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Utilizing GIS for Estimation Bearing Capacity of Shallow Foundation in Baquba City, Iraq

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Abstract: This paper aims to estimate the allowable bearing capacity of shallow foundations in Baqubah City, Diyala Governorate, Iraq, using Geographic Information System (ArcGIS Pro) together with Terzaghi's bearing-capacity equation. Three common foundation types were considered in the analysis, such as square foundations (1.5 × 1.5 m), strip foundations (1 × 1 m), and rectangular foundations (2 × 4 m), and the calculations were conducted at different foundation depths across the study area. The analysis was based on geotechnical information obtained from 76 boreholes distributed in different locations within Baqubah City. Soil parameters available in the investigation reports were used to calculate the allowable bearing capacity values. In some boreholes where the undrained shear strength (Cu) was not directly available in the reports, the values were estimated from Standard Penetration Test (SPT) results using empirical correlations commonly reported in geotechnical literature. The calculated results were then integrated with GIS techniques to produce spatial maps showing the differences in allowable bearing capacity in the study area. The Inverse Distance Weighting (IDW) interpolation method was used to produce these maps based on the available borehole data. This method was chosen because it is simple and works well when the number of available data points is limited. The maps prepared in this paper show that the soil bearing capacity is not the same across Baqubah city and that the allowable bearing capacity changes from one place to another depending on soil conditions and foundation depth. The results showed that the allowable bearing capacity ranges from (3.1 to 22.9) t/m² with higher values showed in northern parts due to stronger soil conditions. These results provide useful preliminary information for engineers when selecting suitable foundation types during the early stage of foundation design. Still, detailed geotechnical investigations are required for final design before construction.

Keywords: GIS; Shallow foundation; Terzaghi equation; Diyala Governorate; Soil bearing capacity

1. Introduction

Soil bearing capacity is an important factor in geotechnical engineering because it shows how much load the soil can safely support. Engineers usually estimate this value before designing shallow foundations such as strip, square, or rectangular footings. If the soil strength is not evaluated properly, problems such as settlement or shear failure may occur, which may affect the stability of structures.

Geographic Information System (GIS) has recently been used in many engineering studies to help analyze spatial data and present soil information in map form. Using GIS makes it easier to see how soil conditions change from one location to another. It also helps engineers study large areas and understand the general behavior of soils in different parts of a city. The geology of Baqubah City is mostly composed of alluvium, including clay, silt, and sand, which significantly influence the engineering behavior of soils and their bearing capacity. These soil formations play a improve role in evaluating the suitability of shallow foundation systems in the study area.

Different locations and distributions of soils can be found in nature. The type of soil depends on the type of rock, the minerals that comprise the rock, and the climate in the area. The surface of the earth is employed as a building material or for civil engineering projects. .

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The stability of civil engineering construction is affected by the soil's geotechnical features. Most of the soil's geotechnical properties interact with one another, [1]. Finding out the geotechnical properties of the soil under a building is the main objective of subsurface investigation on construction sites. Using geographical information systems, Muhammad and Al-Bayati created a digital geotechnical map of Salah al-Din Governorate in 2020. Since 24 locations with three boreholes each down to a depth of up to 10 meters were evaluated, these maps encompass a variety of geotechnical properties, [2]. The SPT-N is sometimes the only on-site test available and is the most commonly utilized and feasible technique to evaluate soil strength in many parts of the world, [3]. In Malaysia, maps presenting soil type and strength (SPT-N values) at various depths were explored, along with GIS data processing, [4].

From basic data warehousing to intricate spatial analysis and graphical presentation, GIS is a geotechnical engineering technology that can do it all. It is a relatively recent approach for using GIS to automate research and repetitive operations. Open GIS Opportunities for displaying data, analysis, and development of project engineer abilities, [5]. Several governorates in Iraq and other nations have made use of this type of technology. It has been established to have easy and efficient access to soil bearing capacity and geotechnical appropriate ties. Numerous kinds of study have been performed in the Najaf Governorate; a database of soil bearing capacity was established using a distance reverse weighting (IDW) tool and a geographic information system (GIS 10.2.1), [6]. The soil's horizontal and vertical geotechnical modifications were analyzed using the USCS classification of the holy city of Najaf, Iraq, [7]. To determine geotechnical features and give subterranean parameters and information for foundation design, ground investigation is needed [8]. The angle of internal friction for the city of Kufa and the center of Najaf was investigated by the research, [9], and the probabilistic values were forecast using geographic information systems, which created geotechnical maps. Additionally, digitized geotechnical maps were generated for the geotechnical parameters utilized in the preliminary design, and the types of soil layers in Wasit Governorate were investigated. The most essential characteristics are groundwater levels, uniformity coefficient, compressibility parameters, soil bearing capacity, and shear resistance, [10]. Data from 164 wells that were tabulated in an excel sheet were used to produce digital maps as input data. Maps showing the southern Iraqi city of Basra's geotechnical properties and soil bearing capacity were made using GIS, [11]. Following gathering data and logical inference from various investigations employing 85 test wells, the researcher utilized statistical analysis methods to describe and depict the geotechnical properties of the Sulaymaniyah soil in the Kurdistan region of Iraq and its geographical change, [12]. In the Imam district of the Babel Governorate, Iraq, geotechnical maps of the soil's bearing capacity, soil layer features, and groundwater quality were also created employing the GIS 9.3 software, [13]. Soil bearing capacity is an important factor in the design of shallow foundations because it controls the ability of soil to carry structural loads. Several geotechnical studies discussed methods used to estimate soil bearing capacity based on soil properties and foundation dimensions, [14].

Many classical studies explained the behavior of shallow foundations and methods used to estimate soil bearing capacity under different soil conditions, [15]. Several recent studies have investigated the spatial variation of soil bearing capacity using field tests and GIS techniques. Rahman (2025) prepared thematic maps of allowable bearing capacity for Bogura District in Bangladesh using geotechnical data and GIS analysis. The results showed that the bearing capacity of soil varies significantly across the study area depending on soil type, groundwater conditions, and foundation depth. The study demonstrated that GIS-based mapping is an effective tool for evaluating soil bearing capacity and supporting foundation design [16]. Similarly, Hamdani et al. (2025) developed geotechnical zonation maps of soil bearing capacity using GIS interpolation techniques. Their results indicated that the bearing capacity values change spatially according to soil stratification and geotechnical parameters obtained from field investigations. The study concluded that integrating GIS with geotechnical data can improve the accuracy of estimating soil bearing capacity and provide useful information for engineering planning and construction projects [17]. In addition, Sitharam and Anbazhagan (2021) analyzed the spatial variability of soil bearing capacity using geostatistical methods combined with GIS techniques. The study showed that integrating geotechnical field data with spatial analysis improves the accuracy of estimating soil bearing capacity and helps in producing reliable geotechnical maps for foundation design [18]. However, there are still few studies that focus on mapping the allowable bearing capacity in Baqubah city using GIS together with geotechnical investigation

data. Most previous studies only describe soil properties in general without preparing maps that show how the bearing capacity changes with foundation depth investigated the spatial variation of soil bearing capacity using Standard Penetration Test (SPT) data combined with MATLAB-based analysis. In this study, SPT values were collected from different boreholes and used to estimate soil strength parameters. The researchers calculated the allowable bearing capacity of soil at various depths and locations, and then generated thematic maps to illustrate the variation in bearing capacity across the study area. The results showed that soil bearing capacity is not uniform and varies significantly depending on depth and location, highlighting the importance of spatial analysis in geotechnical investigations [19]. Al-Mamoori et al. (2025) investigated the spatial variation of shallow soil bearing capacity in Al-Najaf City using SPT data and MATLAB analysis. Measurements from 464 boreholes were corrected for overburden pressure and groundwater effects, and the allowable bearing capacities were calculated at different depths. The study produced thematic maps showing significant lateral and vertical variations in soil bearing capacity, highlighting the importance of spatial analysis in geotechnical design [20]. As a result, this study aims to estimate the allowable bearing capacity of shallow foundations in Baqubah City using Terzaghi's equation integrated with GIS techniques to produce spatial maps. This work provides one of the first GIS-based assessments of bearing capacity variation in the study area.

2. Study Area

The study area is located in Diyala Governorate, with Baqubah District serving as the administrative center of the governorate, in eastern Iraq. The Diyala Governorate is situated around 57 kilometers northeast of the capital, Baghdad. Diyala Governorate lies between latitudes 31°45′ N and 33°30′ N and longitudes 44°30′ E and 46°45′ E. It is located next to Salah Al-Din Governorate to the north, Kirkuk Governorate to the northeast, and Wasit Governorate to the south. The study area was selected due to the availability of geotechnical investigation data, such as Standard Penetration Test (SPT) results. These data were were to determine the allowable bearing capacity of shallow foundations. The Fig. 1 shows the location of Diyala Governorate and Fig. 2 shows Baqubah city.



Fig. 1 Location of Diyala Governorate.

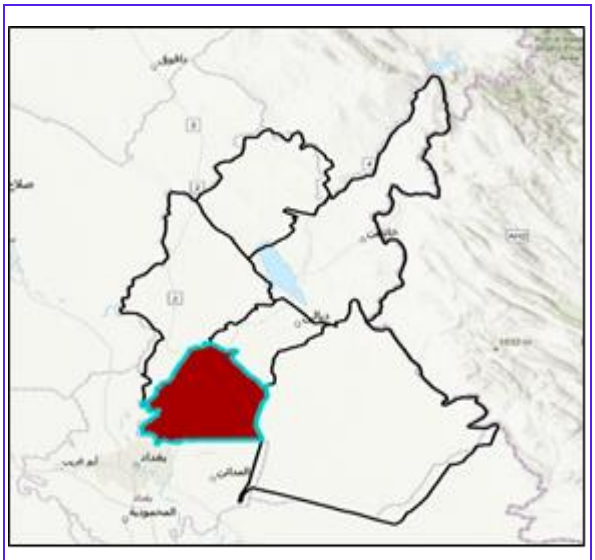


Fig. 2 Baqubah city location within Diyala Governorate.

3. Methodology

3.1 Data Collection

Geotechnical data were obtained from available site investigation reports within the study area. The dataset included information from 76 boreholes distributed in different locations across Baqubah City. The data included Standard Penetration Test (SPT) results from many boreholes, soil classification, unit weight of soil, and

excavation depths. Moreover, the undrained shear strength (Cu) for cohesive soils was obtained either from laboratory test results or estimated using empirical correlations with SPT values. These parameters were used to estimate the allowable bearing capacity using Terzaghi's equation, as Cu is an important factor in shallow foundation design for cohesive soils. After organizing the data, the borehole locations and soil parameters were entered into the GIS environment to allow spatial analysis and map preparation. The research utilized data extracted from soil investigation reports containing the results of Standard Penetration Tests (SPT) and laboratory tests from local soil laboratories in Diyala Governorate.

3.2 Calculation of Bearing Capacity

Terzaghi's bearing capacity equation was used in this paper to estimate the allowable bearing capacity of the soil. Terzaghi's equation was selected due to its simplicity and wide application in shallow foundation design, especially under relatively homogeneous soil conditions. It is commonly used for preliminary estimation of bearing capacity. Other methods, like Meyerhof, Hansen, or Vesic, can give more detailed results, but Terzaghi's equation is accurate for initial evaluation. The available data (SPT values, Cu, and unit weight) fit well with this method, making it practical. Three foundation types were considered a square footing (1.5 × 1.5 m), a strip footing (1 × 1 m), and a rectangular footing (2 × 4 m). Calculations were performed for excavation depths of 1 m and 2 m only. The ultimate bearing capacity ($q_u$lt) was first determined for each case and then divided by an adequate factor of safety to obtain the allowable bearing capacity ($q_a$ll).

Bearing Capacity for Strip Footing: $qu = c\,Nc + q\,Nq + 0.5\,\gamma\,B\,N\gamma$ .....(1)

Bearing Capacity for Square Footing: $qu = 1.3\,c\,Nc + q\,Nq + 0.4\,\gamma\,B\,N\gamma$ .....(2)

Bearing Capacity for Rectangular Footing:

$$qu = c\,Nc\,(1 + 0.3\frac{B}{L}) + q\,Nq + 0.5\,\gamma\,B\,N\gamma\,(1 - 0.2\,\frac{B}{L}) \quad \text{.....(3)}$$

Factor of Safety (Fs) =3

Allowable Bearing Capacity: $qall = \frac{qu}{F.S}$ ……(4)

Where: q_{ult} is the ultimate bearing capacity (t/m^2)

C is the cohesion of soil (t/m^2)

B is the width of foundation (m)

$$q = \gamma\,Df \quad \text{……(5)}$$

The γ is the effect unit weight of soil (kN/m^3) and Df is the depth of foundation (m)

The bearing capacity factors (Nc, Nq, and Nγ) were determined according to the soil friction angle using Terzaghi's bearing capacity charts and common geotechnical references, for example, Bowles (1996). These bearing capacity factors depend mainly on the internal friction angle.

The unit weight of the soil was taken from the available borehole investigation reports. When same of the undrained shear strength (Cu) was not directly reported, it was estimated from the Standard Penetration Test (SPT_N70) results using empirical correlations proposed. The shear strength of the clay soil, cu. Shear resistance is extracted by bearing capacity since it is equal to the bearing's capacity divided by two by Bowles (1996) as shown in Table 1.

Table 1.Estimated Undrained Cohesion (Cu) from Standard Penetration Test (SPT), [14].

Consistency	Description	N_{70}	$q_{(u)}$ kPa	Remakes
Vary soft	NC-Young clay	0-2	<25	Squishes between fingers when squeezed
Soft	NC-Young clay	3-5	25-50	Very easily deformed by squeezing
Medium	NC-Young clay	6-9	50-100	-
Stiff	Increasing OCR-Aged cemented	10-16	100-200	Hard to deform by hard squeezing
Very stiff	Increasing OCR-Aged cemented	17-30	200-400	Very hard to deform by hand squeezing
Hard	Increasing OCR-Aged cemented	>30	>400	Nearly impossible to deform by hand

3.4 Software Used

ArcGIS Pro software was used to prepare spatial distribution maps of the allowable bearing capacity at excavation depths of 1 m and 2 m. The calculated values at borehole locations were integrated into the GIS environment to generate continuous maps that used the variation of bearing capacity across the study area. These maps support preliminary foundation design and site selection.

3.5 Inverse Distance Weighting (IDW)

The Inverse Distance Weighting (IDW) interpolation method was employed to produce bearing capacity maps. This method is based on the assumption that points closer to the prediction location have a greater influence than those farther away. IDW was selected because it is simple to apply, suitable for a limited number of boreholes, and preserves measured values without producing unrealistic estimates. The method has been widely used in geotechnical and spatial analysis studies. The IDW interpolation method was selected because it is simple and suitable for spatial prediction when the number of data points is limited. In addition, it has been widely used in geotechnical mapping studies. The Fig. 3 illustrates the distribution of borehole points in Baqubah City.Kriging was not used or compared because the data points are uneven and concentrated in a specific area, which could affect the results. As a result, used The Inverse Distance Weighting (IDW) interpolation method.

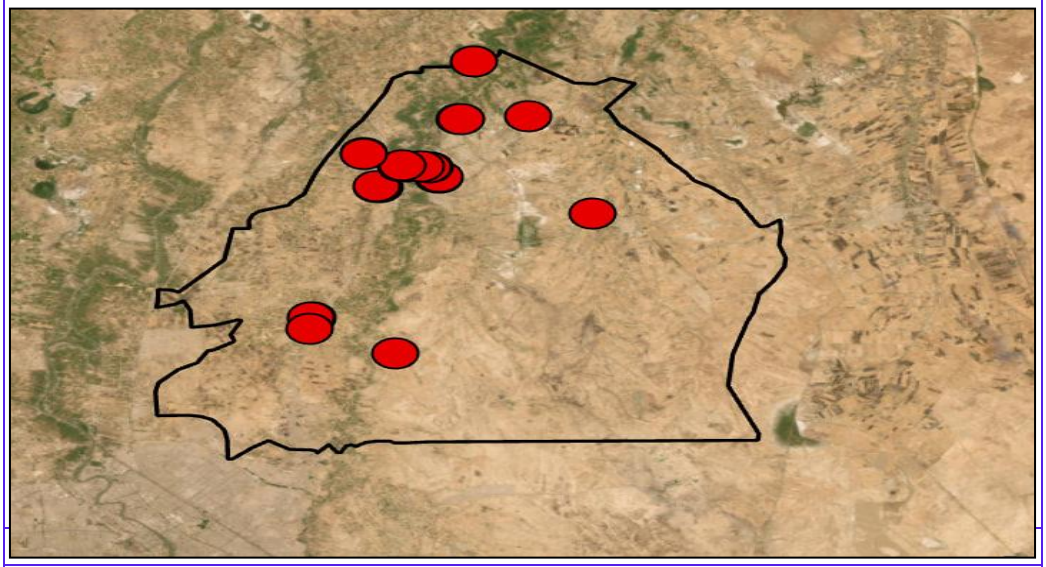


Fig 3. Distribution of borehole points in Baqubah City.

3.6 Validation

The results were validated using a quantitative validation approach. Some borehole location was discarded from the interpolation process and was not entered into the GIS software. The measured values at this location were then compared with the values predicted from the IDW maps. The comparison showed acceptable agreement between the measured and estimated values, showing that the adopted method provides reasonable accuracy for preliminary design purposes. However, the results are intended for initial assessment and do not replace detailed field investigations. In this study, the validation was qualitative rather than quantitative because the aim was to provide a preliminary overview of the variation of allowable bearing capacity across the study area, and not to perform detailed foundation design for specific locations. Validation was mainly qualitative with more data points, higher accuracy could be achieved, and indicators like RMSE could be used for better evaluation in future studies.

3.7 Flowchart

Figure (4) shows the flow chart of steps used for drawing maps of allowable bearing capacity using GIS.

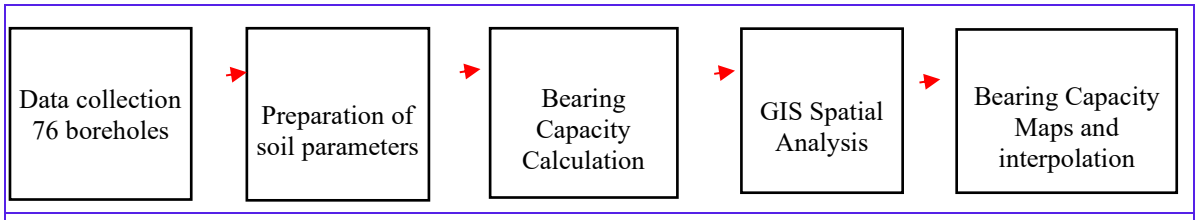


Fig 4. Research workflow for estimating allowable bearing capacity using GIS.

4 Results and Discussion

4.1 Allowable Bearing Capacity

The Fig. 5 illustrates allowable bearing capacity ($q_a$ll) map for strip footing at an excavation depth of 1 m, it shows clear spatial variability, where the values were classified to illustrate the spatial distribution. Low values, represented by light green color, range from (5.1–11) t/m² and are mainly observed in the southern and some northern parts of the study area.

Moderate values, shown in yellow, range between (11.1–3) t/m² and are concentrated in the central regions, whereas high values, represented by orange to red colors, range from (13.1–16.4) t/m², showing better surface soil conditions.

At an excavation depth of 2 m, the Fig. 6 $q_a$ll map for strip footing showing a significant increase in bearing capacity values compared to the 1 m depth. The rang of low-value zones represented by light green (5.1–11) t/m² decreases, while moderate and high classes, shown in yellow and orange (11.1–13) t/m², expand. This improvement is linked to increased effective stress and improvement soil shear strength with depth, leading to higher allowable bearing capacity.

The Fig. 7 allowable bearing capacity ($q_a$ll) map for square footing at an excavation depth of 1m shows clear spatial variability across the study area. Low values, represented by dark green color, range from (3.9–6.5) t/m² and are mainly concentrated in the southern and southeastern parts, showing relatively weaker soil conditions. Moderate values, shown in light green to yellow, range between (6.6–12) t/m² and cover a large portion of the central area. In contrast, high values, represented by orange to red colors, range from (12.1–21.3) t/m² and are predominantly observed in the northern parts and some localized zones, showing improved surface soil property. Fig. 8 shows the allowable bearing capacity (qall) distribution for square footing at a foundation depth of 2 m. Compared with the map at 1 m depth, the values generally increase across the study area. Zones with higher bearing capacity become more visible, especially in the northern parts of Baqubah. This increase is mainly due to the greater depth of the foundation, which leads to higher effective stress and improved soil strength, resulting in higher allowable bearing capacity value.

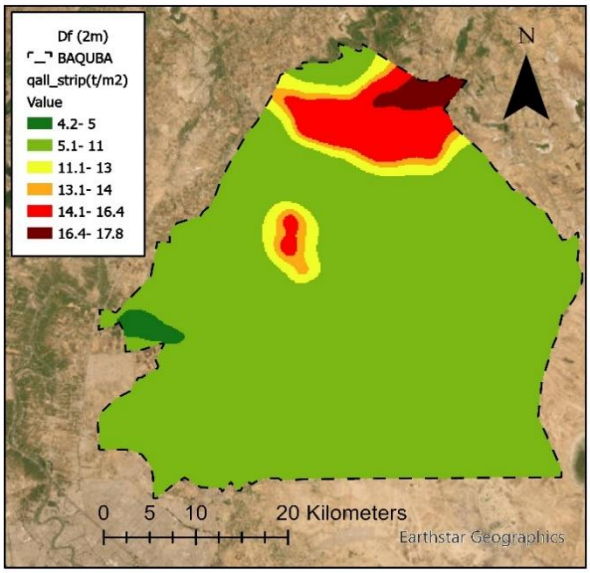


Fig 5. Allowable Bearing Capacity Map for Strip Footing at Foundation Depth of 1m.

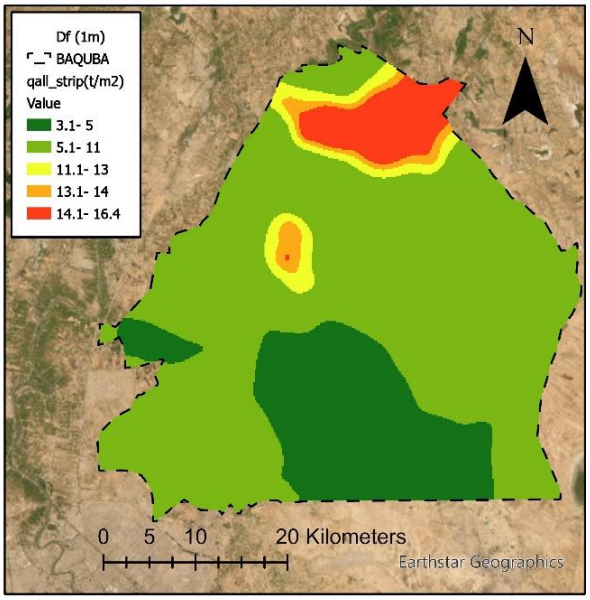


Fig 6. Allowable Bearing Capacity Map for Strip Footing at Foundation Depth of 2m.

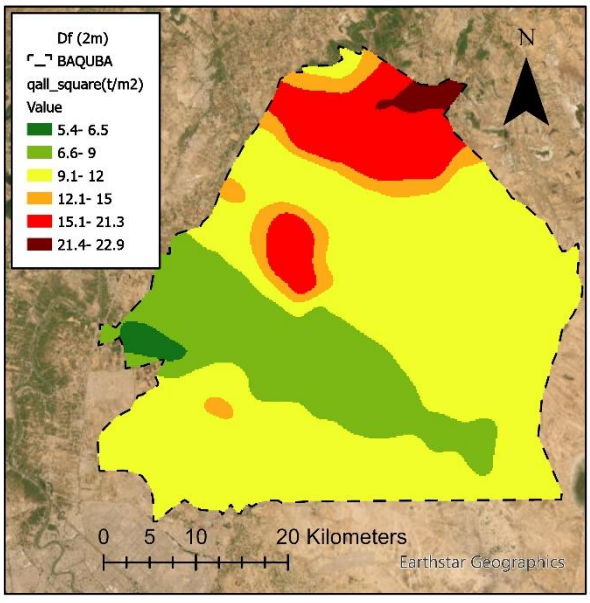


Fig 7. Allowable Bearing Capacity Map for Square Footing at Foundation Depth of 1m.

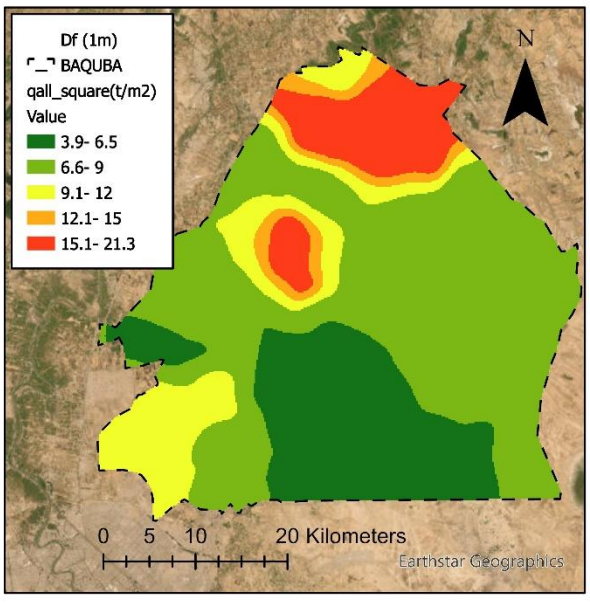


Fig 8. Allowable Bearing Capacity Map for Square Footing at Foundation Depth of 2m

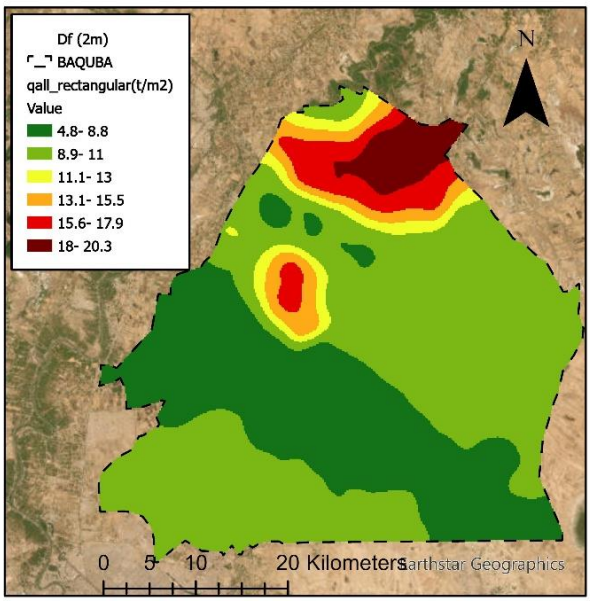


Fig 9. Allowable Bearing Capacity Map for Rectangular Footing at Foundation Depth of 1m.

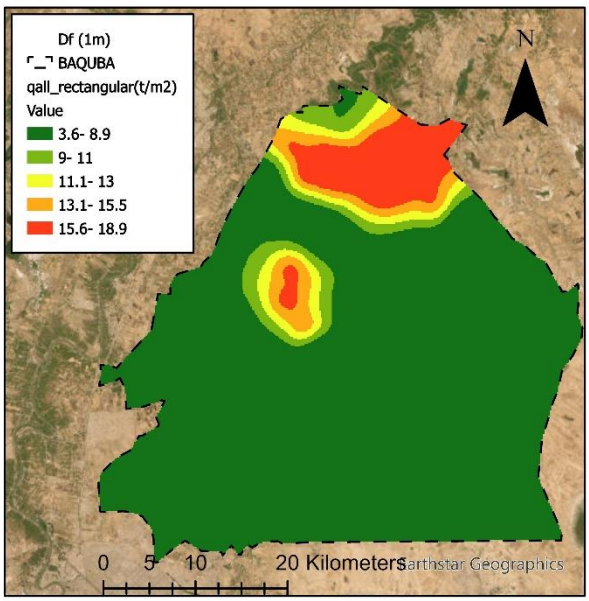


Fig 10. Allowable Bearing Capacity Map for Rectangular Footing at Foundation Depth of 2m.

In the Fig. 9, allowable bearing capacity ($q_a$ll) map for rectangular footing at an excavation depth of 1 m shows clear spatial variability across the study area. Low values, represented by dark green, range from 3.4 to 8.9 t/m² and dominate most parts of the area, particularly the southern and central regions, indicating relatively weak surface soil conditions. Moderate values, shown in light green to yellow, range between 9 and 13 t/m² and appear in scattered zones. In contrast, high values, represented by orange to red, range from 13.1 to 18.9 t/m² and are mainly concentrated in the northern parts, with a localized zone in the central area, reflecting improved soil strength.

At an excavation depth of 2 m, the Fig. 10 illustrates $q_a$ll map for rectangular footing reveals a noticeable increase in bearing capacity values compared to the 1 m depth. The low-value zones (4.8–8.8 t/m²), shown in dark green, while the moderate classes (8.8–13 t/m²), shown in light green and yellow, expand. In the northern parts of the study area, shown in orange to dark red, become more clear high to very high values (15.5–20.3 t/m²). This rise is due to higher effective stress and better geotechnical properties in the deeper soil layers, especially those with greater density and cohesion, which increase the allowable bearing capacity of rectangular footings. The results of soil classification indicate that the predominant soil types in Baqubah are clayey soils, mainly classified as CL (lean clay) and CH (high plasticity clay) according to the Unified Soil Classification System (USCS). This reflects the dominance of cohesive soils in the study area, which significantly influences the geotechnical behavior and bearing capacity characteristics.

The maps showing the allowable bearing capacity (qall) for strip, square, and rectangular footings show that the soil's strength varies across the study area. For the strip footing at a foundation depth of 1 m, the values are about 3.1 to 9 t/m². Lower values appear mainly in the southern parts of the area, while moderate and higher values are more common in the central and northern parts. When the foundation depth of 2 m increases, the allowable bearing capacity becomes higher in many locations. At large depths this increase is likely due to stronger soil layers and higher effective stress. A similar trend can be seen for square and rectangular footings. For the square footing at a depth of 1 m, the values range from 3.9 to 21.3 t/m², which also shows clear variation across the study area. At a depth of 2 meters, higher values are more common, especially in the northern areas of Baqubah. This suggests that the soil conditions in those areas might be better. The rectangular footing also shows an increase in allowable bearing capacity when the depth increases, where moderate and high values become more common compared with the results at 1 m depth. Generally, the results shows that the allowable bearing capacity generally increases with foundation depth. It can also be noticed that square and rectangular footings usually give higher values than strip footings at the same depth. This difference is related to the effect of footing size and shape on the bearing capacity

calculation. The GIS maps help show how soil properties vary across the study area based on the available borehole data. These maps are meant to give a general or preliminary understanding of how the allowable bearing capacity changes within the study area. The allowable bearing capacity (qall) values were obtained from 76 borehole points in the study area. For clarity, only the minimum, maximum, and average values are shown in Table 2 and Table 3 to represent the range of soil conditions for square, strip, and rectangular footings at a foundation depth of 1 and 2 m. The results of this study is agreed with study by [21]. The footing shape also shows to influence the bearing capacity. Square and rectangular footings often give higher values compared to strip footings. This could be related to their larger contact area and better load distribution. The GIS maps organized in this study help show how soil properties change across Baqubah City and can be useful for initial analysis. On the other hand, the results depend on the available borehole data and the interpolation method used.

Table 2. Representative allowable bearing capacity (qall) values for square, strip, and rectangular footings at a foundation depth of 1 m.

Footing Type	Minimum qall (T/m^2)	Maximum qall (T/m^2)	Average qall (T/m^2)
Strip	3.1	16.4	7
Square	3.9	21.3	9
Rectangular	3.4	18.9	8

Table 3. Representative allowable bearing capacity (qall) values for square, strip, and rectangular footings at a foundation depth of 2 m.

Footing Type	Minimum qall (T/m^2)	Maximum qall (T/m^2)	Average qall (T/m^2)
Strip	4.2	17.8	8.1
Square	5.4	22.9	10.4
Rectangular	4.8	20.3	9.3

5. Conclusions

This paper used GIS together with Terzaghi's equation to evaluate the allowable bearing capacity of shallow foundations in Baqubah City. Based on the results, a number of observations can be made.

- The allowable bearing capacity is not uniform over the study area. This variation mainly comes from differences in soil properties between locations. In some zones the values are clearly higher, while in others they are relatively low.
- It can also show that increasing the foundation depth leads to higher bearing capacity values. This is likely, since the effective stress increases with depth and the soil becomes stronger.
- In the definition of footing type, square and rectangular footings usually give higher bearing capacity compared to strip footings. This may be associated with their geometry and the way loads are distributed.
- Another point is that the northern parts of the study area generally show better soil conditions than the southern parts. However, this trend is not exactly the same at all locations.
- The GIS maps were helpful in showing the spatial variation of soil properties. They give a general idea about the soil behavior and can support preliminary design in the early stages.
- On the other hand, some limitations should be stated. Cu values were estimated using empirical correlations, and no advanced statistical validation methods were applied.
- Because of these limitations, the results should be treated with caution. They are relevant for preliminary assessment but not sufficient for final design without detailed site investigation.
- In future work, it would be better to use more advanced interpolation methods such as Kriging and also include statistical validation methods to improve the validity of the results.

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References

[1] Mahmoud, M.I., Dessouky, M.I., Deyab, S. and Elfouly, F.H. (2007), "Comparison between Haar and Daubechies Wavelet Transformions on FPGA Technology", International Journal of Aerospace and Mechanical Engineering, 1(2), 141-145.

[2] Sahib, M., Hasan, M. and Satea, K. (2020), "Geotechnical Maps for Salah Al-Deen-Iraq", IOP Conference Series: Materials Science and Engineering, 737, 012224.

[3] Al-Jabban, W.J.M. (2013), "Estimation of Standard Penetration Test (SPT) of Hilla City Iraq by Using GPS Coordination", Jordan J. Civ. Eng., 7(2), 133–145.

[4] Wan-Mohamad, W.N.S. and Abdul-Ghani, A.N. (2011), "The Use of Geographic Information System (GIS) for Geotechnical Data Processing and Presentation", Procedia Eng., 20, 397–406, https://doi.org/10.1016/j.proeng.2011.11.182.

[5] Hellawell, E.E., Lamont-Black, J., Kemp, A.C. and Hughes, S.J. (2001), "GIS as a Tool in Geotechnical Engineering", Proc. Inst. Civ. Eng. Geotech. Eng., 149(2), 85–93, https://doi.org/10.1680/geng.2001.149.2.85.

[6] Al-Maliki, L.A.J., Al-Mamoori, S.K., El-Tawel, K., Hussain, H.M., Al-Ansari, N. and Jawad Al Ali, M. (2018), "Bearing Capacity Map for An-Najaf and Kufa Cities Using GIS", Engineering, 10(05), 262–269, https://doi.org/10.4236/eng.2018.105018.

[7] Kareem, S., Jasem, A.L.A., Hussain, K.E. and Nadhir, M.H. (2020), "Horizontal and Vertical Geotechnical Variations of Soils According to USCS Classification for the City of An-Najaf, Iraq Using GIS", Geotech. Geol. Eng., 38(2), 1919–1938, https://doi.org/10.1007/s10706-019-01139-x.

[8] Kamal, M.A., Arshad, M.U. and Zaidi, B.A. (2015), "Appraisal of Geotechnical Characteristics of Soil for Different Zones of Faisalabad (Pakistan)", J. Eng. Appl. Sci., 17, 1–10.

[9] Al-Mamoori, S.K., Kareem, S.L., Al-Maliki, L.A. and El-Tawil, K. (2021), "Geotechnical Maps for Angle of Internal Friction of An-Najaf Soil-Iraq Using GIS", Wasit J. Eng. Sci., 8(2), doi: 10.31185/ejuow.vol8.iss2.166.

[10] Aldefae, A.H., Mohammed, J. and Saleem, H.D. (2020), "Digital Maps of Mechanical Geotechnical Parameters Using GIS", Cogent Eng., 7(1), doi: 10.1080/23311916.2020.1779563.

[11] Kadhim, M.M., Al-Saoudi, N.K.S. and Ziboon, A.R.T. (2013), "Digital Geotechnical Maps of Basrah City Using Geographical Information Systems Technique", Eng. Technol. J., 31(4 Part A), 599–617.

[12] Ahmed, C., Mohammed, A. and Tahir, A. (2020), "Geostatistics of Strength, Modeling and GIS Mapping of Soil Properties for Residential Purpose for Sulaimani City Soils, Kurdistan Region, Iraq", Model. Earth Syst. Environ., 6(2), 879–893, https://doi.org/10.1007/s40808-020-00715-y.

[13] Kadhim., N. K. and Al-abody, A.A.M. (2015), "The Geotechnical Maps for Bearing Capacity By Using GIS and Quality of Ground Water for Al-Imam District (Babil–Iraq)", International Journal of Civil Engineering and Technology, 6(10), 176–184.

[14] Bowles, J.E. (1996), Foundation Analysis and Design, McGraw-Hill, New York, NY, USA.

[15] Terzaghi, K. (1943), "Theoretical Soil Mechanics", John Wiley & Sons, New York, USA.

[16] Rahman, M. M. (2025) GIS-based allowable bearing capacity thematic maps of shallow foundation for Bogura District, Bangladesh. International Journal of Engineering and Geosciences, 10(3), 329-338.

[17] Hamdani, D., et al. (2025) Geotechnical zonation maps of soil bearing capacity using GIS interpolation techniques. Engineering, Technology & Applied Science Research.

[18]Sitharam, T. G., and Anbazhagan, P. (2021).Spatial variability of soil bearing capacity using geostatistical and GIS techniques. Arabian Journal of Geosciences, 14(12), 1–12.

[19] Karkush, M. O., et al. (2020), "Thematic Maps for the Variation of Bearing Capacity of Soil Using SPTs and MATLAB", Geosciences, Vol. 10, No. 9, pp. 329.

[20]Mamoori, S. K., Karkush, M., Al-Baghdadi, W., & Al-Rumaithi, A. (2025). *Spatial Variation of Shallow Soil Bearing Capacity Using SPT Data CXand MATLAB Analysis*. Civil Engineering Journal, 11(11), 4745–4761. https://doi.org/10.28991/CEJ-2025-011-11-017.

[21] Fehan, A.J. and Abbas, H.O. (2026), "Mapping of Allowable Bearing Capacity for Square and Strip Footing of Al-KhalisCity", Bilad Alrafidain Journal for Engineering Science and Technology, 5(1). https://doi.org/10.56990/bajest/2026.050103.

Appendix

N.	Site	Df 1m	Spt	C u	Ø	Terzaghi equ. Qall (t/m^2)			Df 2m	Spt	Ø	cu	Terzaghi equ. Qall (t/m^2)			Coordination	
						strip	square	Rect.					Strip	Square	Rect.	East	North
1	Baqubah Al-Jadeda - Taboo Street 1	1m	10	50	0	9.8	12.6	11.5	2m	10	50	0	10.1	12.9	11.2	465259	3733996
2	Baqubah Al-Jadeda - Taboo Street 2	1m	10	50	0	9.8	12.6	11.5	2m	10	50	0	10	12.9	11.2	465262	3733984
3	Baqubah-Alabbara-Al-Ashaari School-1	1m	17	85	0	16.4	21.3	19.2	2m	17	85	0	16.8	21.7	18.9	469722	3740009
4	Baqubah-Alabbara-Al-Ashaari School-2	1m	15	75	0	14.6	18.8	17	2m	15	75	0	14.9	19.2	16.7	469746	3740017
5	Baqubah-Alabbara-Al-Ashaari School-3	1m	16	80	0	15.5	20.1	18.1	2m	16	80	0	15.9	20.4	17.8	469732	3740041
6	Baqubah-Alabbara-Baghdad School-1	1m	16	80	0	15.5	20.1	18.2	2m	16	80	0	15.9	20.4	17.8	475449	3740295
7	Baqubah-Alabbara-Baghdad School-2	1m	16	80	0	15.5	20.1	20.3	2m	18	90	0	17.8	22.9	17.8	475446	3740306
8	Baqubah-Alabbara-Baghdad School-3	1m	14	70	0	13.6	17.6	15.9	2m	14	70	0	13.9	17.9	15.6	475436	3740301

9	Baqubah-Alabbara-Zaganya-Al Tathamen	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.8	470836	3747254
10	Baqubah-Alabbara-Zaganya-Al Tathamen	1m	8	40	0	7.9	10.2	9.3	2m	8	40	0	8.1	10.4	9	470824	3747231
11	Baqubah-Alabbara-Zaganya-Al Tathamen	1m	7	35	0	6.9	8.9	11.5	2m	10	50	0	10	12.9	7.9	470842	3747225
12	Baqubah-Altahreer-syria-1	1m	7	35	0	6.9	8.9	8.2	2m	7	35	0	7.2	9.2	7.9	467962	3732611
13	Baqubah-Altahreer-syria-2	1m	8	40	0	7.9	10.2	10.4	2m	9	45	0	9.1	11.6	9	467918	3732643
14	Baqubah-Altahreer-syria-3	1m	6	30	0	5.9	7.6	9.2	2m	8	40	0	8.1	10.4	6.8	467964	3732651
15	Baqubah-Archaeology Protection Police	1m	5	25	0	5	6.4	8.3	2m	7	35	0	7.3	9.3	5.7	467116	3733912
16	Baqubah-Archaeology Protection Police	1m	3	15	0	3.1	4	6.1	2m	5	25	0	5.4	6.8	3.6	467089	3733913
17	Baqubah-Archaeology Protection Police	1m	4	20	0	4	5.2	7.2	2m	6	30	0	6.4	8.1	4.6	467119	3733906
18	Baqubah-Archaeology Protection Police	1m	5	25	0	5	6.4	9.4	2m	8	40	0	8.3	10.6	5.7	467104	3733894
19	Baqubah-Archaeology Protection Police	1m	4	20	0	4	5.2	7.2	2m	6	30	0	6.4	8.1	4.6	467093	3733885
20	Baqubah-Buhruz District-School Project-1	1m	5	25	0	5	6.4	9.2	2m	8	40	0	8.1	10.4	5.7	464334	3710412
21	Baqubah-Buhruz District-School Project-2	1m	4	20	0	4	5.2	6	2m	5	25	0	5.3	6.7	4.6	464336	3710418
22	Baqubah-Family and Childhood Welfare Police	1m	5	25	0	5	6.4	6.2	2m	5	25	0	5.4	6.9	5.7	466400	3734052
23	Baqubah-Family and Childhood Welfare Police	1m	9	45	0	8.8	11.4	10.5	2m	9	45	0	9.2	11.8	10.1	466406	3734055
24	Baqubah-Family and Childhood Welfare Police	1m	5	25	0	5	6.4	6.1	2m	5	25	0	5.4	6.8	5.7	466405	3734044
25	Baqubah-Family and Childhood Welfare Police	1m	9	45	0	8.8	11.4	11.6	2m 22 m	10	50	0	10.2	13	10.1	466418	3734055
26	Baqubah-Family and Childhood Welfare Police	1m	10	50	0	9.8	12.6	11.6	2m	10	50	0	10.2	13	11.2	466414	3734042
27	Baqubah-Hospital-New Bulding-1	1m	7	35	0	7	9	10.5	2m	9	45	0	9.2	11.8	8	462713	3731455
28	Baqubah-Hospital-New Bulding-2	1m	7	35	0	7	9	10.4	2m	9	45	0	9.1	11.6	8	462917	3731442
29	Baqubah-Hospital-New Bulding-3	1m	16	80	0	15.5	20.1	18.1	2m	16	80	0	15.8	20.4	17.8	462931	3731349
30	Baqubah-Hospital-New Bulding-4	1m	7	35	0	7	9	8.3	2m	7	35	0	7.3	9.3	8	462714	3731376
31	Baqubah-Hospital-New Bulding-5	1m	5	25	0	5.1	6.5	6	2m	5	25	0	5.3	6.8	5.8	462693	3731461

32	Baqubah-Kanaan-Al-Zobaydat School-1	1m	6	30	0	6	7.7	10.3	2m	9	45	0	9	11.6	6.8	480761	3728021
33	Baqubah-Kanaan-Al-Zobaydat School-2	1m	6	30	0	6	7.7	9.2	2m	8	40	0	8.1	10.4	6.8	480773	3728018
34	Baqubah-Kanaan-Al-Zobaydat School-3	1m	5	25	0	5	6.4	9.3	2m	8	40	0	8.2	10.4	5.7	480771	3728028
35	Baqubah-Khan Bani Saad-Police Station-1	1m	7	35	0	6.9	8.9	9.4	2m	8	40	0	8.3	10.6	7.9	457165	3713535
36	Baqubah-Khan Bani Saad-Police Station-2	1m	8	40	0	7.9	10.2	10.5	2m	9	45	0	9.2	11.8	9	457163	3713522
37	Baqubah-Khan Bani Saad-Police Station-3	1m	8	40	0	7.9	10.2	9.4	2m	8	40	0	8.3	10.6	9	457158	3713514
38	Baqubah-Khan Bani Saad-Police Station-4	1m	8	40	0	7.9	10.2	11.6	2m	10	50	0	10.2	13	9	457182	3713508
39	Baqubah-Khan Bani Saad-Police Station-5	1m	7	35	0	6.9	8.9	8.3	2m	7	35	0	7.3	9.3	7.9	457185	3713525
40	Baqubah-Khan Bani Saad-Water Project-1	1m	9	45	0	8.9	11.4	10.3	2m	9	45	0	9	11.6	10.2	457299	3714837
41	Baqubah-Khan Bani Saad-Water Project-10	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.8	457251	3714912
42	Baqubah-Khan Bani Saad-Water Project-11	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.9	457256	3714915
43	Baqubah-Khan Bani Saad-Water Project-12	1m	8	40	0	7.9	10.2	11.4	2m	10	50	0	10	12.8	9	457258	3714922
44	Baqubah-Khan Bani Saad-Water Project-13	1m	5	25	0	5	6.4	5.9	2m	5	25	0	5.2	6.6	5.7	457219	3714915
45	Baqubah-Khan Bani Saad-Water Project-14	1m	4	20	0	4.1	5.2	4.8	2m	4	20	0	4.2	5.4	4.6	457213	3714926
46	Baqubah-Khan Bani Saad-Water Project-15	1m	3	15	0	3.2	4	6	2m	5	25	0	5.3	6.7	3.6	457217	3714934
47	Baqubah-Khan Bani Saad-Water Project-16	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.9	457223	3714939
48	Baqubah-Khan Bani Saad-Water Project-17	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.9	457234	3714936
49	Baqubah-Khan Bani Saad-Water Project-18	1m	9	45	0	8.8	11.4	4.8	2m	4	20	0	4.2	5.4	10.1	457297	3714884
50	Baqubah-Khan Bani Saad-Water Project-19	1m	5	25	0	5	6.4	5.9	2m	5	25	0	5.2	6.6	5.7	457336	3714874
51	Baqubah-Khan Bani Saad-Water Project-20	1m	9	45	0	8.8	11.4	11.5	2m	10	50	0	10.1	12.9	10.1	457299	3714843
52	Baqubah-Khan Bani Saad-Water Project-20	1m	6	30	0	5.9	7.6	8.1	2m	7	35	0	7.1	9.1	6.8	457322	3714833
53	Baqubah-Khan Bani Saad-Water Project-21	1m	4	20	0	4.1	5.2	5.9	2m	5	25	0	5.2	6.6	4.7	457320	3714825
54	Baqubah-Khan Bani Saad-Water Project-22	1m	4	20	0	4.1	5.2	4.8	2m	4	20	0	4.2	5.4	4.7	457331	3714845

55	Baqubah-Khan Bani Saad-Water Project-23	1m	4	20	0	4	5.2	4.8	2m	4	20	0	4.2	5.4	4.6	457292	3714860
56	Baqubah-Khan Bani Saad-Water Project-24	1m	5	25	0	5.1	6.5	7.1	2m	6	30	0	6.2	8	5.8	457244	3714876
57	Baqubah-Khan Bani Saad-Water Project-3	1m	7	35	0	7	9	8.1	2m	7	35	0	7.1	9.1	8	457244	3714839
58	Baqubah-Khan Bani Saad-Water Project-4	1m	5	25	0	5.1	6.5	5.9	2m	5	25	0	5.2	6.6	5.8	457240	3714848
59	Baqubah-Khan Bani Saad-Water Project-5	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.8	457235	3714842
60	Baqubah-Khan Bani Saad-Water Project-6	1m	5	25	0	5	6.4	7	2m	6	30	0	6.1	7.8	5.7	457232	3714852
61	Baqubah-Khan Bani Saad-Water Project-7	1m	5	25	0	5.1	6.5	5.9	2m	5	25	0	5.2	6.6	5.8	457226	3714851
62	Baqubah-Khan Bani Saad-Water Project-8	1m	6	30	0	6	7.7	7	2m	6	30	0	6.2	7.9	6.9	457268	3714868
63	Baqubah-Khan Bani Saad-Water Project-9	1m	3	15	0	3.1	3.9	5.9	2m	5	25	0	5.2	6.6	3.5	457252	3714904
64	Baqubah-New Baqubah-Health center-1	1m	4	20	0	4	5.2	7.1	2m	6	30	0	6.2	7.9	4.6	464751	3734014
65	Baqubah-New Baqubah-Health center-2	1m	5	25	0	5	6.4	8.2	2m	7	35	0	7.2	9.2	5.7	464765	3734010
66	Baqubah-Teaching Hospital-1	1m	5	25	0	5	6.4	9.2	2m	8	40	0	8	10.3	5.7	464857	3734140
67	Baqubah-Teaching Hospital-2	1m	3	15	0	3.1	4	5.9	2m	5	25	0	5.2	6.6	3.6	464851	3734145
68	Baqubah-the industry assembler-AL-	1m	6	30	0	6	7.7	10.4	2m	9	45	0	9.1	11.7	6.8	461617	3735675
69	Baqubah-the industry assembler-AL-	1m	6	30	0	5.9	7.6	12.6	2m	11	55	0	11	14.1	6.8	461667	3735625
70	Baqubah-the industry assembler-AL-	1m	5	25	0	5	6.4	5.9	2m	5	25	0	5.2	6.6	5.7	461697	3735625
71	Baqubah District – Khan Bani Saad Police Directorate	1m	8	40	0	7.9	10.2	9.5	2m	8	40	0	8.4	10.6	9	457174.8	3713526
72	Baqubah District – Khan Bani Saad Police Directorate	1m	6	30	0	6	7.7	9.3	2m	8	40	0	8.2	10.5	6.8	457177.3	3713515
73	Baqubah District – Khan Bani Saad Police Directorate	1m	9	45	0	8.8	11.4	11.5	2m	10	50	0	10	12.9	10.1	457164.7	3713515
74	Baqubah District – Khan Bani Saad Hospital 1	1m	13	65	0	12.6	16.4	14.8	2m	13	65	0	13	16.7	14.5	492893.9	3758125
75	Baqubah District – Khan Bani Saad Hospital 2	1m	12	60	0	11.7	15.1	13.7	2m	12	60	0	12	15.4	13.4	492917.5	3758099
76	Baqubah District – Khan Bani Saad Hospital 3	1m	13	65	0	12.6	16.4	14.8	2m	13	65	0	13	16.7	14.5	492927	3758076