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A Study of the Groundwater Level Spatial Variability in the Messara Valley of Crete

E.A. Varouchakis (1), D.T. Hristopulos (1), and G.P. Karatzas (2)

(1) Mineral Resources Engineering, Technical University of Crete, Chania, Greece (varuhaki@mred.tuc.gr, dionisi@mred.tuc.gr / Fax: 0030 28210-37853 / Phone: 003028210-37688), (2) Department of Environmental Engineering, Technical University of Crete, Chania, Greece (karatzas@mred.tuc.gr / Phone: 003028210-37792)

The island of Crete (Greece) has a dry sub-humid climate and marginal groundwater resources, which are extensively used for agricultural activities and human consumption. The Messara valley is located in the south of the Heraklion prefecture, it covers an area of 398 km^2, and it is the largest and most productive valley of the island. Over-exploitation during the past thirty (30) years has led to a dramatic decrease of thirty five (35) meters in the groundwater level. Possible future climatic changes in the Mediterranean region, potential desertification, population increase, and extensive agricultural activity generate concern over the sustainability of the water resources of the area. The accurate estimation of the water table depth is important for an integrated groundwater resource management plan. This study focuses on the Mires basin of the Messara valley for reasons of hydro-geological data availability and geological homogeneity. The research goal is to model and map the spatial variability of the basin's groundwater level accurately. The data used in this study consist of seventy (70) piezometric head measurements for the hydrological year 2001-2002. These are unevenly distributed and mostly concentrated along a temporary river that crosses the basin. The range of piezometric heads varies from an extreme low value of 9.4 meters above sea level (masl) to 62 masl, for the wet period of the year (October to April). An initial goal of the study is to develop spatial models for the accurate generation of static maps of groundwater level. At a second stage, these maps should extend the models to dynamic (space-time) situations for the prediction of future water levels. Preliminary data analysis shows that the piezometric head variations are not normally distributed. Several methods including Box-Cox transformation and a modified version of it, transgaussian Kriging, and Gaussian anamorphosis have been used to obtain a spatial model for the piezometric head. A trend model was constructed that accounted for the distance of the wells from the river bed. The spatial dependence of the fluctuations was studied by fitting isotropic and anisotropic empirical variograms with classical models, the Matérn model and the Spartan variogram family (Hristopulos, 2003; Hristopoulos and Elogne, 2007).

The most accurate results, mean absolute prediction error of 4.57 masl, were obtained using the modified Box-Cox transform of the original data. The exponential and the isotropic Spartan variograms provided the best fits to the experimental variogram. Using Ordinary Kriging with either variogram function gave a mean absolute estimation error of 4.57 masl based on leave-one-out cross validation. The bias error of the predictions was calculated equal to -0.38 masl and the correlation coefficient of the predictions with respect of the original data equal to 0.8. The estimates located on the borders of the study domain presented a higher prediction error that varies from 8 to 14 masl due to the limited number of neighbor data. The maximum estimation error, observed at the extreme low value calculation, was 23 masl.

The method of locally weighted regression (LWR), (NIST/SEMATECH 2009) was also investigated as an alternative approach for spatial modeling. The trend calculated from a second order LWR method showed a remarkable fit to the original data marked by a mean absolute estimation error of 4.4 masl. The bias prediction error was calculated equal to -0.16 masl and the correlation coefficient between predicted and original data equal to 0.88 masl. Higher estimation errors were found at the same locations and vary within the same range. The extreme low value calculation error has improved to 21 masl.

Plans for future research include the incorporation of spatial anisotropy in the kriging algorithm, the investigation of kernel functions other than the tricube in LWR, as well as the use of locally adapted bandwidth values. Furthermore,

pumping rates for fifty eight (58) of the seventy (70) wells are available display a correlation coefficient of -0.6 with the respective ground water levels. A Digital Elevation Model (DEM) of the area will provide additional information about the unsampled locations of the basin. The pumping rates and the DEM will be used as secondary information in a co-kriging approach, leading to more accurate estimation of the basin's water table.

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