase towards the north-eastern part of the alluvial aquifer. Four piezometric maps were produced using ESRI's ArcGIS 10.4 software by using the Spatial Analyst toolbox and Inverse Distance Weight (IDW) interpolation technique. IDW was selected as opposed to kriging interpolation due to the imbalanced spatial distribution of the measurement points across the study area. Further, the root mean squared error (RMSE) indicator by IDW was lower in comparison to the difference between observed and calculated values.

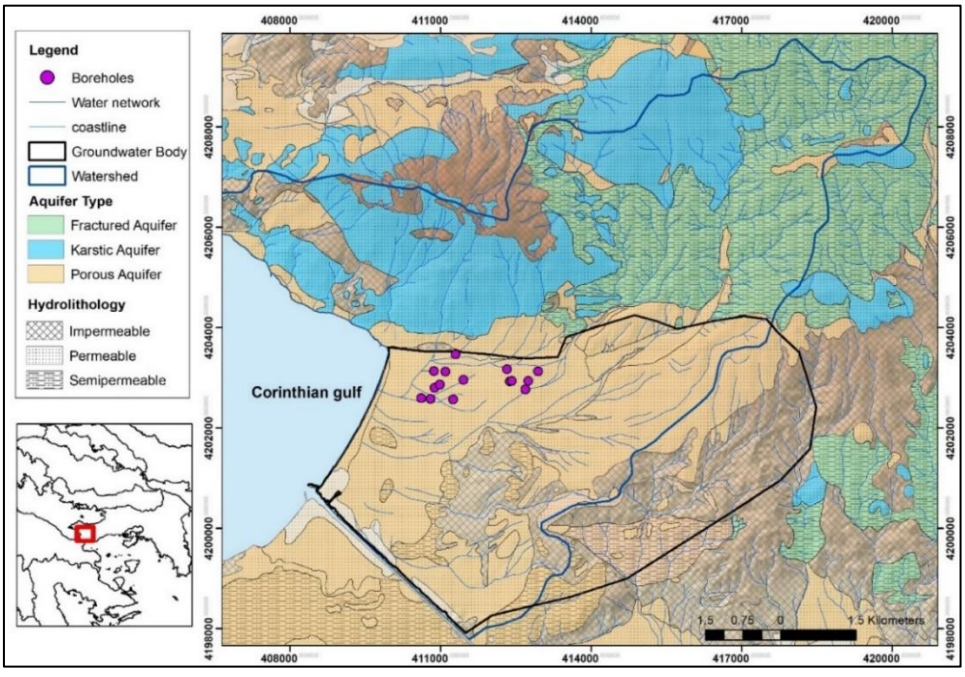

Figure 1. Hydrolithological map of Loutraki basin and groundwater monitoring boreholes.

The aquifer is under unconfined conditions in the upstream part, transforming in confined conditions in the coastal part. Groundwater recharge occurs through infiltration of rainfall and torrents. Limited recharge originates from the upstream boundary of the aquifer via fractured rocks. Groundwater flow has a direction from north-east to south-west, and the piezometric head ranges from higher than 12.73 m to below sea level (<-0.48 m) (Fig. 2). A seasonal variation of the piezometric head between wet and dry seasons of both 2009 and 2017 is noted by comparing the maps. During the dry season (Fig. 2a, c), the piezometric head decreases reaching negative values near the coastal zone at the south-west part of the basin. This is attributed to increased groundwater abstractions during the summer months. No significant variations were observed between the wet and dry seasons of 2009 and 2017. This indicates that the quantitative status of the aquifer remained relatively stable within the 8-years period. However, it must be highlighted that the risk of sea water intrusion in the coastal zone is high during the dry season. This is also proved by the fact that electrical conductivity and chloride concentrations increase near the coastal zone (Pyrgaki *et al*., 2016). Therefore, water managers must take measures in order to avoid aquifer overpumping during summer months in order to minimise the risk of sea water intrusion in the coastal part of the aquifer system.

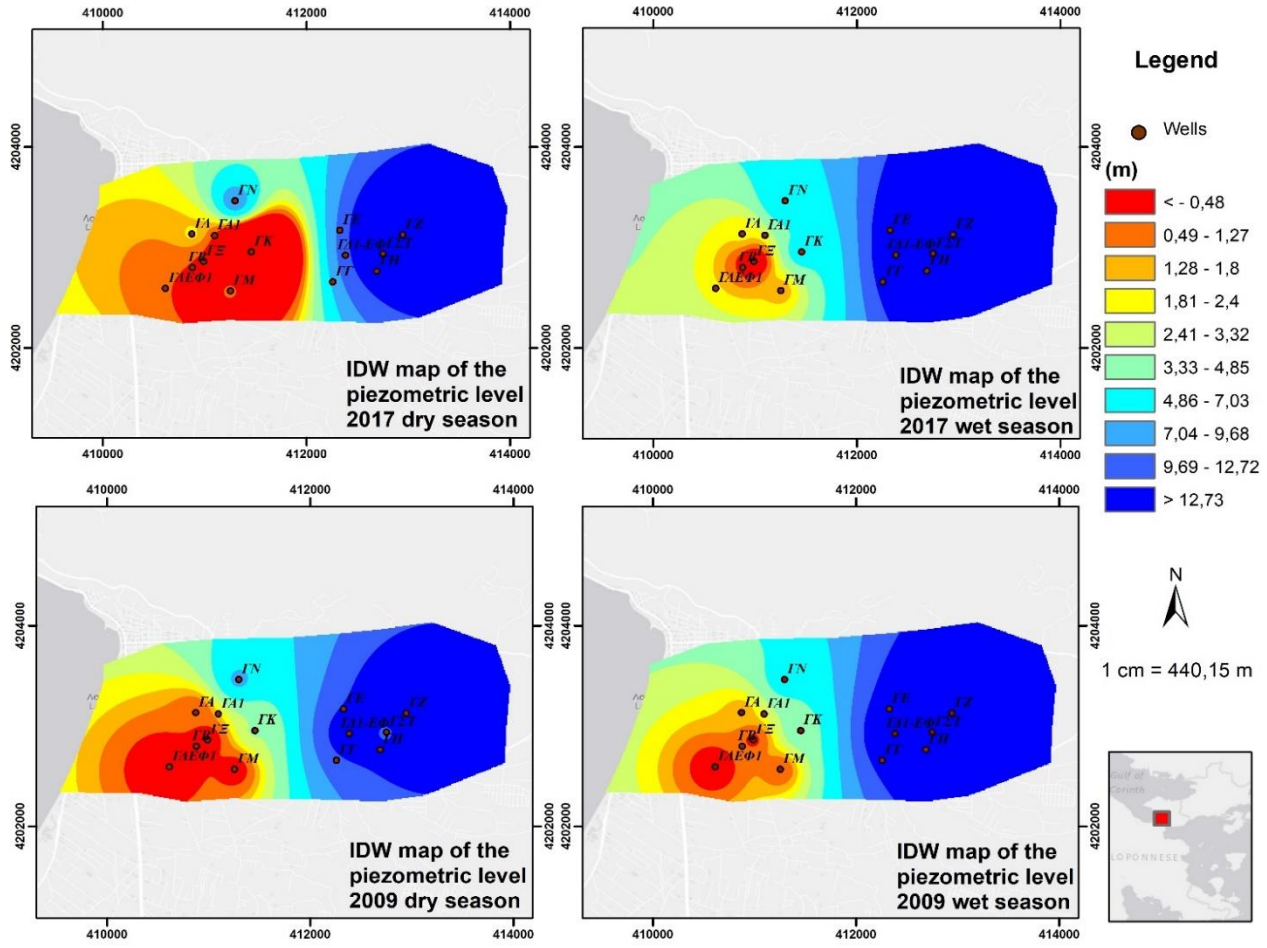

Figure 2. Piezometric maps of the alluvial porous aquifer of Loutraki during the dry (a), wet (b) season of 2017, and dry (c) and wet (d) season of 2009.

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