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Optimum Site Selection for Groundwater wells using Integration between GIS and Hydrogeophysical Data

Abstract*- This paper aim to select the best site to drill a groundwater wells by using of Geographic Information System (GIS) as a tool for decision-making. The study conducted in Fadak farm in Bahr Al-Najaf which is located west and southwest of Najaf city, and extends more than (40 km) away from it, to drill a new wells for irrigations usages. The optimal location selected depending on the available hydrogeophysical data includes resistivity, depth, thickness and transmissivity of aquifer. The weighted factor maps generated for the evidence layers were given weights depending on the significance of each parameter, these parameters were integrated in GIS to precisely to find the preferable sites. Finally, region was divided in to three classes; good medium, and bad according to the importance of each input factors using an overly combing method.*

Keywords*- Groundwater; GIS; Site Selection; Spatial Analysis; Weighted Overlay; Hydrogeophysical Data.*

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1. Introduction

The Over the past decades, the demand for irrigation using groundwater has increased for many reasons, including the growing need for farmers to manage themselves and manage their irrigation applications. Selection of well sites relies on traditional field studies using existing water point sites as guidelines. Generally, the systematic approach of groundwater exploration is lacking. The overall, this paper aimed to utilize GIS towards systematic approach in groundwater investigation. Many researchers have carried out a number of previous studies by applying integration between geophysics and remote sensing for groundwater assessment, i. g [1,2]. GIS is the most efficacious modern technology used to make spatial multi criteria decisions that target potential ground water resources. GIS used to carry out the suitability model for groundwater well sites selection using spatial correlation, integrating and weighting for all the datasets. Spatial Analysis is a process, which examines the locations, relationships between the features and attributes of spatial dataset. The suitability model produce new information beneficial for groundwater resource development. Site selection is a decision making tool for recognizing the optimum locations by overlapping multiple geospatial criteria. The major goal of this paper is find optimal locations to drill new groundwater wells using techniques to analysis the hydrogeophysical data.

2. Study Area

I. Location

The study area lie in Bahr Al-Najaf which is located west and southwest of Najaf city as shown in Landsat 8 image with spatial resolution 30 m (Figure 1), and extends more than (40 km) away from it. Bahr Al-Najaf is considered as a closed topographic depression at the eastern edge of the western desert, with simple relives of low hills [3]. It generally occurs within two physiographic units, the first is the gypsoferious plain due to presence of saline soils, and the second is the Pleistocene terraces as a result of occurrence of Tar Al-Najaf and the Mesas features, according to the recent subdivisions of Al-Naqash [4].

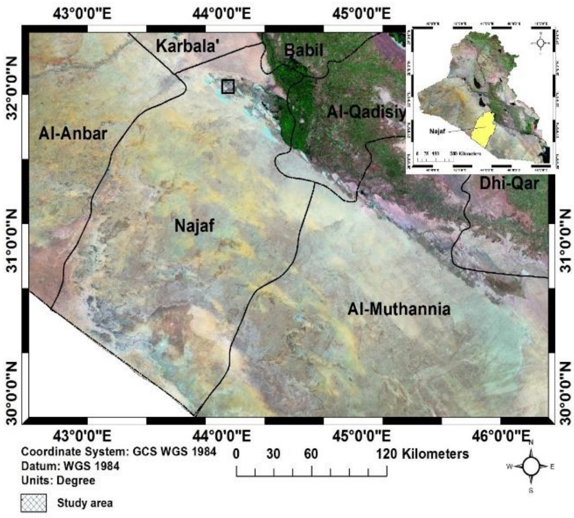

Figure 1: Location of the study area (Landsat 8 image)

II. Geological and Hydrological status

Recent deposits (Quaternary deposits) cover a huge part of Najaf Sea area represented by Pleistocene and Holocene deposits including valley terraces, gypsum crust, deposits of slopes, moorlands deposit depression filling deposits, flood plain deposits, valley-filling deposits, dunes and sand plates in addition to artificial deposits resulted from human interference. As for pre-quaternary deposits ages, they range from Paleocene to the upper Miocene represented by formations of Um Ardhuma, Al-Dammam, Al-Ghar, Al-Furat, Al-Nefile, Al-Fatha, Injana, Zahra and Al-Dibdiba [5]; while Fadak farm is belonged to the lower-upper Eocene age and represented by Al-Dammam formation which is divided to three members depending on rock and physical changes. Al-Dammam formation is considered as to be in unconformity with Al-Furat formation, which tops it, and Russ formation lies beneath it [6]. It generally consists of carbonate rocks (limestone and Dolomite), with Nummulites and extends to cover wide area of the western and southern desert of Iraq [5]. Al-Dammam formation is the main groundwater aquifer of the area where its thickness reaches (300 meters). The deep groundwater within Al-Dammam aquifer is of (2500-3500µs/cm) electric conductivity of sulphatic water type; and it is regarded as the desired one [7]. In addition, this aquifer has a large value of storage coefficient reaches (4.77 E-05), so it is hydrogeologically classified as confined type with relatively high piezometric pressure [8]. Its Porosity is a secondary type due to highly fractured carbonate rocks with presence of paleokarast features [6]. Many evidences show the presence of anisotropy and preferential permeability in this aquifer [9].

III. Hydrogeophysical data

Hydrogeophysical data includes the geoelectrical and hydraulic parameters. The geoelectrical parameters, derived from the results of the vertical electrical sounding interpretation, are represented by the bulk resistivity of aquifer and its thickness. The depth of aquifer, which in turn reflects the depth of the potential excavation to reach the groundwater, where the Hydraulic parameters are derived from the pumping test results of wells drilled in the area. One of the most important hydraulic parameters is Transmissivity (T), which is defined as the ability of the aquifer to pass the water through cross section of the aquifer of a square area unit at the prevailing temperature [10]. Transmissivity is equal to the product of hydraulic conductivity (K) multiplied by the saturated thickness of the aquifer (H) [11]. Consequently, it is the rate of water flow under hydraulic gradient through a cross section of a width unit over the whole aquifer saturated thickness [12]. The hydrogeophysical data of aquifer for the study area includes resistivity, depth, thickness and transmissivity of aquifer as shown in (Table 1).

3. Methodology

The optimal location will be selected depending on the available hydrogeophysical data (Table 1) including aquifer resistivity, aquifer depth, aquifer thickness and transmissivity. Figure 2 explain the methodology flowchart.

I. Reclassifying Datasets

The first step to building the suitability model is derivation of databases, such as depth, in this approach for every criteria input, each cell in the study area has a different value for each layer. The suitability map can be created by combined the derived datasets in order to identify the potential locations to drilling new wells [13].

However, because it is not possible to combine them in their present form, the next step is reclassify the previous maps into a relative five classes to have a common value. In the resulted maps, the good areas to drill a well refer as number five while the number one indicated bad areas.

Table 1: Hydrogeophysical Data of Aquifer [14]

Longitude	Latitude	Depth (m)	Resistivity (Ω.m)	Thickness (m)	Transmissivity (m/day)
44°2'48.29"E	32°1'44.3"N	23.81	67.8	227	299.639036
44°2'7.91"E	32°1'43.08"N	70	65.7	305	387.2850024
44°1'33.83"E	32°1'43.14"N	81.67	114	320	586.2609978
44°0'55.07"E	32°1'43.14"N	63.26	119	219	474.5609974
44°0'32.63"E	32°1'39.6"N	43.23	42	228	142.0491039
44°3'27.59"E	32°1'11.16"N	63.45	77.9	125	147.6036259
44°2'55.01"E	32°1'8.46"N	42	66.5	172	201.0605765
44°2'11.39"E	32°1'10.2"N	20.56	46.4	172	81.52976204
44°1'33.41"E	32°1'11.1"N	14.71	79.4	185	284.1429747
44°0'57.95"E	32°1'7.56"N	21.74	54.8	179	150.0401611
44°4'5.99"E	32°0'39.48"N	48.48	53.9	132	43.38194885
44°3'27.23"E	32°0'39.6"N	22.24	51.2	181	131.1626474
44°2'53.63"E	32°0'41.7"N	73.83	42.2	257	183.3917531
44°2'11.21"E	32°0'38.7"N	152.9	78.4	163	237.8852794
44°1'35.03"E	32°0'28.98"N	31.75	18	181	216.0248977
44°3'54.47"E	32°0'6.66"N	23.2	46.8	184	106.7791932
44°3'28.13"E	32°0'7.5"N	66.85	59.4	126	60.2017454
44°2'53.69"E	32°0'6.8"N	24.72	73.1	200	282.5792009
44°3'46.01"E	31°59'24.96"N	24.05	72	238	335.3168876
44°3'7.91"E	31°59'27.72"N	49.51	34	198	25.01410367
44°3'54.11"E	31°58'47.94"N	17.62	58	121	38.83228867
44°3'21.23"E	31°58'52.02"N	12.41	51	125	6.917487573
44°3'24.35"E	31°58'35.4"N	14.77	70	112	75.61808492

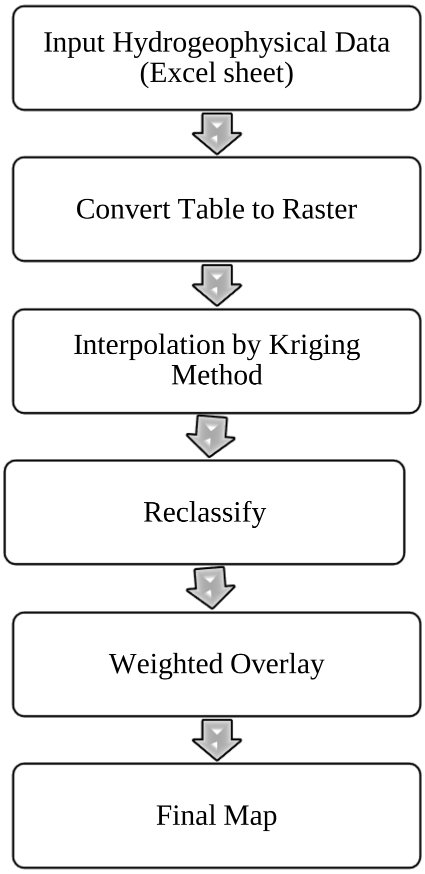

Figure 1: Methodology flow chart.

II. Weighted Overlay Suitability Model

To find the optimal location to drill new wells it should to combine the reclassified datasets. All the datasets reclassified to a same scale measurement for values to diverse and dissimilar inputs in order to create an integrated analysis. (The more suitable cell has higher value) each inputs layer have been weighted according to its importance then assign each layer by a percentage of influence, where transmissivity 40%, resistivity 30%, thickness 20%, depth 10% of the aquifer. The higher the percentage is the more influence a particular input will have in the suitability model. The weighted Suitability analysis was developed using GIS techniques depending on a number of thematic layers [15]. Accordingly, the input layers may not be same important. Each individual cell in the raster is reclassified into units of suitability and then multiply those by a weight in order to assign the relative importance to each one, and finally add them together to find final weight. Additionally this equation interpreted to obtain a suitability value for every cell on the map [16].

$$S = \sum wi \ \mathrm{xi} \qquad (1)$$

Where,

wi = The weight of the i factor map

xi = Criteria class score of factor i

S = Suitability index for each pixel in the map.

In this paper, all the thematic layers were integrated in ArcGIS 10.2 platform in order to prepare a map depicting suitable site to drill new water well. The total weights of each pixel of the final integrated layer were derived from the following equation;

$$S = (AE_w AE_r + AR_w AR_r + AZ_w AZ_r + AT_w AT_r) \quad (2)$$

Where,

S is the dimensionless for new well location index for each pixel in the final integration layer.

AE is the Aquifer Depth.

AR is the Aquifer resistivity.

Az is the Aquifer thickness.

And AT is Aquifer transmissivity.

The subscript letter ‘w’ represents the weight of each factor, while ‘r’ represents the range of each class of the individual factor (Table 2).

The transmissivity given the higher percentage weight (40%) because it has a close relationship with the water quantity and abundance as well as the possibility of regeneration. while the aquifer resistivity factor given a 30% percentage weight because it is related to the quality of water (salinity of water), where salinity of water increases when the resistivity is decreases. The minimum percentage weight have been given to aquifer thickness (20%) and aquifer depth (10%) respectively, because they are important in estimating the water quantity and the cost of drilling wells.

Table 2: The weight of the factor.

sample	Factor	Wight
AT	Aquifer Transmissivity	40%
AR	Aquifer Resistivity	30%
AZ	Aquifer Thickness	20%
AE	Aquifer Depth	10%

4. Results and Discussion

In This Paper, the input layers has been used to evaluate the out comes from Integration between GIS and hydrogeophysical data. By overlay combination method in GIS (i-e Value of Resistivity, Aquifer Depth, Aquifer thickness and Aquifer transmissivity).

I. Reclassifying the Aquifer Depth Map

Aquifer Depth map have been reclassified in order to integer values instead of ranges, then use it as inputs in the weighted model. The reclassify function was applied to reclassify this map. A value of five was assigned to the most suitable range (low depth value) and one to the least suitable range (High depth value). All the layers should have the same range of classes (1 to 5). Figure 3 shows the aquifer depth map and Figure (4) shows the reclassified of this map.

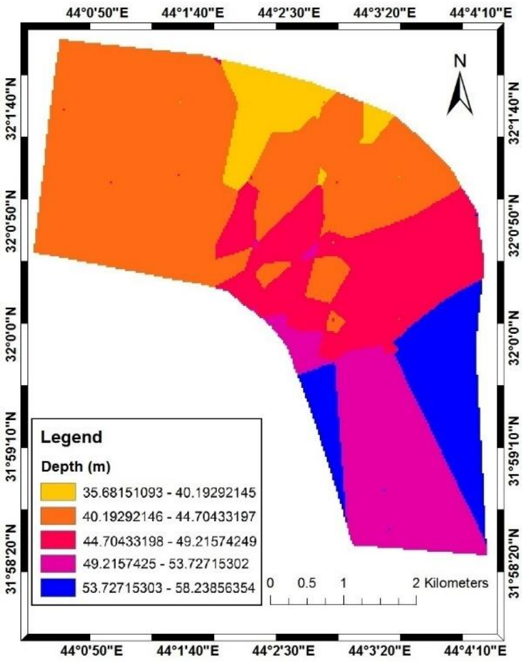

Figure 3: Aquifer depth map

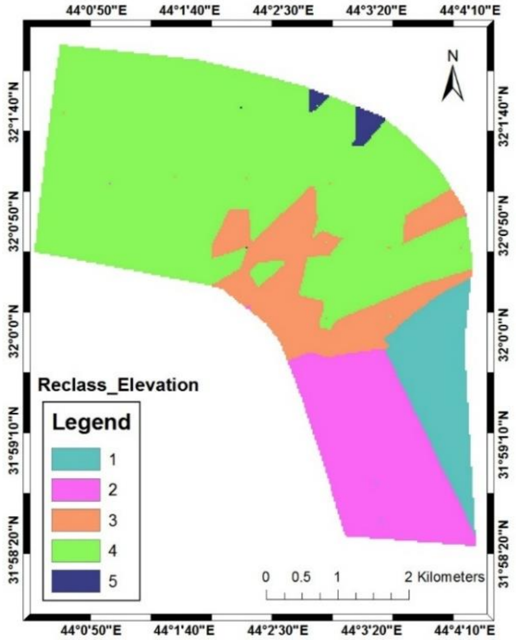

Figure 4: Reclassifying the aquifer depth map.

II. Reclassifying the Aquifer Resistivity Map

Aquifer Resistivity map have been reclassified to integer values instead of ranges to be used as inputs in the weighted model. A value of five was assigned to the most suitable range (high resistivity value) and 1 to the least suitable range (low resistivity value). Figure 5 shows the resistivity map and Figure 6 shows the reclassified of this map.

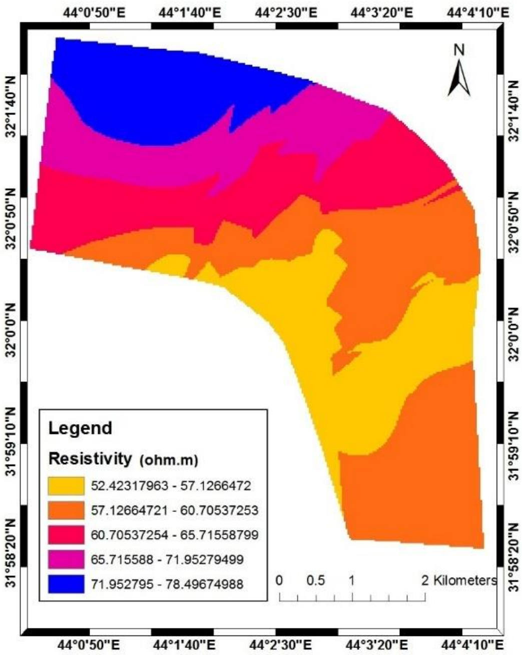

Figure 5: Aquifer resistivity map

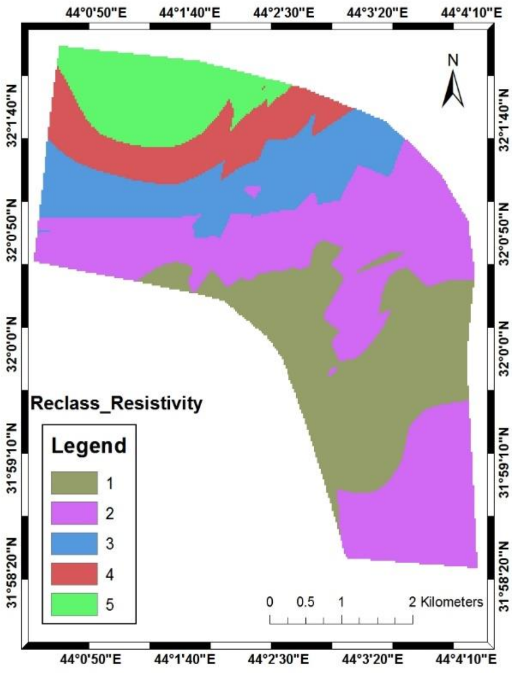

Figure 6: Reclassifying the aquifer resistivity map

III. Reclassifying the Aquifer thickness Map

Aquifer Thickness map have been reclassified to integer values instead of ranges to be used as inputs in the weighted model. A value of 5 was assigned to the most suitable range (high value) and one to the least suitable range (low value). Figure 7 shows the thickness map and Figure 8 shows reclassified of this map.

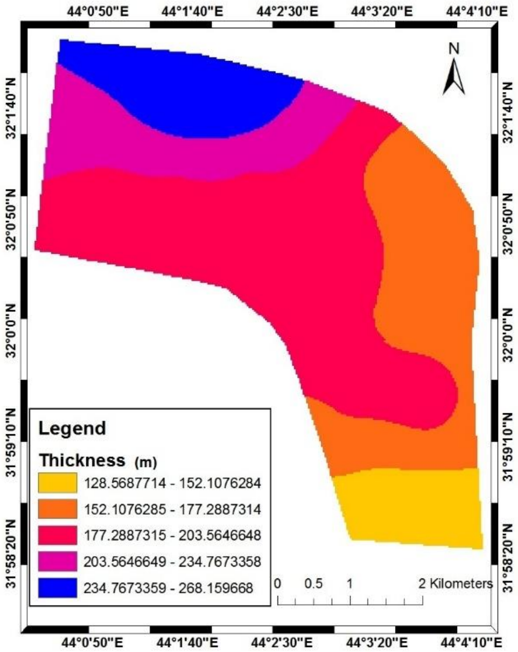

Figure 7: Aquifer thickness map

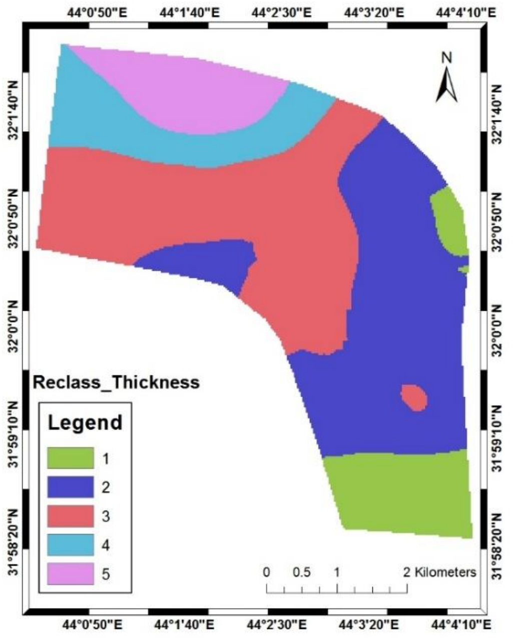

Figure 8: Reclassifying the Aquifer Thickness

IV. Reclassifying the Aquifer transmissivity map

Aquifer Resistivity map have been reclassified to integer values instead of ranges to be used as inputs in the weighted model. A value of five was assigned to the most suitable range (high transmissivity value) and one to the least suitable range (low transmissivity value). Figure 9 shows the transmissivity map and Figure 10 shows reclassified of this map.

V. The Optimal Sites Selection

Now in the resulted map each pixel have a value, which indicates its suitability. Pixels with the value of three is most suitable. Therefore, the optimal site location to drill new wells has the value of three. While the proses, several locations selected as the optimum locations depending on the input factors. Groundwater exploratory drilling sites were investigated and identified by using available Hydrogeophysical data consisting of (thickness, resistivity, depth and transmissivity of the aquifer), GIS was used to integrate these geospatial dataset in a suitability map for selecting optimal groundwater well locations. The optimal sites have been identified. This method is dynamic and can be performed even more by adding new layers data to derive more relevant factors to develop the groundwater prospect. The results map (Figure 11) straight forward to used by decision makers to find the best groundwater wells location.

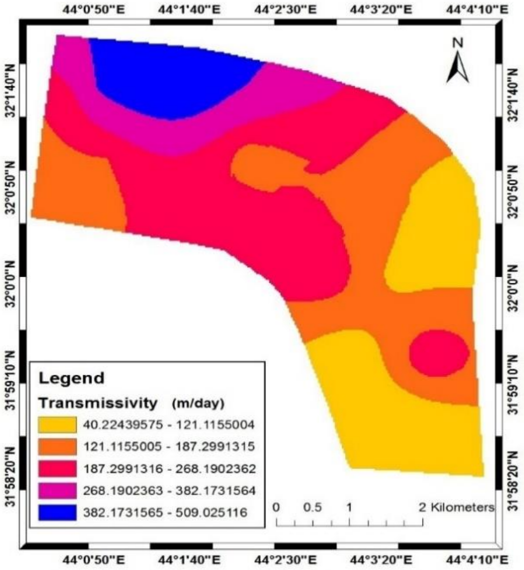

Figure 9: Aquifer transmissivity

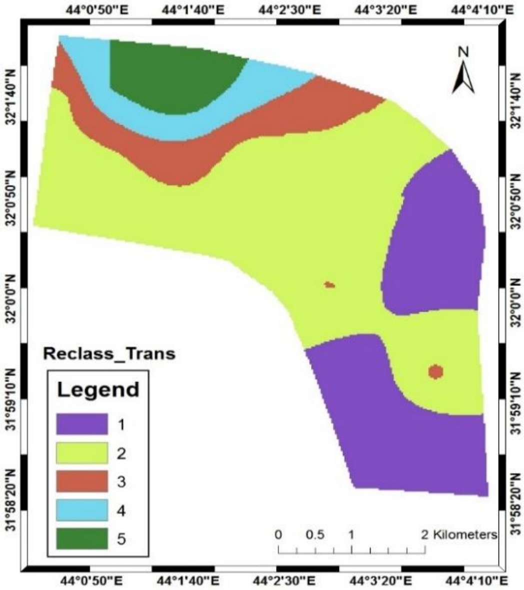

Figure 10: Reclassifying the Aquifer Transmissivity

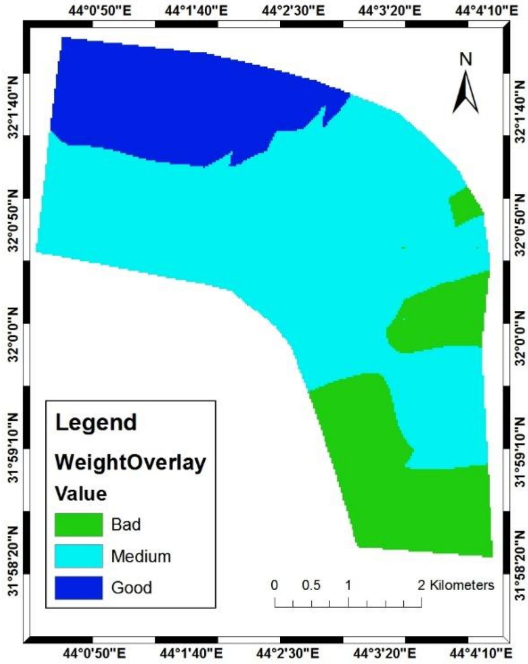

Figure 11: Final Site Evaluation

5. Conclusion

- In this paper, the region was divided into three classes; good, medium, and bad according to the importance of each input factors using an overly combing method.
- Each inputs Hydrogeophysical factors have been weighted according to its importance then assign each layer by a percentage of influence, where transmissivity 40%, resistivity 30%, thickness 20%, depth 10% of the aquifer.
- The weighted overlay method by ArcGIS, consider to be an effective tool in managing, planning a geospatial data, spatially in site suitability studies, the GIS have been used to input, store, organize and analyze the available data.
- A methodological approach in conducting a research using GIS was presented selecting location of groundwater wells sites as a case study, where the spatial analysis, visualization and query capabilities of GIS employed in selecting the groundwater well sites for a precondition set of criteria. Attribute table for all the pixels in the suitability map of ArcGIS could be exported; hence, all the pixels characteristics could be used as an Input layer, an accurate result could be obtained for the entire map.

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