

Comparison of Two Deterministic Interpolation Methods for Predicting Ground Water Level in Baghdad

Muammar H. Al-Taee

Civil Engineering Department, Misan University

muammar_altaee@yahoo.com

Aqeel Al-Adilli

Building and Construction Engineering Department, University of Technology

Nagaratnam Sivakugan

College of Science, Technology and Engineering, James Cook University, Townsville, Australia

Abstract

Surface interpolation techniques are commonly employed for creating continuous data (raster data) from a distributed set of data points over a geographical region. In this paper, the comparison between two spatial interpolation techniques (Natural Neighbouring (NN) and Inverse Distance Weighting (IDW)) is done. The goal is to determine which method creates the best real representation of measured ground water levels in Baghdad Governorate. Raster surface generation (ground water prediction map) is obtained for each method by using average ground water level measured at 206 wells in the study area. These maps show spatial variation in the ground water level and they are quite different. IDW method results a smoother map and lesser error than NN method. Thus, the analysis shows that IDW creates a better representation of reality for measuring ground water levels in Baghdad Governorate.

Key words: Spatial interpolation ,Inverse Distance Weighting ,Natural Neighbouring ,Baghdad.

الخلاصة

ان تقنيات الاستكمال الداخلي للسطوح غالبا ماتستخدم لخلق بيانات مكانية من بيانات متقطعة (نقطيه) واقعة ضمن منطقة جغرافية معينه، وفي هذه الدراسة تم اجراء مقارنة بين طريقتين من طرق الاستكمال الداخلي وهما طريقة المجاوره الطبيعيه (NN) وطريقة معكوس المسافه الموزونه (IDW). الهدف كان هو تحديد اي من الطريقتين تعطي افضل تمثيل حقيقي لمناسيب المياه الجوفيه المقاسة ضمن محافظة بغداد، ومن كل طريقة تم رسم سطح شبكي لمنسوب الماء الجوفي (خارطة تنبئيه بمنسوب الماء الجوفي) لمنطقة الدراسة باستخدام بيانات 206 بئر موزعه بشكل عشوائي ضمن محافظة بغداد. بينت هذه الخرائط تباين مكاني في منسوب الماء الجوفي وانهما مختلفتين عن بعضهما تماما. كانت نتائج طريقة IDW اكثر نعومه واقل خطأ من طريقة NN لذا تُعتبر طريقة IDW افضل من الثانية في التباين بمنسوب المياه الجوفيه في محافظة بغداد.

الكلمات المفتاحية: - الاستكمال الداخلي، عكس المسافه الموزون، الجوار الطبيعي، بغداد.

1. Introduction

Interpolation is a method or mathematical function which estimates the values at locations where no measured values are available. Spatial interpolation supposes the attribute data are continuous over space. This permit the estimation of the attribute data at any location within the space boundary. Another assumption is that the attribute is spatially dependent, indicating the closer values are more likely to be similar than the values farther apart. The objective of spatial interpolations is to create a surface raster that is intended to give the best representation of empirical reality. Thus, the method selected must be assessed for accuracy (Azpurua and Ramoos, 2010). There is no unique preferred method for data interpolation. The requirements of the algorithm selection criteria need to be based on the actual data, the level of required accuracy, and the time and computer software available. Selecting an appropriate spatial interpolation method is essential for surface analysis since different methods of interpolation can result in different surfaces and ultimately different results.

2. Description of The Study Area

Baghdad Governorate lies in the middle of Iraq within the Mesopotamians Plain. It is the capital of Iraq. Tigris river passes through Baghdad city dividing it into two parts; Karkh on the west of river and Rusafa on the east of river. Baghdad city is bounded from the east by Diyala river which joins Tigris river in the southeast of Baghdad city. The Army Canal, 24 km long, recharges from Tigris river in the northern part of Baghdad city and terminates in the southern part of Diyala river (Al-Hiti, 1985). The information mentioned before is shown in Figure 1.

The information of two hundred six wells that were drilled by the General Commission of Ground Waters and the National Center for Water Resources Management in Iraq are used in this study; the distribution of these wells is shown in Figure 2. Most of these wells lie within Baghdad Governorate and few little lie on the border of it and nearby it. Forty nine of 206 wells lie within Baghdad city. The static ground water level recorded at these wells are used to draw a ground water contour map by using the IDW method and the NN method for Baghdad Governorate.

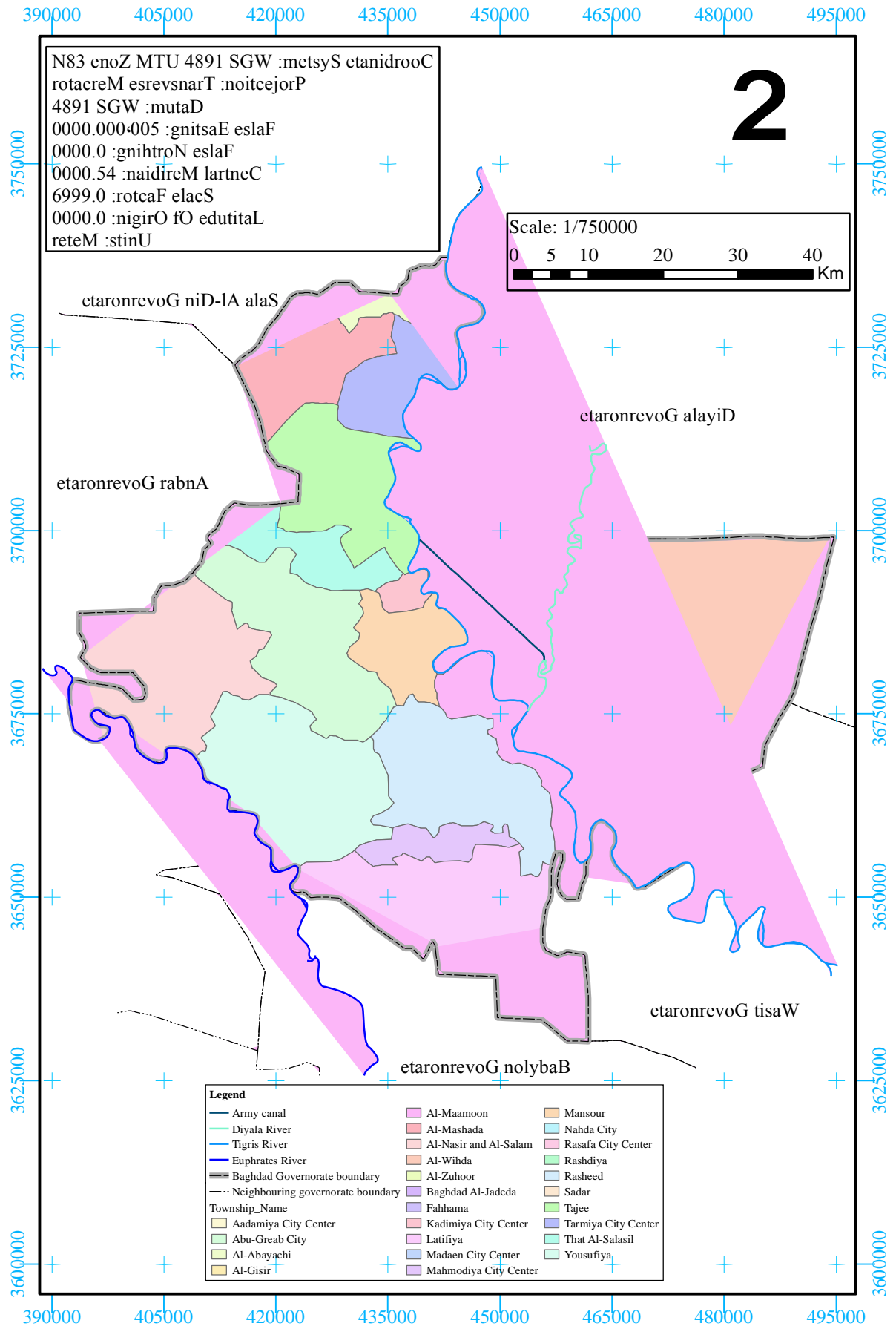


Figure 1: Administrative map of Baghdad Governorate

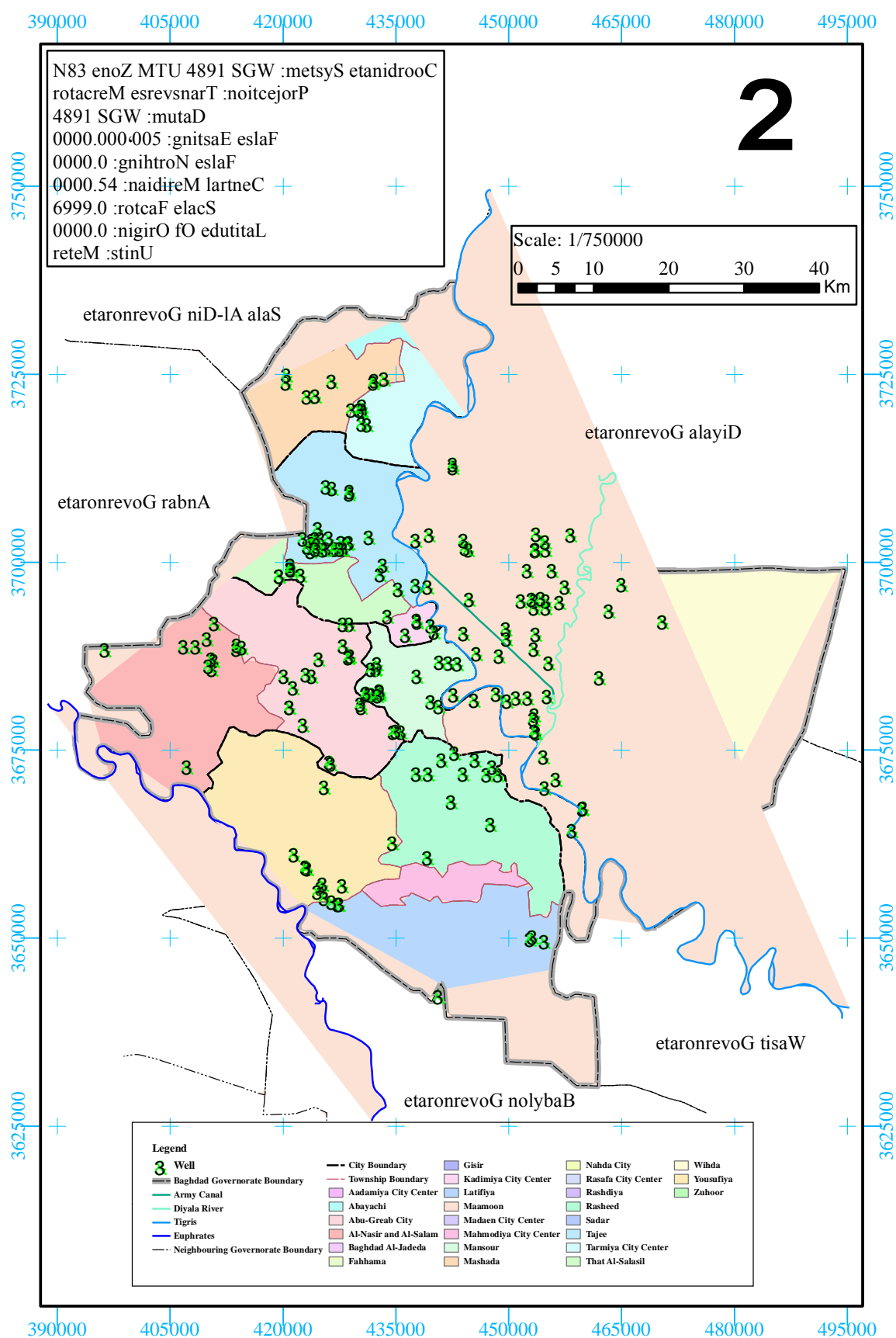


Figure 2: Distribution of wells on Baghdad Governorate

3. Natural Neighbour Interpolation (NN)

This method uses a weighted average of local data based on the concept of natural neighbour coordinates derived from Thiessen's polygons (Boots, 1999) for the bivariate, and Thiessen's polyhedra for the trivariate case (Watson, 1992). The value in an unsampled location is computed as a weighted average of the nearest neighbouring values with weights depending on areas or volumes rather than distances. The number of given points used for the computation at each unsampled point is variable depending on the spatial configuration of data points. Natural neighbour linear interpolation leads to a rubber-sheet character of the resulting surface. The addition of blended gradient information derived from data points by local preinterpolation allows to make a smooth surface everywhere with tautness similar to tension. The value of tautness is controlled by two empirically selected parameters which modify the shape of the blending function. The result is a surface with smoothly varied gradients and passing through data points, blended from natural neighbour local trends, with local tunable tautness, and with the capability to calculate derivatives and integrals. The method has been used typically for topographic, bathymetric, geophysical, and soil data (Laslett *et.al.*, 1987; McCauley and Engel, 1997; Watson and Philip, 1987).

4. Inverse Distance Weighted Interpolation (IDW)

This is one of the simplest and most readily available methods. It is based on an assumption that the value at an unsampled point can be approximated as a weighted average of values at points within a certain cut-off distance, or from a given number m of the closest points (typically 10 to 30). Weights are usually inversely proportional to a power of distance that at an unsampled location \mathbf{r} leads to an estimator as shown in the following (Burrough, 1986; Watson, 1992):

$$F(\mathbf{r}) = \sum_{i=1}^m w_i z(r_i) = \frac{\sum_{i=1}^m z(r_i) / |\mathbf{r} - \mathbf{r}_i|^p}{\sum_{j=1}^m 1 / |\mathbf{r} - \mathbf{r}_j|^p}, \dots\dots\dots(1)$$

where p is a parameter (typically $p=2$).

While this basic method is easy to implement and is available in almost any GIS, it has some well-known shortcomings that limit its practical applications (Burrough, 1986; Franke and Nielson, 1991; Watson, 1992). This method often does not reproduce the local shape implied by data and produces local extrema at the data points. A number of enhancements have been suggested, leading to a class of multivariate blended IDW surfaces and volumes (Franke and Nielson, 1991; Tobler and Kennedy 1985; Watson 1992). However, most of these modifications are not implemented within GIS.

5. Comparison between Ground Water Prediction Maps

In this section we use a GIS software package ArcGIS 10.5 and ArcToolbox/ Spatial Analyst tools for the interpolation methods (IDW and NN) in this study. The maps are produced with the ArcMap module of the ArcGIS by using the average static water level observed at 206 wells within Baghdad Governorate. The differences between predicted and observed values are summarized using root mean square error (RMSE) which is computed from the following equation (Krivoruchko, 2006):

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (\hat{Z}(x_i) - z(x_i))^2}, \dots\dots\dots(3)$$

where $\hat{Z}(x_i)$ is the predicted value, $Z(x_i)$ is the observed value, and N is the total number of data.

The raster surface generated from each IDW and NN interpolation method is used to predict ground water level for 206 well. Then, the RMSE is computed for each raster and the raster that gives smaller RMSE is considered the best one in predicting ground water level (static) in Baghdad Governorate.

Figure 2 and 3 shows the spatial distribution of ground water level in the study area obtained by Natural Neighbouring Interpolation and Inverse Distance Weighting Interpolation (with power parameter $p=2$). The prediction map provided by two interpolation methods (Figure 2 and Figure 3) is different. The comparison of IDW and NN maps indicated that IDW method has resulted in a smoother map.

More quantitative comparison of these two techniques is obtained by comparing RMSE statistics as shown in Table 1. The best model is selected based on the smallest root mean square prediction error (RMSE). For NN method RMSE is equal to 0.771 m while IDW gives RMSE equal to 0.496 m.

Graphical comparisons between the actual and the predicted values for each interpolation method are also given as Figure 5 and 6.

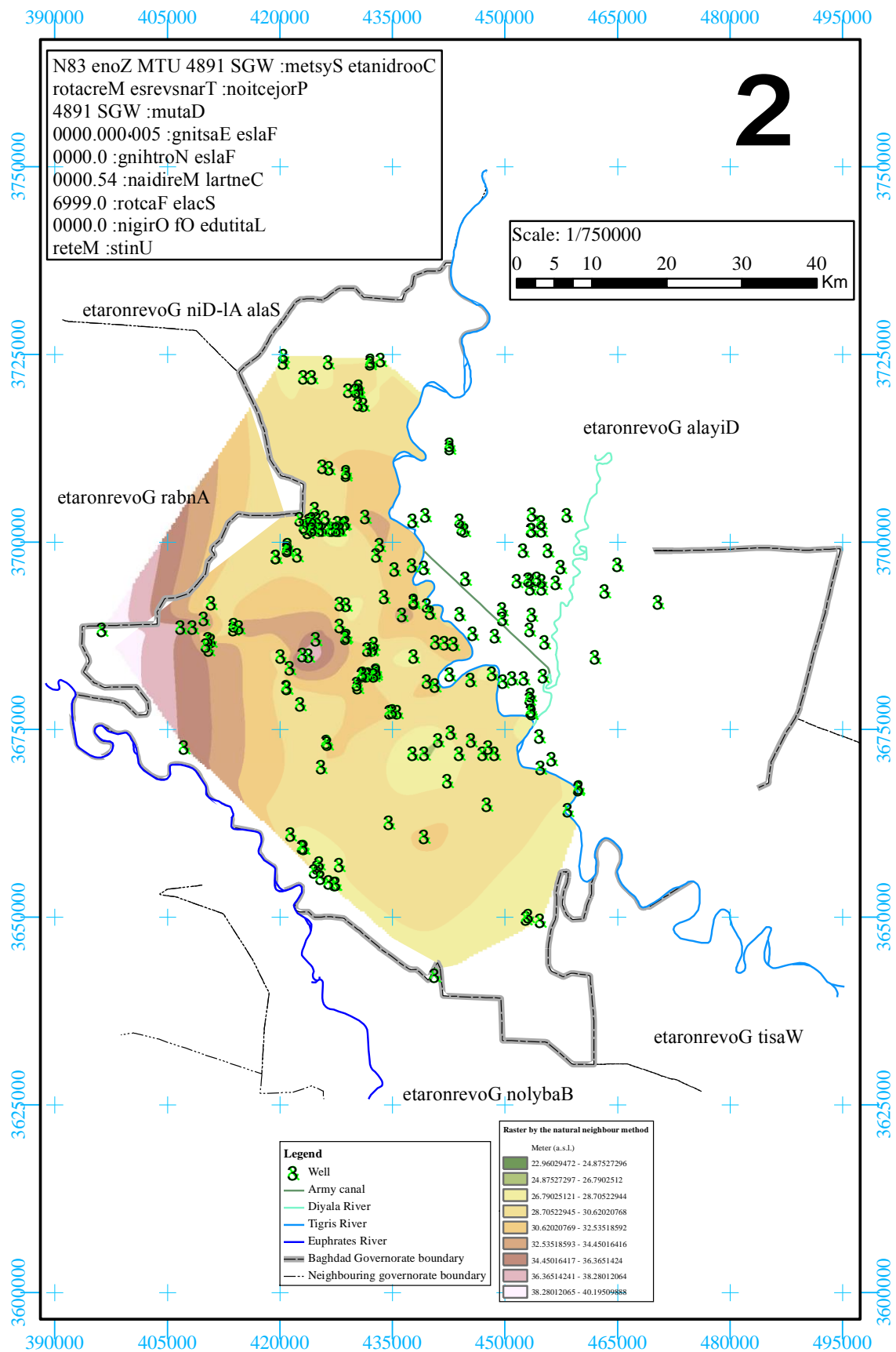


Figure 3: Prediction map of ground water level for Baghdad Governorate generated by Natural Neighbour Interpolation method.

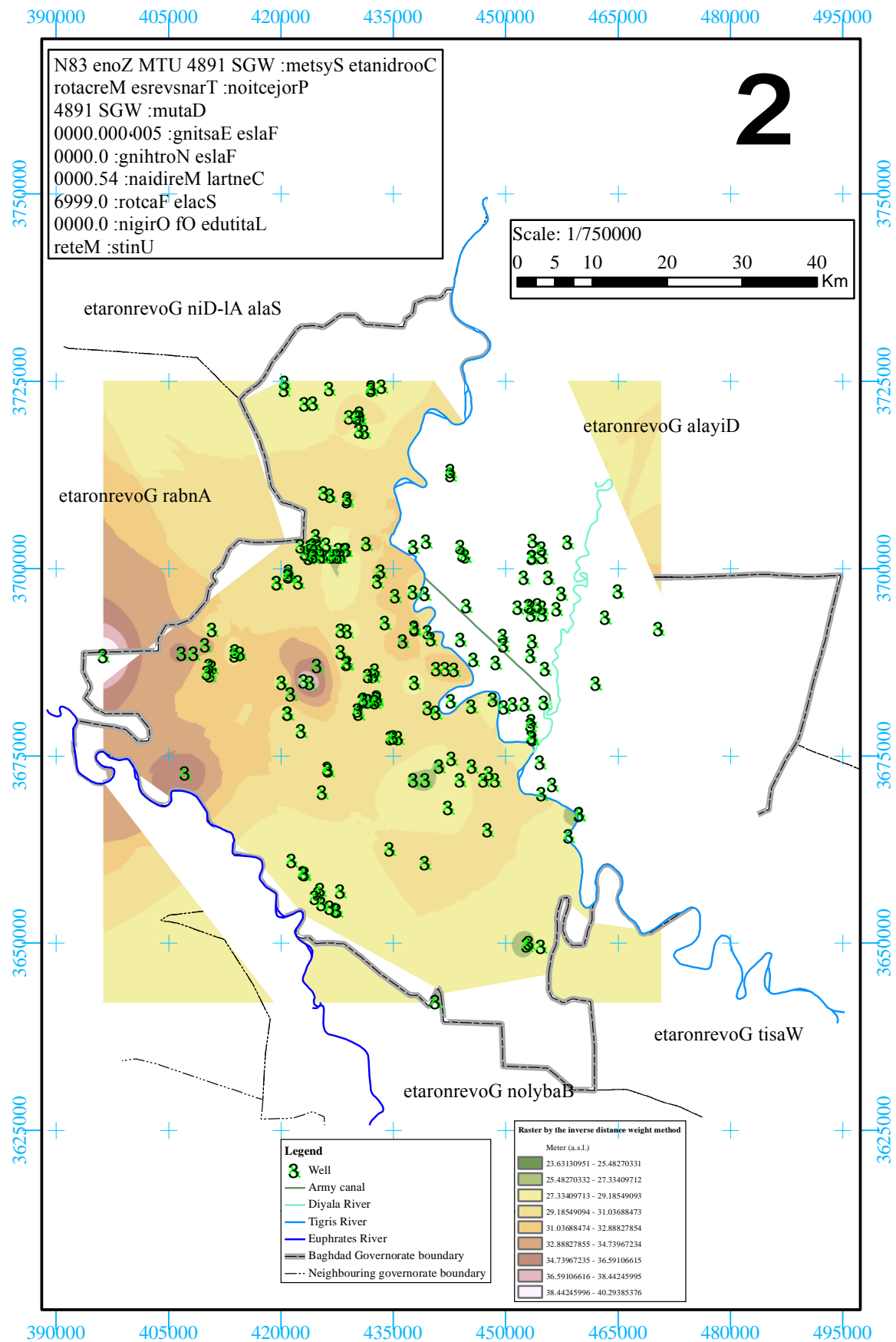


Figure 4: Prediction map of ground water level for Baghdad Governorate generated by Inverse Distance Weighting Interpolation method.

Table 1: RMSE for ground water level for NN and IDW interpolation method.

Interpolation method	RMSE (m ²)
Natural Neighbour	0.771
Inverse Distance Weight	0.496

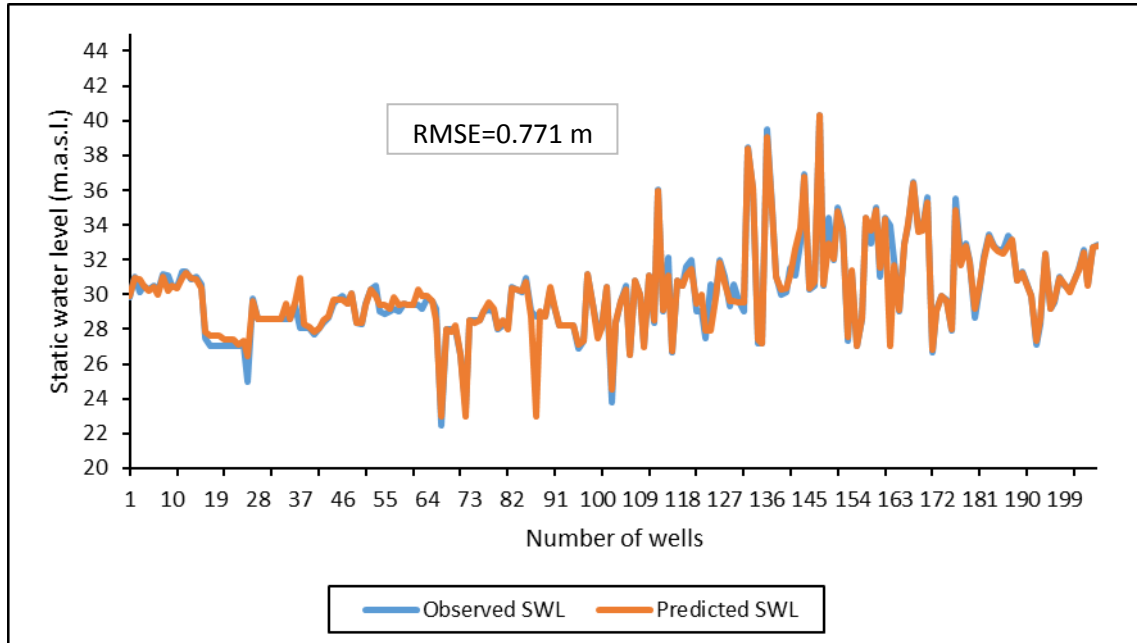


Figure 5: Comparison of predicted ground water level (SWL) in Baghdad Governorate as obtained from NN method with observed ground water level at 206 wells.

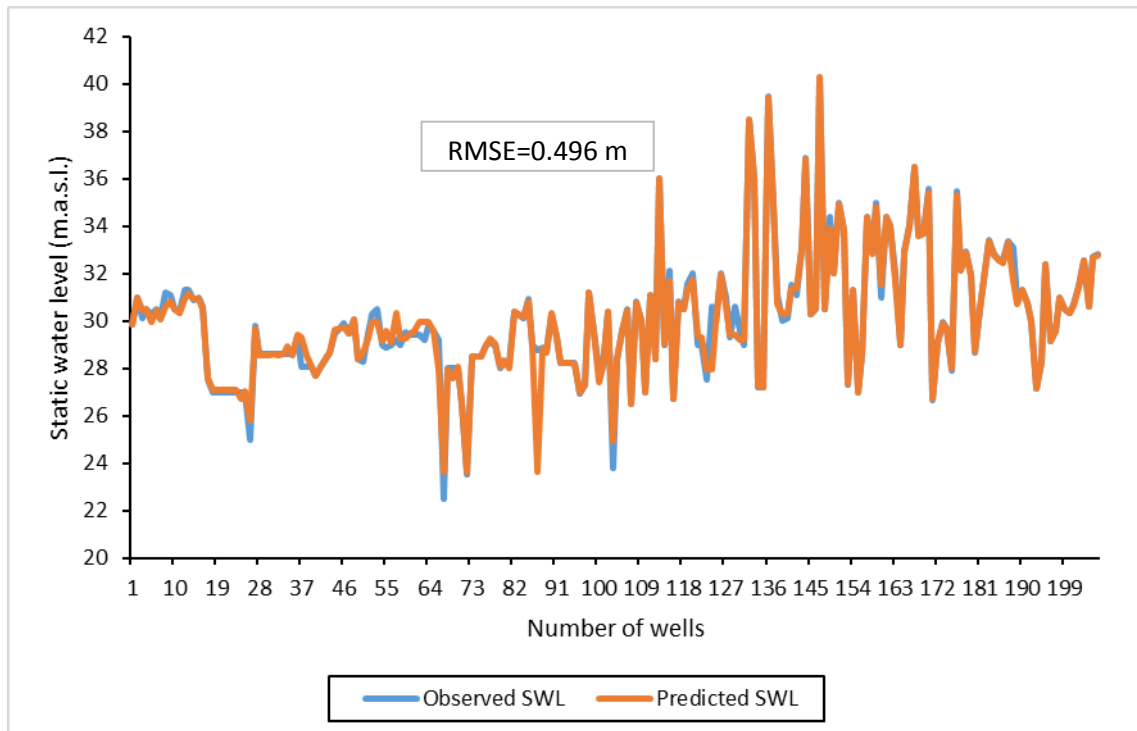


Figure 6: Comparison of predicted ground water level (SWL) in Baghdad Governorate as obtained from IDW method with observed ground water level at 206 wells.

6. Conclusion

Ground water maps which are obtained from ground water level (static water level) data measured at 206 wells for Inverse Distance Weighting (IDW) and Natural Neighbour (NN) interpolation method shows the spatial variation in the ground water level in the study area and there are quite different. IDW interpolation method has resulted in smoother map.

It is found that the root mean sum error (RMSE) between predicted and observed ground water level (SWL) for all wells is 0.771 when using the NN interpolation method and 0.496 when using the IDW interpolation method. Therefore, the IDW is considered the best method for predicting ground water level in Baghdad Governorate.

References

- Al-Hiti, B. M. ,1985, **Groundwater quality within Baghdad area**, M.Sc. thesis, College of Science, University of Baghdad, 235p, (in Arabic).
- Azpurua M. and Dos Ramos K., 2010, **A comparison of spatial interpolation methods for estimation of average electromagnetic field magnitude**, Progress In Electromagnetic Research M, 14, 135–145.
- Boots, B. ,1999, **Geographical Information System**, Volume 1, John Wily and Sons, USA.
- Burrough, P. A.,1986, **Principles of geographical information systems for land resources assessment**, Oxford, *Clarendon Press*.
- Franke, R. and Nielson, G. ,1991, **Scattered data interpolation and applications: a tutorial and survey**, In Hagen H, Roller D (eds) *Geometric modelling: methods and applications*. Berlin.
- Krivoruchko, K. ,2006, **Introduction to Spatial Data Analysis in GIS**, ESRI Press.
- Laslett, G. M.; McBratney, A. B.; Pahl, P. J.; and Hutchinson, M. F. ,1987, **Comparison of several spatial prediction methods for soil pH**, Journal of Soils Science 38: 32–50.
- McCauley, J. D. and Engel, B. A. ,1997, **Approximation of noisy bivariate traverse data for precision mapping**, Transactions of the American Society of Agricultural Engineers 40: 237–45.
- Tobler, W. R. and Kennedy, S. ,1985, **Smooth multi-dimensional interpolation**, Geographical Analysis 17: 251–7.
- Watson, D. F. ,1992, **Contouring: a guide to the analysis and display of spatial data**. Oxford, *Pergamon*.
- Watson, D. F. ,1992, **Contouring: a guide to the analysis and display of spatial data**. Oxford, *Pergamon*.
- Watson, D. F. and Philip, G. M. ,1987, **Neighborhood based interpolation**, Geobyte 2: 12–16.