Mapping the Spatial Extend of Groundwater Level using Geostatistical Techniques: A Case Study Around the Area of Palakkad, Kerala, India

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***Abstract*-Information of the ground water levels in an aquifer is a need for the sustainable management of the ground water resources. But the limited number of, monitoring sites in a given aquifer are not always sufficient to accurately represent the water table. Geostatistical methods can be used to predict the groundwater level at unvisited locations of an aquifer. This paper deals with the application of Geostatistics for the spatial analysis of groundwater level of Palakkad region.**

Keywords- Ground Water, Geostatistics, Groundwater level, ordinary Kriging, semivariogram.

I.INTRODUCTION

Successful management of groundwater resources using numerical models requires knowledge of spatial distribution of hydraulic heads, aquifer parameters and other input data. Spatial interpolation techniques play a vital role in sustainable management of groundwater system by estimating the model input parameters at regular grid points from their measurements at random locations.There are two main groupings of spatially interpolation techniques: deterministic and geostatistical. Deterministic interpolation techniques create surfaces from measured data based on either the extent of similarity (inverse distance weighted) or the degree of smoothing (radialbasis functions). Geostatistical interpolation techniques utilize the statistical properties of the measured data to produce the raster maps (M.I. Kamali et al.2015). Geostatistics requires considerable computational effort, including two critical and time-consuming processes: estimation of the semivariogram and determination of the best fitted semivariogram model. However, geostatistics often yields the most accurate estimates, because it takes the spatial structure of the variables into account, and, in addition, enables the quantification of corresponding estimation errors. Geostatistics is including different types of Kriging method such as Ordinary, Simple, Universal, Probability, Indicator, Disjunctive and Cokriging. Kriging quantifies the spatial correlation of the data which is called variography and then presents a prediction for the locations without any measured data.

A number of studies have been conducted to determine the depth to ground water level in theother parts of the world. Bernard Ofosu et al (2014) successfully demonstrated how ground water level can be mapped integrating GIS with borehole data. Available depth to ground water level information can be used to determine the effects of ground water on civil engineering structures during the preliminary investigations. Borehole information on ground water level across Ashanti region for 37 observation wells was used to predict the depth to ground water level. The data was interpolated using kriging interpolation techniques in a GIS environment. Map showed ground water level is spatially distributed.A case study by Vijay Kumar (2007) describes how universal kriging can be used to interpolate hydraulic heads in an area where measurements are made at random places. The technique is appliedfor the estimation of groundwater levels for the post-monsoon period of 1990 in an arid area of Rajasthan State, India. The unbounded omni-directional semivariogram indicates the presence of drift in groundwater levels and so the need for universal kriging. Considering the semivariogram in the direction of least drift as the underlying semivariogram, the drift order was estimated by a cross-validation procedure.Mevlut Uyan etal they conducted a study to determine and evaluate the spatial changes in the depletion of groundwater level differences by using geostatistical methods based on data from 58 groundwater wells during the period from April 1999 to April 2008.The Determination of Reference Evapotranspiration for Spatial Distribution Mapping Using Geostatistics by M.I. Kamali et al. (2015) the study compares two approaches for preparation of spatial distribution maps of ET0 in Mazandaran province of Iran. The differences between the interpolation methods are more depended strongly on the nature of the variables under study, data spatial configuration, number of available samples, the assumption drawn and the selected criteria for the interpolation than the method of interpolation.

II. STUDY AREA

The study area selected is Palakkad district of Kerala(Fig.1), located in the realm of tropical climate lying between 10°21’–11°14’N lat. and 76°02’ - 76°54’E long. Palakkad is a major Paddy growing area of the State.The annual rainfall varies from 1883 to 3267 mm based on long term normal .The district receives on an average 2362 mm of rainfall annually.

Groundwater in the district is mostly developed through dug wells and bore wells for domestic, agricultural and for industrial needs. A good percentage of the households in the district have their own drinking water wells. Recently the bore well culture has picked up and gained momentum in the district.

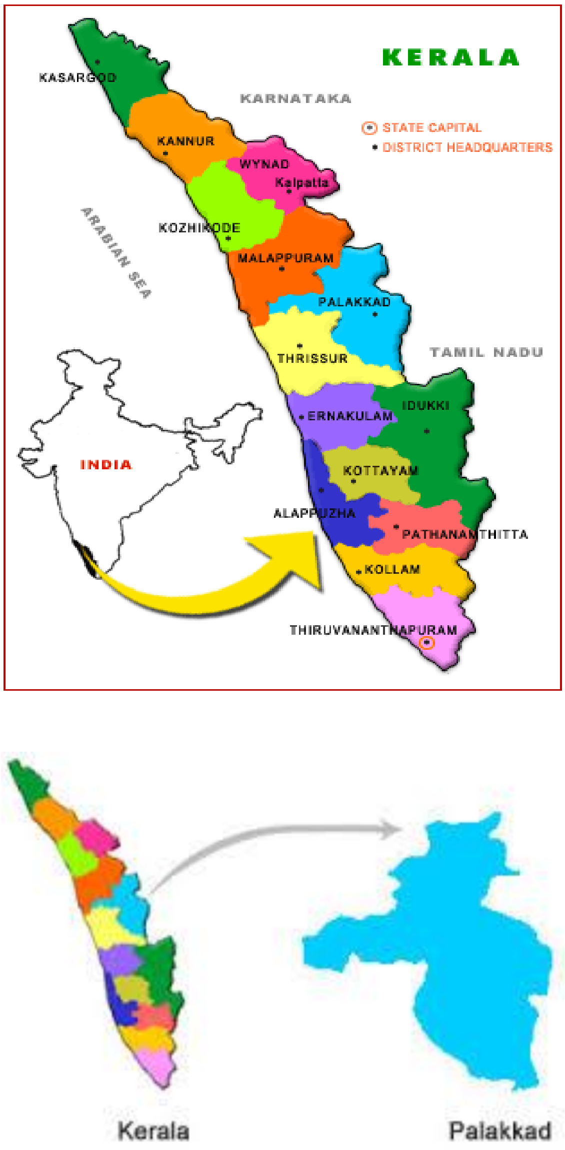


Fig 1 The Location of study area

The ground water level fluctuation varies from 2 to 4 m bgl and the maximum fluctuation is noticed in the eastern part of the district. In the central and western part the fluctuation ranges from 2- 3 m. (ground water department booklet of palakkad.)

III.MATERIALS AND METHODS

3.1Data collection

Map representing respective points of measurements (observation well) (Fig.2) and the observation well data were collected from the groundwater department, Kerala. The year 2009 was selected for the study. The stasticaltable shows ground water level data

WELL NO	MAX W L	MIN W L	AVG WL	Northing	Easting
114	6.76	8.83	7.90	1189778	622676.6
115	5.12	7.82	7.02	1194226	629111.3
116	1.79	3.28	2.52	1189840	638642.2
134	2.03	7.95	6.10	1203135	644162
PKD S-11	3.54	12.88	6.46	1195860	649660.6
PKD S-12	5.31	10.10	7.82	1191329	650555.8
PKD S-5	5.99	10.81	8.74	1214225	650779.8
PKD S-10	4.70	11.60	9.37	1205278	653444.2
157	4.28	12.24	9.29	1197763	654791
122	1.43	4.16	2.85	1173895	659496.3
135	6.48	12.22	9.40	1215593	659406.6
160 PKD-1	7.75	11.39	9.98	1215483	659516.4
152	6.73	11.72	8.57	1194475	661148.6
PKD S-9	3.04	7.90	5.49	1194476	661257.9
121 PKD	1.88	4.92	3.45	1171254	662353.8
128	1.78	4.80	3.44	1192829	663671.8
PKD S-14	1.44	6.16	3.71	1215950	664541.1
130	2.59	7.20	4.88	1200141	666259.9
132	3.76	9.25	7.28	1204576	668205.5
PKD S-2	0.57	1.64	0.93	1177145	668343.2
PKD S-4	1.97	4.49	3.09	1186442	669500.1
129	4.00	9.68	7.54	1193749	670884.9
131	0.38	3.62	1.83	1198405	672719.9
160 PKD-12	1.05	2.67	1.61	1184920	674649.1
123	0.71	2.33	1.56	1171538	675046.3
PKD S-3	0.70	4.62	2.10	1185586	675083.2
160 PKD-5	0.2	4.18	2.27	1190899	675711.7
PKD S-15	3.06	7.30	5.46	1196012	680496.5
127	4.44	7.90	6.25	1191146	680632.1
PKD S-1	1.48	5.64	3.07	1181970	681556.6
149	0.4	6.12	2.58	1172017	682047.6
160 PKD-10	2.83	4.82	3.78	1192598	683139.8
148	2.3	5.48	3.6	1172598	687078.6
126	1.61	5.71	3.38	1183787	690189.4
133	0.33	5.23	3.02	1194078	690787.4
PKD S-8	2.70	6.40	3.83	1178154	691643.6
151	2.99	5.84	4.22	1186467	694550.1
PKD S-7	0.17	5.02	2.09	1187497	700451.4

Table 1

3.2Geostatistical Analysis

As we wanted to consider the spatial correlation among measured data and also the geostatistical method has been considered appropriate, Ordinary Kriging, has been selected as the interpolation method. For ordinary kriging the data series should have a normal distribution; otherwise the non-linear Kriging should be used or the data have to be turned into a normal distribution using convertor functions (M.I. Kamali et al 2015). The spatial correlation of the data is evaluated by semivariogram which is as follows

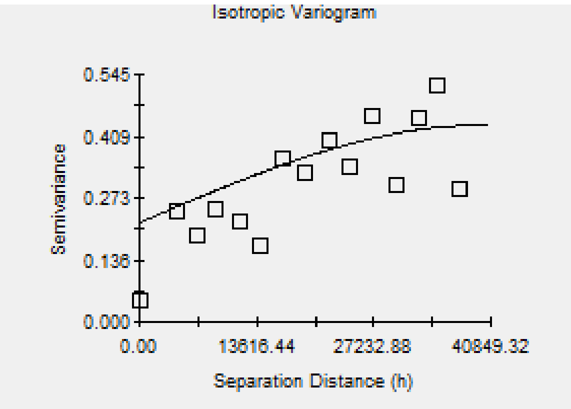


Fig 2. Semivariogram for average water level data

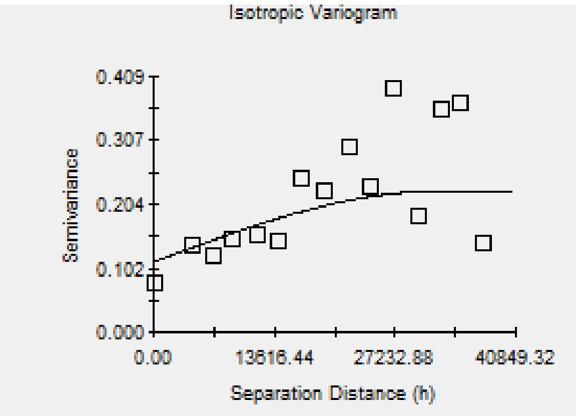


Fig 3. Semivariogram for minimum water level data

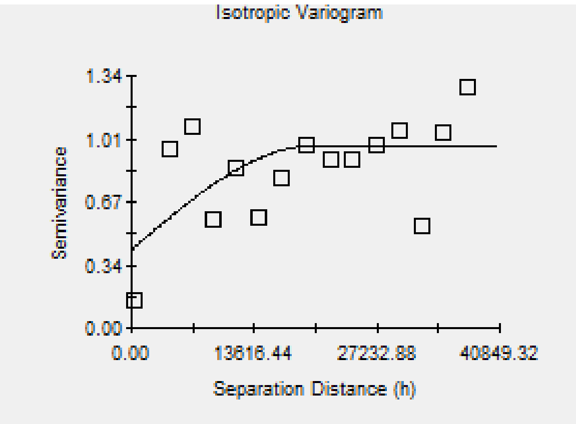


Fig 4. Semivariogram for minimum water level data

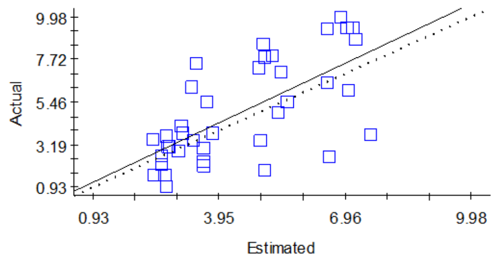
A semivarigram reveals the spatial structure of a variable and how it varies in different directions. In order to investigate geostatistical analysis and spatial correlation of the data, their semivariograms were calculated and different common semivariogram models (e.g., Spherical,Exponential, Gaussian and etc.) were fitted on them (M.I. Kamali et al 2015). In this study most preferable results were obtained by spherical model.spherical model defines mathematically as,

$$(h)=c(1.5\frac{h}{a}-0.5\frac{h^3}{a^3})+c_0 \text{ when } h\geq a \quad (1)$$

$$c_1+c_0 \qquad \text{when } h>a$$

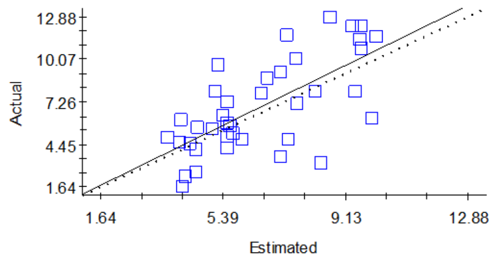
where $c_1+c_0 = \gamma(c_0)$ is called the sill value, c_0 is the nugget effect (usually present) and a is the range or maximum zone of influence(Bernard Ofosu et.al. 2014).

To conduct geostatistical analysis GS+ software was used. For each model,Sill, Range and Nugget would be calculated. When the distance between the samples (h) increases, the value of semivariogram increases to a certain distance and then graph levels off which is called Sill (the model asymptote). The distance between the samples from which the variable values in adjacent areas have little effect on each other and with further increase the samples become independent, is called the Range or Radius of Influence. Also, the semivariogram value for h=0 is called Nugget. Ideally, theNugget should be zero, but in reality this status does not happen due to sampling, measurement and analysis errors of the data (M.I. Kamali et al 2015).



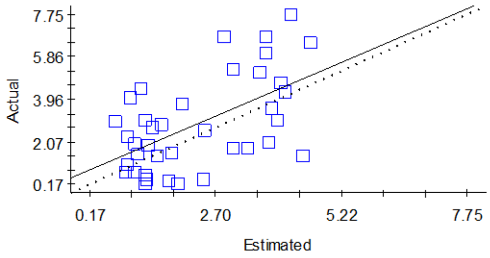
SE=0.196, nugget=0.2131, sill=0.43298, range=39520.83,N/S index=0.496.

Fig 5 . Cross validation diagram for average water level data



SE=0.189, nugget=0.11257, sill=0.22580, range=32140,N/S index=0.501.

Fig 6 . Cross validation diagram for minimum water level data



SE=0.229, nugget=0.4176, sill=0.9736, range=20314.01,N/S index=0.571.

fig 7 . cross validation diagram for maximum water level data

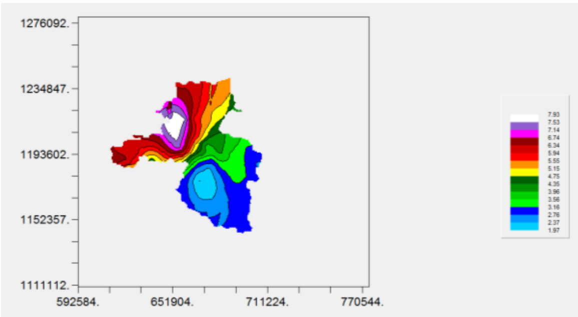


Fig 8. Depth to ground water level diagram for average water level data

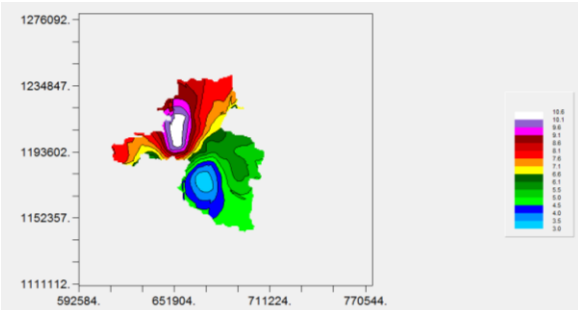


Fig 9 . Depth to ground water level diagram for minimum water level data

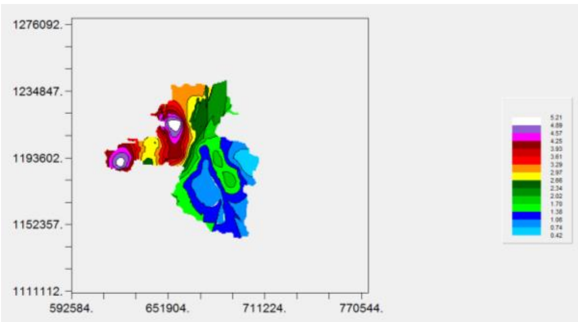


Fig 10. Depth to ground water level diagram for maximum water level data

The N/S index is used to determine the correlation of the data. For N/S index values less than 0.25, between 0.25 and 0.75 and higher than 0.75, the spatialcorrelation is strong, moderate and weak, respectively (M.I. Kamali et al.2015)

IV. RESULTS AND DISCUSSIONS

As it was mentioned, by using Ordinary Kriging interpolation method, the distribution function of the data was analyzed using GS+ software, then semivariogram values of the data were calculated and the best fitted models were determined. This was based on the Correlation of the data was investigated according to the Nugget to Sill ratio (N/S).Then the data were interpolated by Ordinary Kriging method.Then cross validation diagrams were plotted and the amounts of errors were calculated based on Standardized Error (SE).The depth to ground water level varies between 0.93 mto 9.98 m. The area including Cherpulassery, Vellinezhi, and Thchanattukara showed maximum water level in the maps and contain very little water. Based on this map the implication of ground water level on construction activities and civil engineering structures can be evaluated during preliminary stage of civil engineering projects.

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