Gypsum Content Horizontal and Vertical Distribution of An-Najaf and Al-Kufa Cities' Soil by Using GIS

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Abstract **An-Najaf province considered one of the most important cities in Iraq, which is facing a rapid population growth and continuous development in constructions such as housing, hotels, bridges and shopping malls. Therefore, this study aims to create database for the gypsum content in An-Najaf province (Najaf center and Al-Kufa city). To evaluate the spatial variability of gypsum content, 464 boreholes and in situ tests were selected and analyzed using Geographic Information System (GIS). To achieve that, the adopted method consisted of four steps: (1) data collection; (2) geotechnical data georeferencing; (3) interpolation methods and (4) establishment of maps. Nine geotechnical maps were produced for depths (0, 2, 4, 6, 8, 10, 12, 14, 16, and 35) m. Results showed that the largest part of the study area for the depths from 0-4 m had a gypsum content ranged between 10-25% (moderately gypsiferous), whereas the depths from 4-8 m had a gypsum content ranged between 3-10% (slightly gypsiferous), and the depths from 8-35 m had a gypsum content ranged between 0.3-3% (very slightly gypsiferous). This conclude that the layers from 0-4 m are exceeding the allowed limits (10% gypsum content), which may affect the stability of constructions due to the high levels of groundwater in Najaf province.**

***Keywords*—Geotechnical mapping; Geographic Information System (GIS); gypsum content, vertical and horizontal distribution; An-Najaf province**

I. Introduction

An-Najaf province is located at the southwest of Iraq, is one of the most important cities in Iraq due to tourism. The city is facing continues development in construction field such as hotels, bridges and shopping malls. The construction of such projects required the establishment of stable foundation. In this regards, soil characteristics play an important role in constructions. There are several chemical and physical soil properties; the soil gypsum content thus can be one of the most important chemical properties, as it directly affects constructions stability especially when groundwater level is high. This effect appears when gypsum dissolved in water leaving cavities, which lead to differential settlement that cause cracks and collapses of structures.

Gypsum soils are known as soils that have a gypsum content over 2%. Gypsum soil affect the engineering structures because it containing soluble materials. It is considered the worst and most dangerous among engineering soils if not protected from water. Gypsum soils are found in dry and semi-dry areas especially when rainfall is insufficient to remove gypsum from the soil section [1].

Gypsum is a white or transparent metal with a specific gravity 2.32. And hardness 2 according Mohr scale of hardness [2]. In Iraq, gypsum soils covers 125027 m2 which represent 28.6% of the area of Iraq and 6.7% of gypsum land in the world [3]. Geographic information systems (GIS) is considered a very powerful tool to establish the database of soil characteristics. In general, GIS can be defined as an applied pattern to computer technology, which enables us to store and process the data from several sources, whether that data is the quality or quantity, as well as a final result can be gained in form of maps, graphics, tables, models or scientific reports. Geographical database is characterized by enabling users to connect the descriptive components and where they are on the map.

Researchers have directed to adopt geographical information system (GIS) in various engineering fields for facilities it provides, many studies have been implemented to analyze the geotechnical properties of the soil around the globe. for example southern parts of the Indian Ginaa Province [4], another study in Riyadh, Saudi Arabia [5] as well as in Portuguese city of Covilha[6]. In addition to other cities such as the Palestinian city of Nablus[7], Tunis city, Tunisia [8], Algerian city of Sajda, [9], The Brazilian city of Sao Paulo[10]and Indian city Bangalore [11]. In Iraq there are similar studies such as in Baghdad / Rusafa [12] and Hilla/Babylon [13].

Any engineering project needs an extensive investigations of the site soil gypsum content to decide whether the soil suitable to the project or not. These investigations are requiring boreholes in order to conduct chemical and physical tests for different depths. The processes of "digging wells and collecting tests data" are expensive and time consuming. To save money and time, it is useful to create a database about the soil properties. The database is a compilation of large amount of information or data and display them in one way or more to facilitates its use. Hence, it is important to make extensive investigations for the site soil for any construction project.

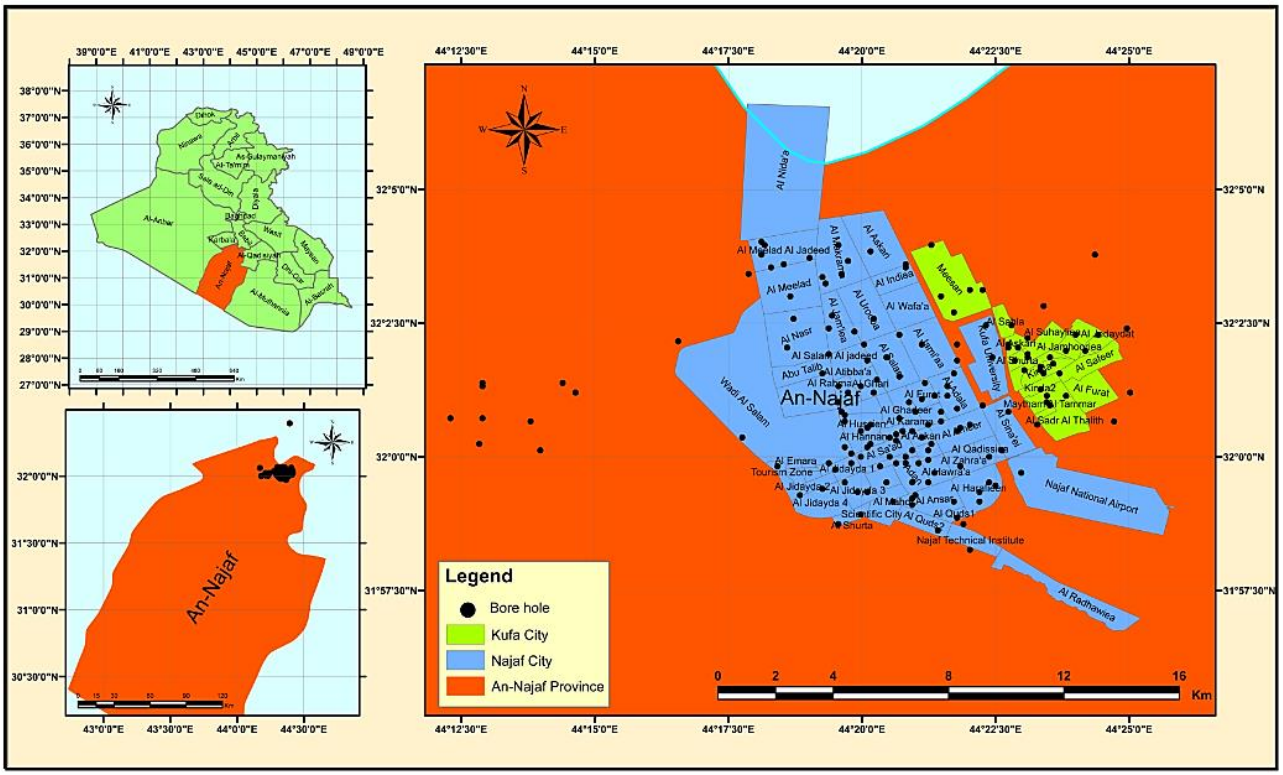


Fig. 1 Location of An-Najaf City

This study aims to collect and analyze tests data then produce geotechnical maps to help presenting information for the horizontal and vertical soil gypsum content in An-Najaf province. To establish geotechnical maps, the interpolations approach are applied by means of IDW, one of the analysis tools in ArcGIS (10.2.1). The established maps of gypsum content help engineers and decision makers to secure urban extension.

This study included collecting, classification and analysis of the information for (464) boreholes in the study area and for depths (0, 2, 4, 6,8,10,12,14,16 and 35) meters. The data that used in this research were taken from the National Center for Construction Laboratories & Researches (NCCLR)/Babylon laboratory reports [14]. Nine Geotechnical maps were produced which could facilitate the soil primary investigation in the future construction works.

II. METHODOLOGY

A. Description of the Study Area

An-Najaf governorate is located at the southwest of Iraq away from the capital Baghdad of about 161 km southwest as shown in figure (1). It has an area of 29000 Km2 and constitutes approximately 7% of Iraq's total area [15]. It is located at the intersection of longitude (436820) eastern and latitude (3540785) northern.

Its geographical area extends between longitudes (433326and 445298) Eastwards and (3527968 and 3550990) latitudes Northwards by degrees system.

The province comprising three districts: Najaf Center district (holly Najaf city, Kufa district and Al- Manathira district). This study cover parts of Najaf and Kufa districts as shown in figure (1).

III. The Gypsum Content Of Soil In Iraq

According to (Buringh), the gypsum is divided into two categories: primary and secondary. The primary gypsum is consist of the original rocks that formed in the old geological ages, while the secondary gypsum is found in soil and formed by the weathering, melting and evaporation factors [16].

According to (Buringh) sites of gypsum soils in Iraq have been identified in figure (2). [14]. Iraqi soils Include different types of salts such as sulfate, carbonate and chlorides. Gypsum is the most prevalent type of salts in the Iraqi soils ranging from (0 - 80) % [17].

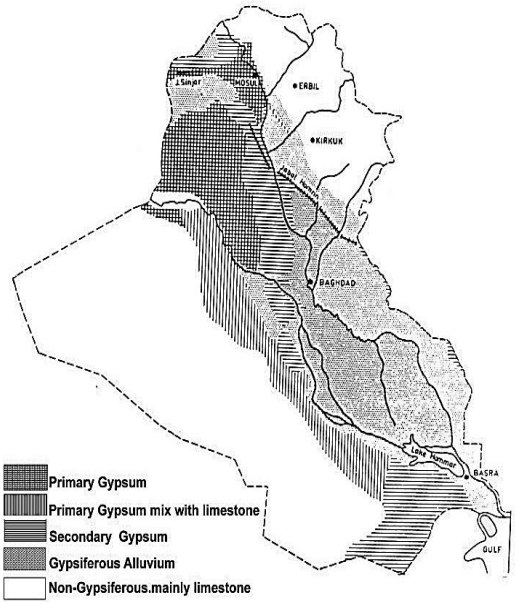


Fig. 2 first map of gypsum distribution in Iraq by Buringh 1960

Studies dealing with gypsum soils use the terms (Gypsiferous soils) and (Gypsies soils) to express soils

contain certain amount of gypsum. Barazanji, A. F (1973) suggested to use the first term (Gypsiferous soils) to identify soils with less than 50% gypsum content. While the second term (Gypsies soils) is used to soils with more than 50% gypsum content and he suggest a classification to the first group according to its gypsum content as shown in table (1) [18].

TABLE (1): CLASSIFICATION OF GYPSUM SOILS ACCORDING TO (BURINGH, 1973).

Gypsum content%	Classification
0-0.3	Non-gypsiferous
0.3-3	Very slightly gypsiferous
3-10	Slightly gypsiferous
10-25	Moderately gypsiferous
25-50	Highly

The following figure shows the soils of Iraq according to this classification.

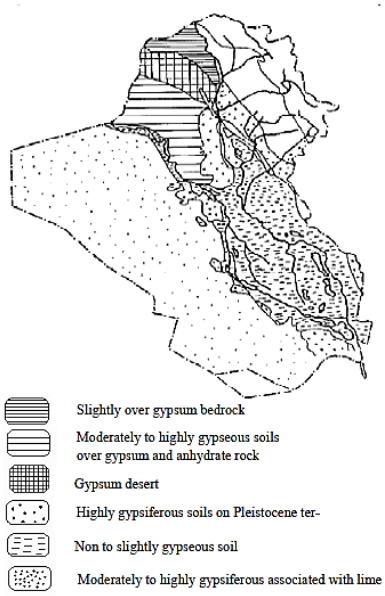


Fig. 3 Classification of Iraqi soils according to Barazanji 1973

Harmful effect of gypsum depends on soil gypsum content, its vertical and horizontal distribution, presence of fresh water resources, and the soil permeability to allow water movement in soil [18]. Engineering risks appears when salt groundwater rise up through solid soil by Capillary action and through tectonic cracks up to the ground surface or for a distance close to the foundations. Water rising lead gypsum salts to deposit at the surface and crystallized there and this process makes soil surface to swell because of crystallization pressure. For example, the swelling reach 103% when calcite transform into gypsum by chemical changes and that had a destructive effect on engineering constructions [19].

Another problem appears when gypsum contact directly with concrete, calcium oxide(CaO) interact with the dissolved sulfate in pores water and Aluminate (Aluminum oxide) in concrete. This interaction create high-stretch compound of calcium sulfate alumina called (Ettringite) which leads to deterioration of construction foundations because of Volumetric expansion that reach 277% Generating high stresses in in hardened concrete leading to fragmentation damage [20]. According to the British Standards (BS 1377-3:1990) the gypsum content in soil must be less than 2.5% [21].

Iraqi Standards for Roads and Bridges 1983 and its amendments, identified the allowed gypsum limit for fill work by 10% maximum, and 10.75 maximum for sub-base used in road construction. Studies showed that increasing of gypsum content make the soil instable and soils with 10-35% gypsum content are unsuitable for incise irrigation canals [22].

IV. Data collection and methods

The data that used in this research was taken from the National Center for Construction Laboratories & Researches (NCCLR)/Babylon laboratory reports. The chemical properties of the soil that covered by this data for this research are: Sulphate content in the soil, Gypsum Content (CaSO4), Chlorides content and Calcium sulphate content. Babylon laboratory represents a branch of the National Center for Construction Laboratories& Research (NCCLR) which subject to the Ministry of Construction and Housing authority. The laboratory conducting geotechnical tests for the Middle Euphrates region in addition to the testing of construction materials since its founding in 1977.Threrfore; information about the province of AL-Najaf and all areas are available and extensively.

After completion all tests soil finally described in the light of the results. Then bind the layers to find bearing capacity of soil as well as mentioning the groundwater level in the paragraphs of the report where it is Measured in situ after the completion of drilling, as well as directly after a period 24 hours. Then the coordinates of the studied sites have been obtained by GPS.

The data were taking from(464) boreholes distributed in AL-Najaf and AL-Kufa cities and for depths (0.5, 2,4,6,8,10,12,14,16 and 35 meters). Locations of boreholes are shown in figure (1).

Nine geotechnical maps were prepared for different depths.

V. RESULTS AND DISCUSSION

The research maps show the follow:

Depths (0-2) meters: the gypsum content is above 10% for almost all the study area accept for the western part that has a gypsum content less than 10% (Map1).

Depths (2-4) meters: the dominate gypsum content is of class (slightly gypsiferous), but large areas (about 35% of the total study area have agypsum content of class (Moderately gypsiferous), which is dangerous on constructions (Map 2).

Depths (4-6): we notice the gypsum of class moderately gypsiferous has receded in many areas (Map 3).

Depths (6-8) meters: very slightly gypsiferous accompanying with slightly gypsiferous layers have appeared in many places (Map 4).

Depths (8-10) meters: very slightly gypsiferous layers in appeared in large areas with few areas of slightly gypsiferous layers (Map 5).

Depths (10-12) meters: very slightly gypsiferous layers in appeared in large areas with few areas of slightly gypsiferous layers and some moderately gypsiferous layers as in (alnasser, qudus1 and qudus 2) neighborhoods (Map 6).

Depths (12-14) meters: The gypsum content in the study area ranged from very slightly gypsiferous to non-

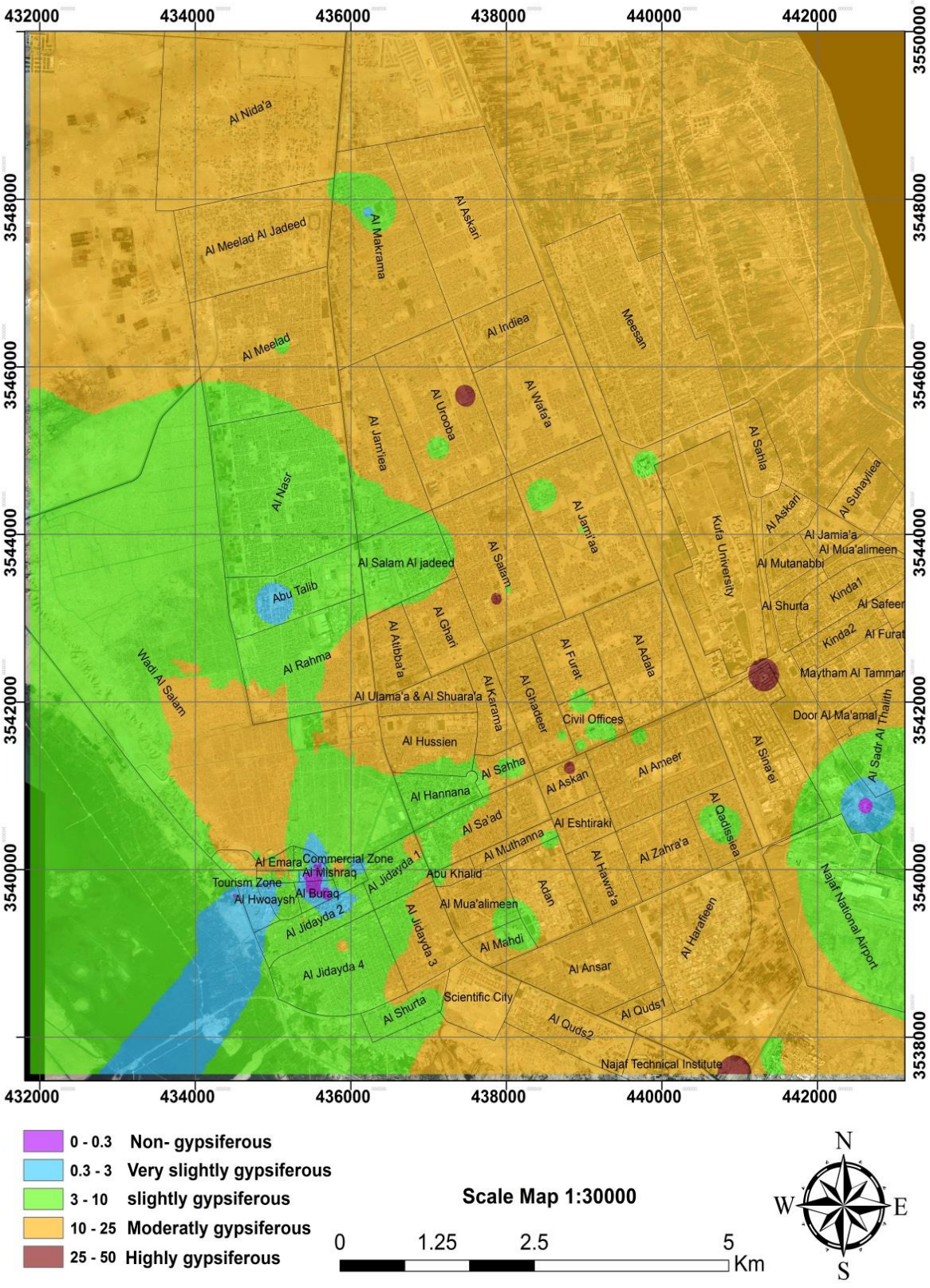
gypsiferous. This content is not dangerous to constructions (Map 7).

Depths (14-16) meters have gypsum content under 10% with few places more than 10%. It is not dangerous (Map 8).

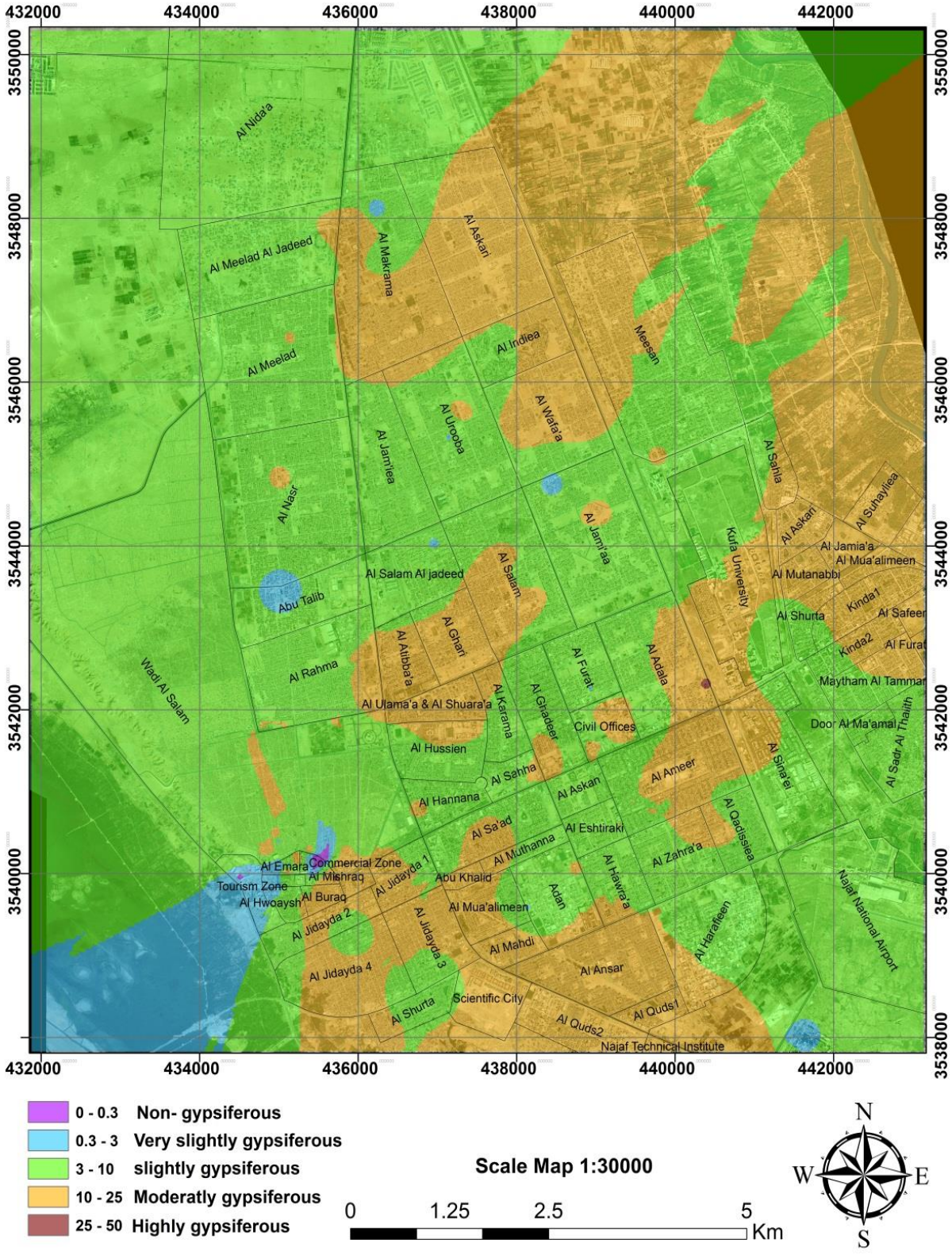
A dangerous Separate layers appeared in (Al-Zahra'a Al-Qadissiea and Al-Harafieen) neighborhoods from depth 16 to 35 meters which values range moderately gypsiferous (Map 9).

Iraqi Standards for Roads and Bridges 1983 identified the maximum gypsum content in soil by 10%. Any value above this limit is dangerous for any construction.

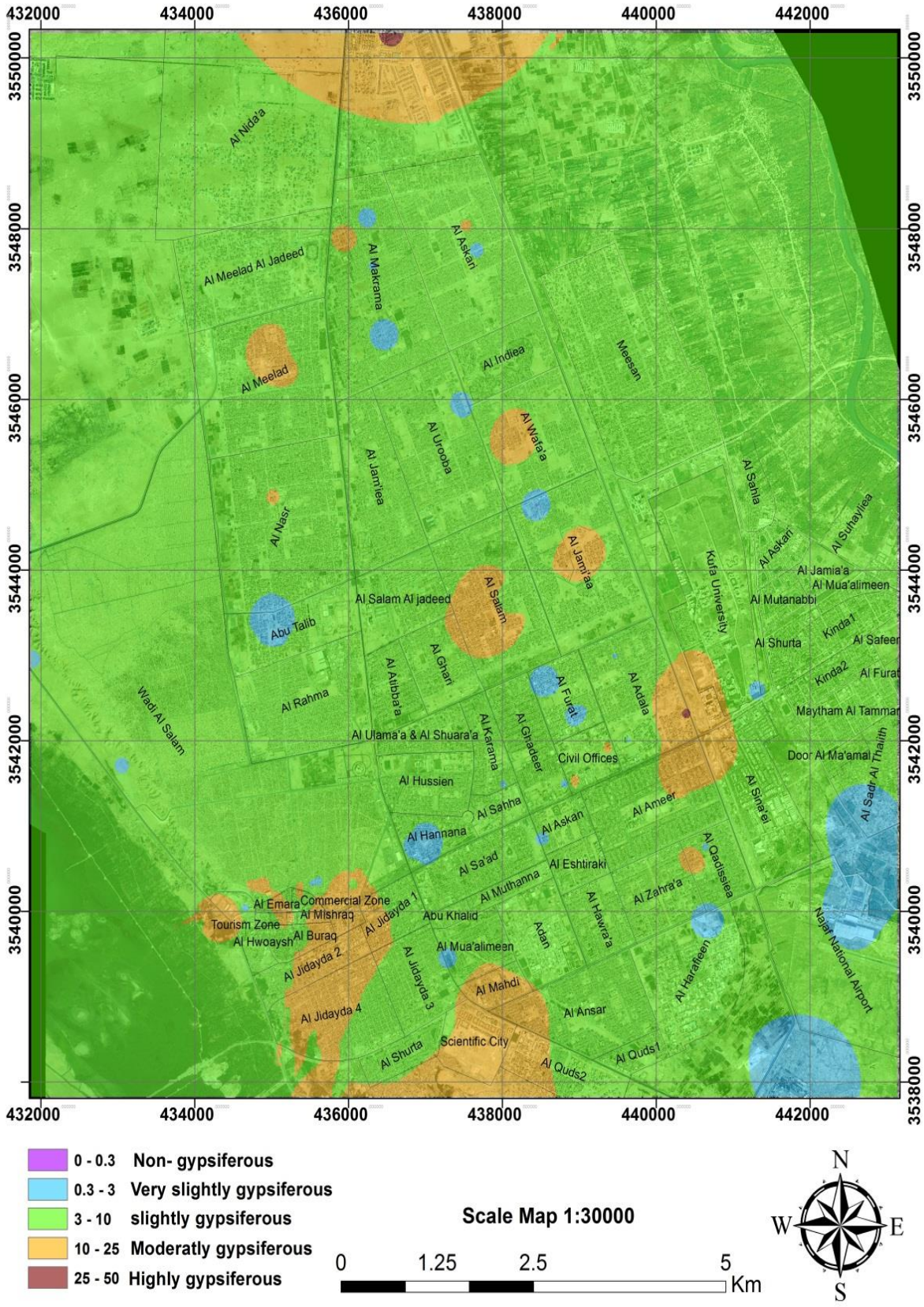
The Iraqi Standard Specification published by the State Corporation of Roads and Bridges (SCRB, 2003) considers salty or gypsiferous soil containing more than 10% of total soluble salts to be unsuitable when used in the top 50 cm of embankments. This value of 10% may be increased up to 20% in areas of low rainfall (less than 100 mm/year).



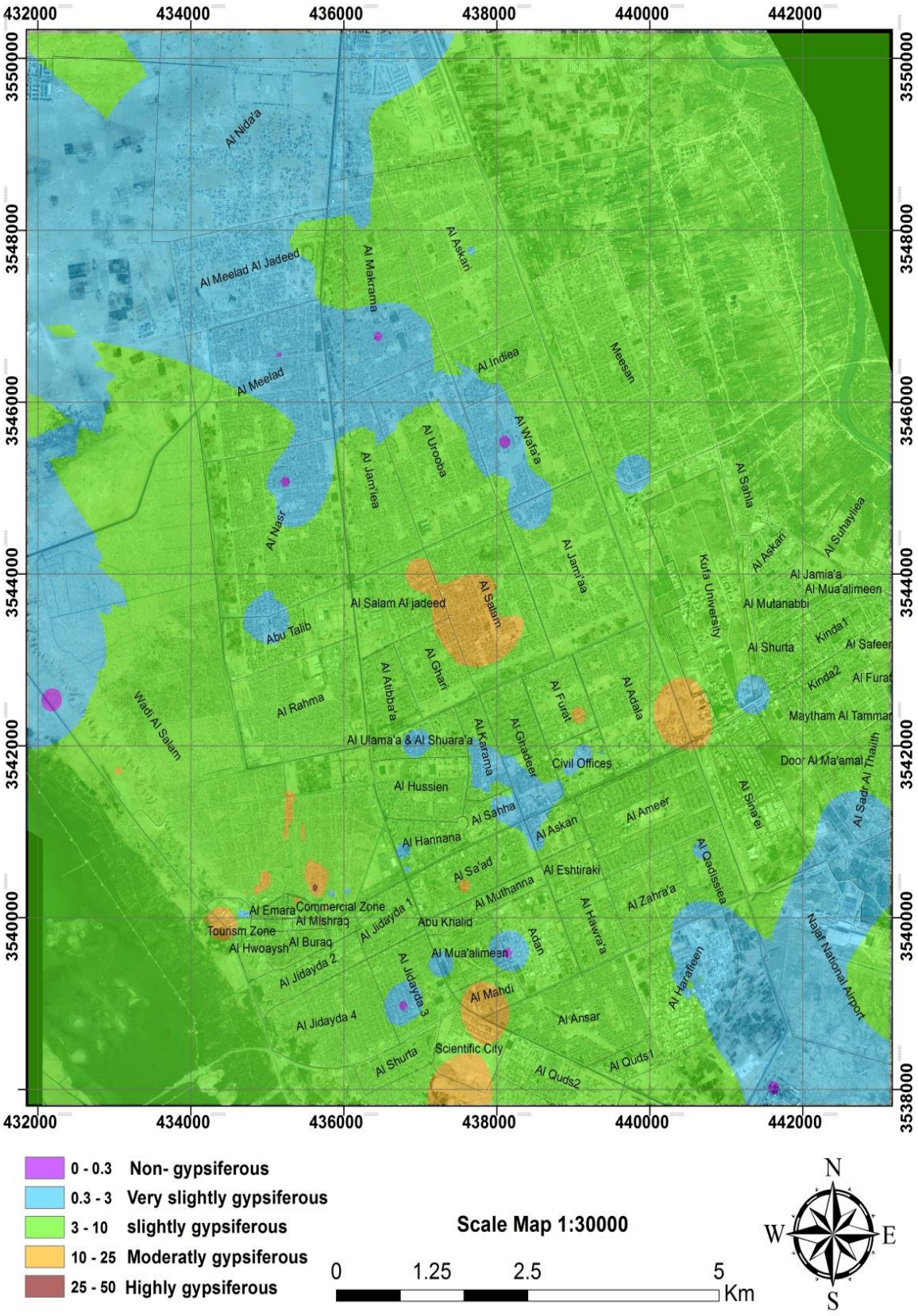
Map 1: Distribution of (gyp%) in Najaf an kufa Cities at depth (0-2)m from N.G.L.



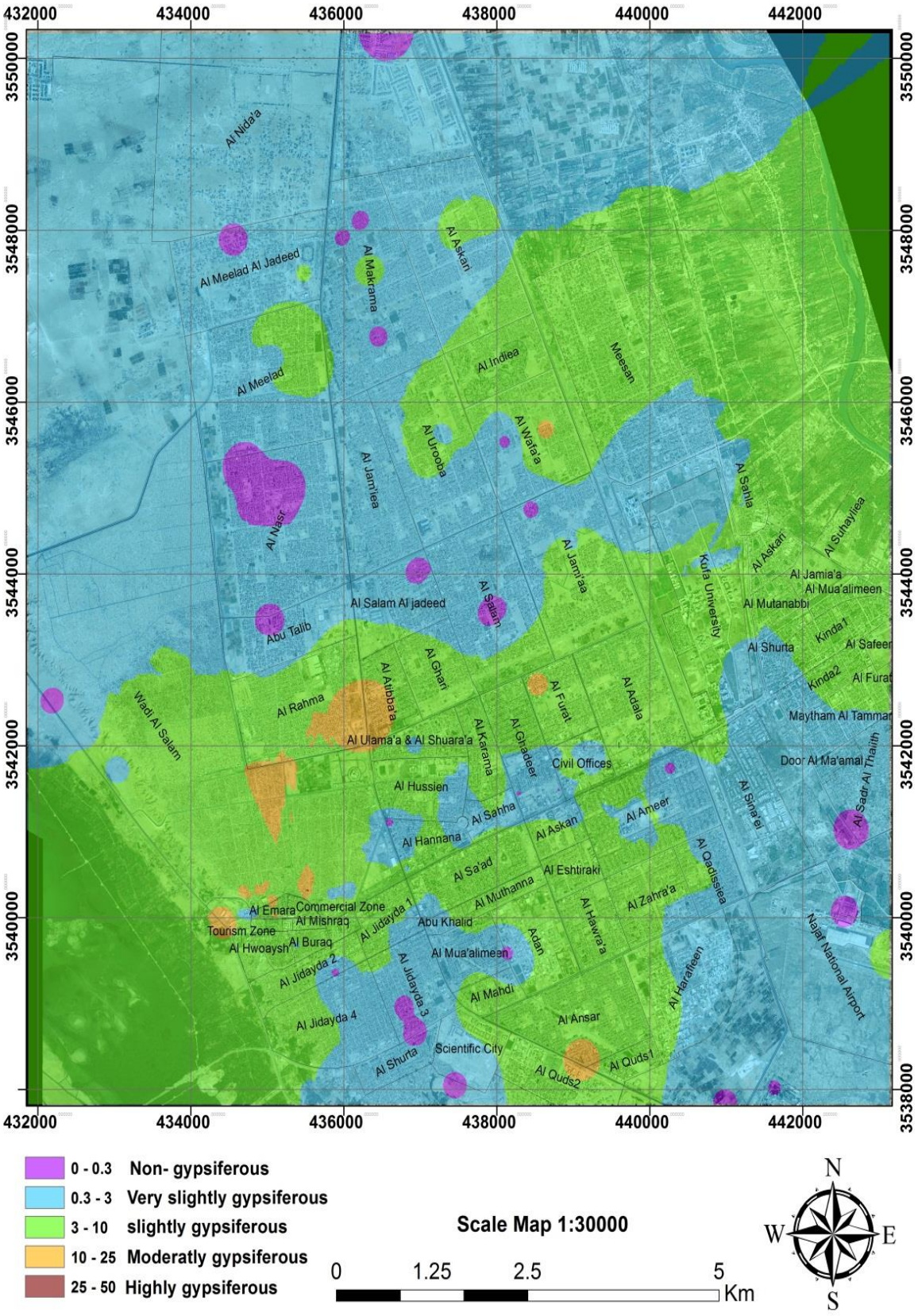
Map (2): Distribution of (gyp%) in Najaf and kufa Cities at depth (2-4)m from N.G.L



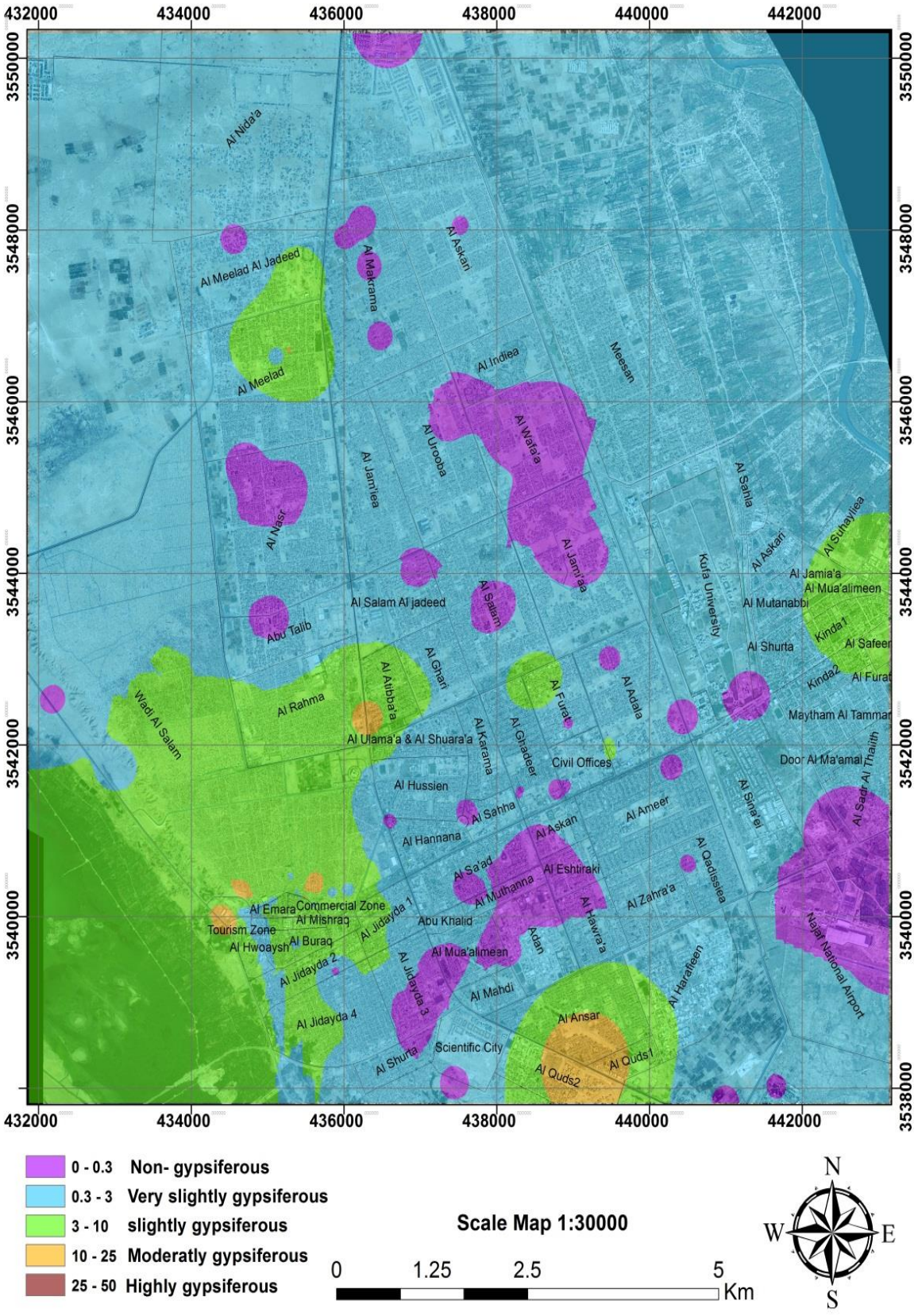
Map (3): Distribution of (gyp%) in Najaf and Kufa Cities at depth (4-6)m from N.G.L



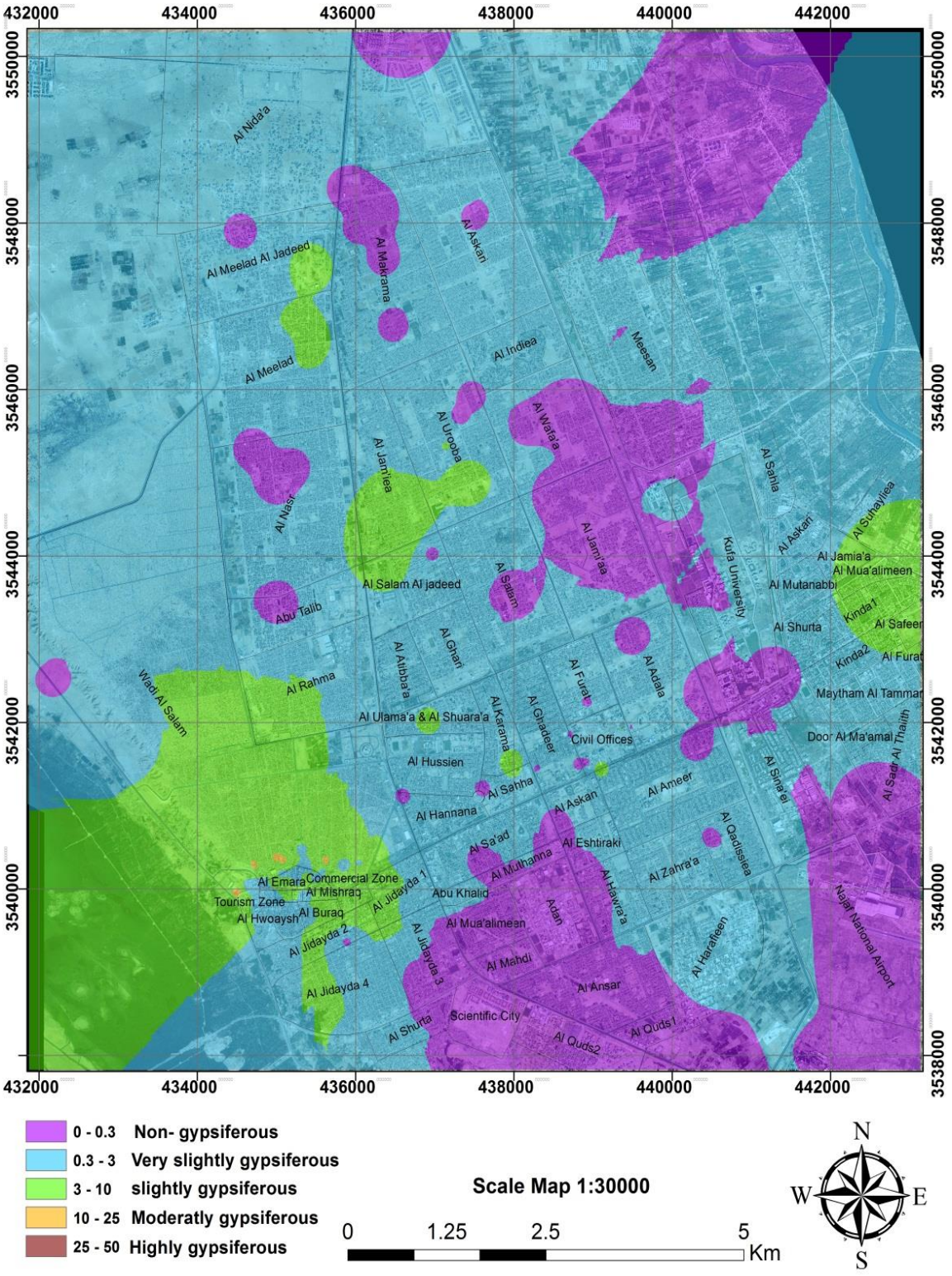
Map (4): Distribution of (gyp%) in Najaf and Kufa Cities at depth (6-8)m from N.G.L



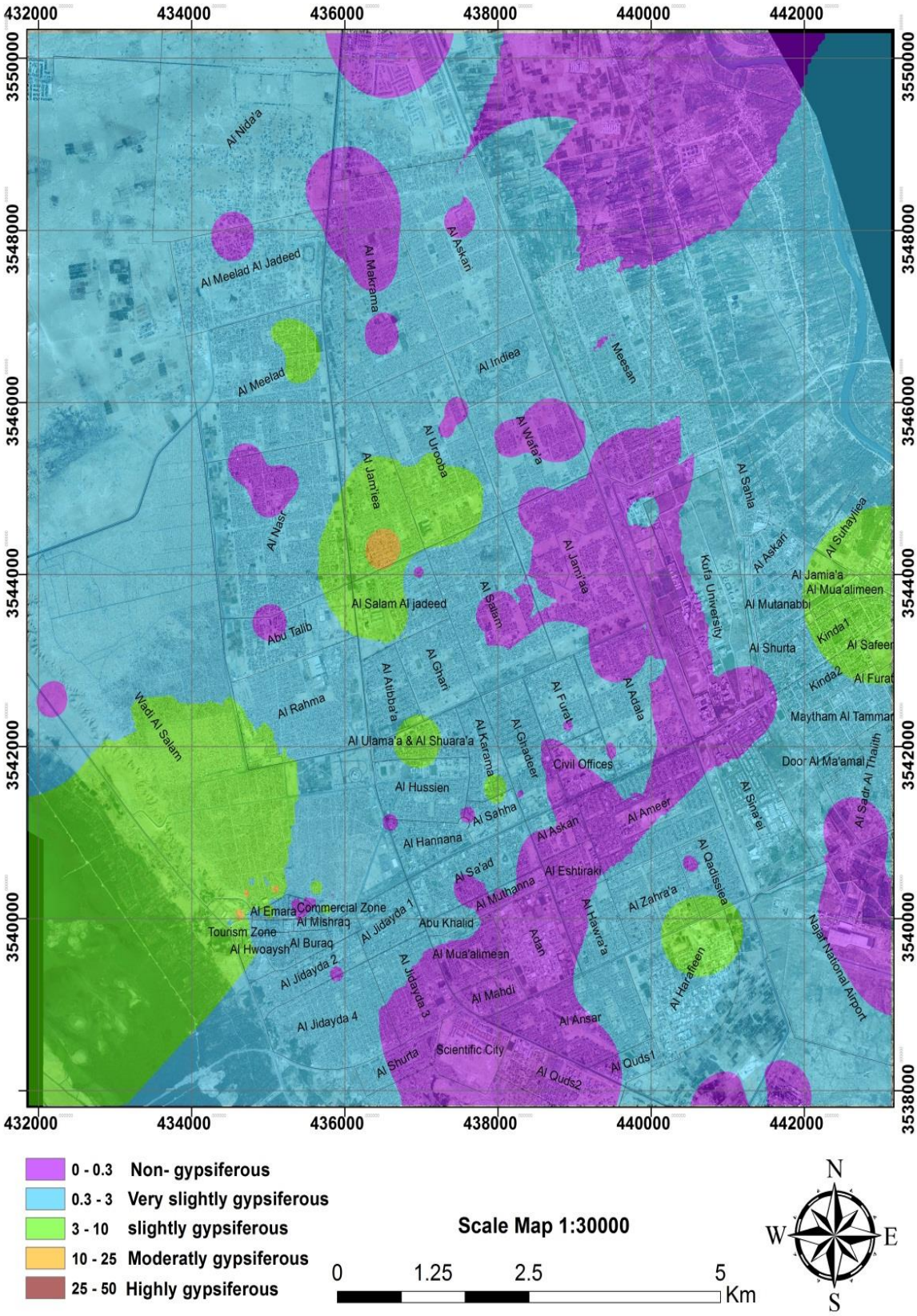
Map (5): Distribution of (gyp%) in Najaf and Kufa Cities at depth (8-10)m from N.G.L



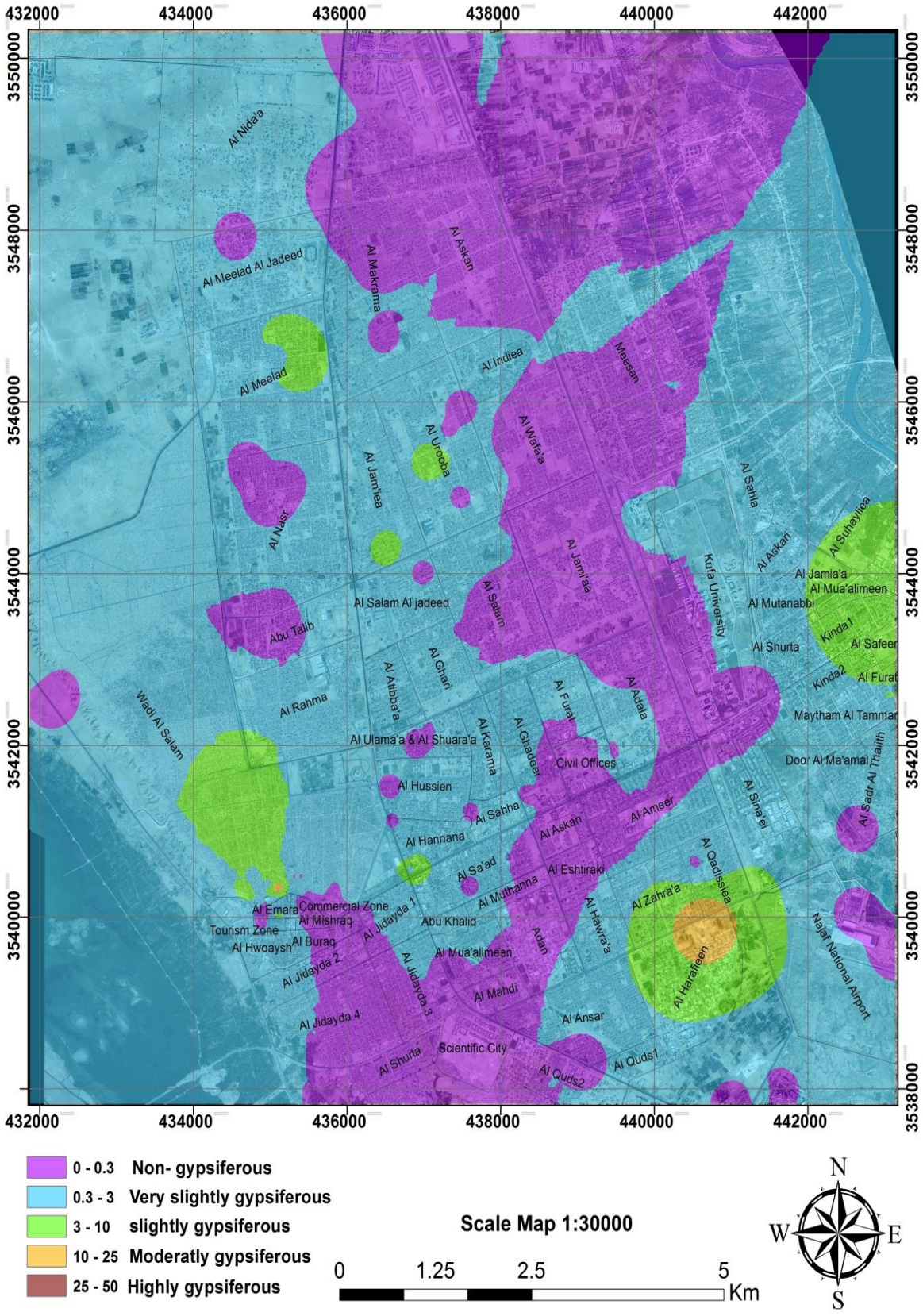
Map (6): Distribution of (gyp%) in Najaf and Kufa Cities at depth (10-12)m from N.G.L



Map (7): Distribution of (gyp%) in Najaf and Kufa City at depth (12-14)m from N.G.L.



Map (8): Distribution of (gyp%) in Najaf and Kufa Cities at depth (14-16)m from N.G.L.



Map (9): Distribution of (gyp%) in Najaf and Kufa Cities at depth (16-35m) from N.G.

VI. Conclusions

Using Geographic Information System (GIS) to produce a geotechnical maps is a helpful way to predict the gypsum content in non Spatial data areas.

Geotechnical maps produced for the study area represent a very powerful database and visual display of the collected data. beside, using these maps will help saving time cost and effort.

Final gypsum content maps can be used as a guidance for geologist and decisions makers to decide the suitability of any construction in the study area, the best foundation design and type of suitable treatment needed.

It's concluded that the greatest part of the study area and for depths (0-2) was moderately gypsiferous (i.e. a gypsum content ranges between 10-25%) and precautions have to be adopted. Moderately gypsiferous soil continuous down to depth 8 meters. While there was a few areas have a gypsum content range between (25-50%).

VII. References

[1] Raed Aziz Mahmoud, Abdulmutallab H. Al- Marsoumi, Anis Abdul Khader Mohammad Ali, 2011, " Study Gypsum Content Of The Soil In Selected Areas Of Basra Province", Basra Journal of Research, Issue XXXVII, the first part, 21-10, ISSN 1817-2695.

[2] Fairbridge, R. W. The Encyclopedia of Geochemistry & Environmental Sciences. Dowden Hutchinson & Ross Inc., Stroudsburg, Pennsylvania, 1321p. .(1972).

[3] Jafarzadah, A.A. and Zinck, J.A., 2000, "Worldwide Distribution and Substational Management of Soils with Gypsum". ISD Ana Sayfasi, Netherlands.

[4] Rajesh, S., Sankaragururaman, D., and Das, A., 2003, " A GIS/LIS Approach for Study on Suitability of Shallow Foundation at Chennal , India ", Map Asia Conference, Emerging Application, Paper from the Internet, GISdevelopment.net .

[5] Sohail Idrees, Rashid Salim Abd, Bashar Mohammed Amin Abdullah, 2013, " The Spatial Analysis for Some Geotechnical Properties in the Left Side of Mosul City by GIS" Tikrit Journal of Science and Engineering, Vol 20, (12-17),.

[6] Cavaleiro , V. M. , Carvalho , J. A. R. & Gomes, L. F., 2006," Geotechnical mapping in the area of Covilha , Portugal. A methodology using GIS" , The Geological Society of London.

[7] Jardaneh, Essam, 2007, " Geotechnical map of the city of Nablus-Palestine" Najah University Journal for Research, Vol 21.

[8] Moufida El May, Mahmoud Dlala, Ismail Chenini (2010) " Urban geological mapping: Geotechnical data analysis for rational development planning" ,Elsevier.

[9] Al- Jubouri Manhal Abdul Salam, 1988. " Geological east of the Tigris River, Mosul area". master thesis. College of Science. University of Al Mosul.

[10] Mendes, Rodolfo Moreda & Lorandi , Reinaldo , 2010 , "Geospatial Analysis of Geotechnical Data Applied to Urban Infrastructure Planning ", Journal of Geographic Information System , Vol. 2 , 23-31.

[11] Anbazhagan , P. , 2010, "GIS Based Subsurface Geotechnical Model of Bangalore", Science and Engineering Research Council http://www.sercdst.org/ar04-05seismicity.htm.

[12] Mahmood, M. Mustafa, 2006 "Digital Geotechnical Map of Baghdad City Al-Rasafah Side Using GIS and Remote Sensing Techniques", Ph.D. thesis, University of Technology, Baghdad, Iraq.

[13] Al-Abody, A. Awad,2012, "Geotechnical Maps for the Soil of Babylon Governorate Using Geographic Information System", Master Thesis, University of Babylon, Engineering College.

[14] National Center for Construction Laboratories & Research (NCCLR).

[15] Kadhim. N. Kadhim and Al-Baaj G. Ahmed, 2016, " The Geotechnical Maps For Gypsum By Using Gis For Najaf City (Najaf - Iraq)", Volume 7, Issue 4, July-August 2016, pp. 329–338 Article ID: IJCIET_07_04_028.

[16] Buringh, P. (1960): "Soils and Soil Conditions in Iraq" Ministry of Agriculture in Baghdad.

[17] Razouki, S. S. and El-Janabi, O. A., 1999, "Decrease in the CBR of Gypsiferous Soil Due to Long-Term Soaking", Quarterly Journal of Engineering Geology.

[18] Al-Khafaji, A. N. 1990, "Some Chemical Properties of South Jazira Irrigation Project", Soil Report Submitted to Dijla Irrigation Center. Mosul.

[19] Thomas D.S. 1997. "Arid Zone Geomorphology". John Wiley and Sons, England.

[20] Zaruba, Q. and Mencl, V. 1976. "Engineering Geology". Elsevier Scientific Publishing Company, Czechoslovakia, 504p.

[21] BS 1377-3:1990. "Methods of Test for Soils for Civil Engineering Purpose", Part 3: Chemical l& Electrochemical Tests.

[22] (FAO) Food and Agriculture Organization of the United Nations. Management of Gypsiferous Soils., www.fao.org/docrep/to323e/to323e0 7.htm (1990).