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Digital Geotechnical Maps of Basrah City Using Geographical Information Systems Technique

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ABSTRACT

The work in this research presents the use of Geographical Information Systems (GIS) and Global Positioning Systems (GPS) which integrated with remote sensing (RS) techniques in geotechnical engineering for Basrah city south of Iraq. These maps provide a powerful database and strong visual presentation of geotechnical data.

The research is performed in several stages that started with the utilize of LNADSAT 7 ETM+ satellite image with 14.25 m resolution within the visible bands of the study area, applying the geometric correction and performing image enhancements by using ERDAS software. Then collection of laboratory tests reports of boreholes is conducted in the study area and projecting their location as a layer using ArcGIS software after determining their position using a GPS instrument. The total number of soil investigated reports is (31) with total number of boreholes is (105).

The results of this study emphasize the possibility of producing digital geotechnical maps by using ArcGIS software that represents the distribution of the geotechnical properties for study area, such as allowable bearing capacity, the normalized undrained shear strength (c_u/P'_o), Liquidity Index and compression index.

Keywords: Digital Geotechnical Maps. Basrah soils. GIS**.**

خرائط رقمية جيوتكنيكية لمدينة البصرة باستخدام تقنيات نظم المعلومات الجغرافية

الخلاصة

تهدف هذه الدراسة إلى إعداد خرائط جيوتكنيكية لمدينة البصرة جنوب العراق باستخدام تقنيات نظم المعلومات الجغرافية GIS ونظام تحديد المواقع العالمي GPS اللذان يتحدان مع تقنيات التحسس النائي RS.. أن هذه الخرائط توفر قاعدة بيانات فعالة وتقدم عرض بصري قوي للمعلومات الجيوتكنيكية. أنجز البحث على عدة مراحل والتي ابتدأت بأستحصال صورة فضائية ضمن الحزمة المرئية لمنطقة الدراسة وتطبيق عمليات التصحيح الهندسي عليها وإجراء التحسين الصوري باستخدام الحزمة البرمجية ERDAS لتحري الخصائص الانعكاسية لسطح التربة، ومن ثم تجميع

المعلومات والنتائج للفحوصات المختبرية للعديد من الحفر الاختبارية المنجزة في منطقة الدراسة وتسقيطها على الصورة الفضائية كطبقة ضمن الحزمة البرمجية ArcGIS بعد أن تم تحديد مواقع هذه الحفر باستخدام تقنيات أجهزة تحديد المواقع العالمي للإحداثيات الـ GPS. إن العدد الكلي لتقارير تحريات التربة المستخدمة في هذه الدراسة هو (٣١) تقرير وبمجموع (١٠٥) حفرة اختبارية.

النتائج المستحصلة من هذه الدراسة شددت على إمكانية إنتاج خرائط رقمية جيوتكنيكية باستخدام الحزمة البرمجية ArcGIS والتي تقدم وصفاً لتوزيع وانتشار الخواص الجيوتكنيكية لمنطقة الدراسة مركز *قضاء البصرة* بمنظور جديد يمكن أن يقدم توصيفاً سهلاً ووصولاً سريعاً لهذه الخواص مثل قابلية التحمل المسموح بها، مقاومة القص المطبعة، مؤشر السيولة ومؤشر الانضغاط.

INTRODCTION

In the field of civil engineering, all projects are nearly built on to, or into, the ground. Whether the project is a structure, a roadway, a tunnel, or a bridge, the nature of the soil at that location is of great importance to the civil engineer [1]. Therefore, in order to assess the general suitability of the site and to prepare an adequate and economic safe design for the proposed project, proper subsurface investigation is to be made. The primary objective of subsoil investigation in civil engineering is to determine the geotechnical properties of the soil underlying the site, and for the necessity of getting it in possible minimum time, cost, efforts and staff the need arises to employ modern means.

Nowadays, with the advances of the information technology including Geographic Information System (GIS) and remote sensing at present, can serve the geotechnical engineer as the very effective tools, not only for non-data area prediction but also used to interpret the complex data area with reliability and accuracy [2].

The essence of using remote sensing techniques to study earth materials is to represent earth surface landscape by various kinds of image and to extract the information of earth surface environment and resources. The imaging process of remote sensing is to record the radiant and reflectance energy of earth materials by different kind of images [3].

GIS is a powerful tool by evaluating of huge numbers of data for the geo-environmental evaluation in performing of such analyses on very large areas in very short times. An important feature of a GIS is the ability to generate new information by integrating the existing diverse datasets sharing a compatible spatial referencing system [4].

GIS are commonly used in a wide span of applications (e.g. topographic base mapping, socio-economic and environmental modeling, and global modeling) that treats information about spatial phenomena. For geotechnical engineering purposes in particular, GIS has been used extensively for slope stability problems, engineering geological, geophysical and geotechnical surface mapping and site investigation data management.

Thus, the present study was undertaken, applying the advantage of the capabilities of GIS and remote sensing techniques to develop a user friendly suitability digital geotechnical map of the study area.

STUDY AREA

Study area is situated in south of Iraq, at (30° 25' 32", 30° 35' 44") latitudes North and (47° 41' 40", 47° 51' 23") longitudes East, known as Basrah district center which represents administrative and commercial center of Basrah governorate. The area covers geographical area of about (148 km2) as shown in figure (1), bounded on the north by Garmatt Ali River, on the south by Abu Al-Khaseeb district administrative boundary, on the east by Shatt Al-Arab River and on the west by Al-Basrah Canal.

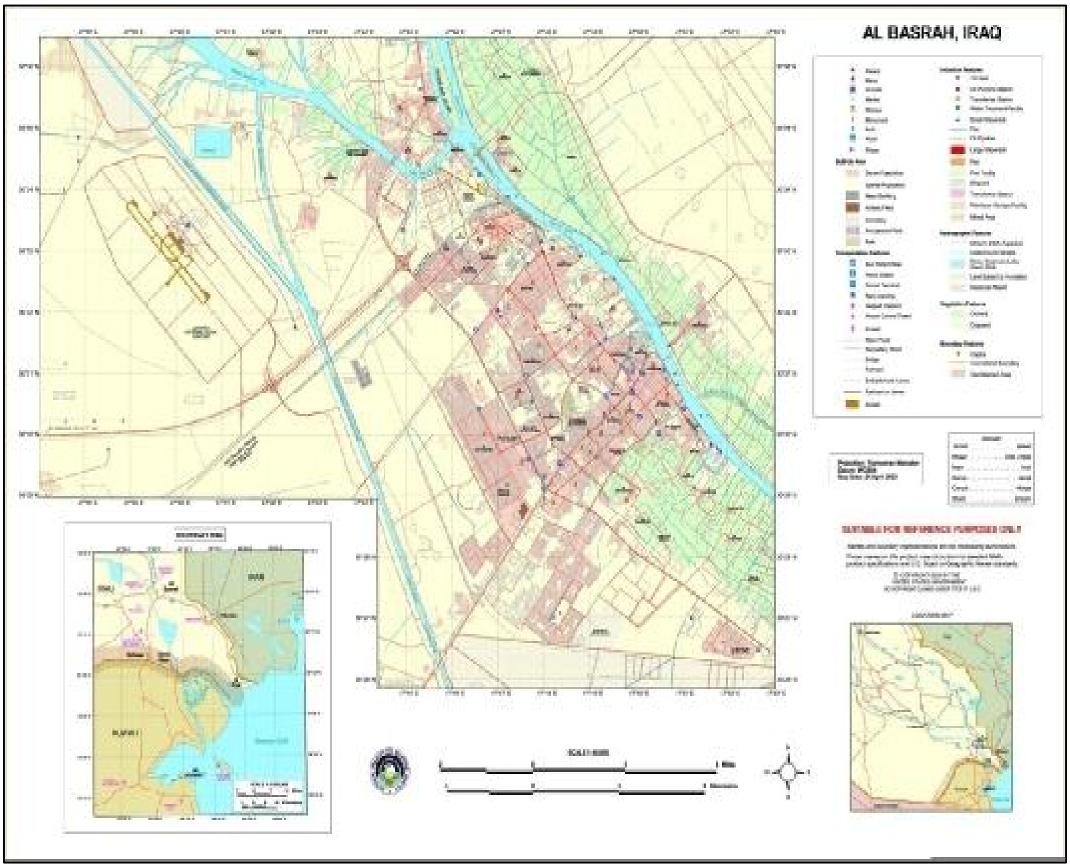

Figure (1) Map of Basrah city (2003) (Source: (NIMA)).

The study area is almost flat with elevation 2.4m above mean sea level [5]**.** The geologic studies reveal that Basrah region (lower Mesopotamian plain) formed as a result of Alpine movement occurred during the Jurassic and cretaceous periods and continued till 2 million years ago, and, then followed up to the present time [6]**.**

The Quaternary sediments during the Pleistocene and Holocene Epochs (2 million years to the present) covered Mesopotamian Plain, where they comprise fluviatile, lacustrine, deltaic, and Aeolian sediments that replace each other both horizontally and vertically. These sediments are represented by Dibddiba, and Al- Hammar Formations, and also by brackish lacustrine sediments. The upper part of Basrah region consists of naturally consolidated surface layers having mix source sediments, including fluvital flood silts and Aeolian deposits [7].

However, sea-level fluctuation and climate changes during the Holocene and differential sedimentation in Lower Mesopotamia are believed to be the main factors that controlled the evolution of the Mesopotamian delta [8].

DATA COLLECTION

Map of Basrah City of scale (1:30,000) is used to define the boundaries of the Mahalahs (Hays) in the study area, figure (1), which is produced in April 2003 by the National Imagery and Mapping Agency (NIMA), United States Governorate.

The Garmin GPS (GPSMAP76CSx) which used is a simple instrument that can record the easting and northing of any point with an accuracy that depends on the number of satellites available at time of acquisition.

Space image for the study area of the satellite Landsat-7 ETM+, three bands with (14.25 m) resolution, acquired in April 2004, is used in this study.

The geotechnical data of this study are collected from site investigation reports of (31) sites distributed all around the city, figure (2). These reports involve (105) boreholes drilled to depth of (10-40 m) below mean sea level. These investigations were performed by different sources (Andrea Engineering Testing Laboratory (AETL), National Center for Construction Laboratories and Researches (NCCLR) Basrah branch, private sector laboratories, and consultant groups).

The reports have included results of both standard laboratory and field tests. Physical properties such as water content, soil classification, index properties, etc… are determined. Results from undrained shear strength parameters, standard penetration test, conventional consolidation characteristics, are also recorded. The water table level at the time of testing is recorded. Some properties are calculated from the measured properties such as the liquidity index, effective overburden pressure at test depth (P'o), over consolidation ratio (OCR), and the normalized undrained shear strength (cu/P'o).

The location (coordinates) of each bore hole is determined either from the test reports (if such data was available) or by using the GPS in the field through visiting the borehole locations and registering their coordinates by a GPS Garmen (GPSMAP76CSx) instrument.

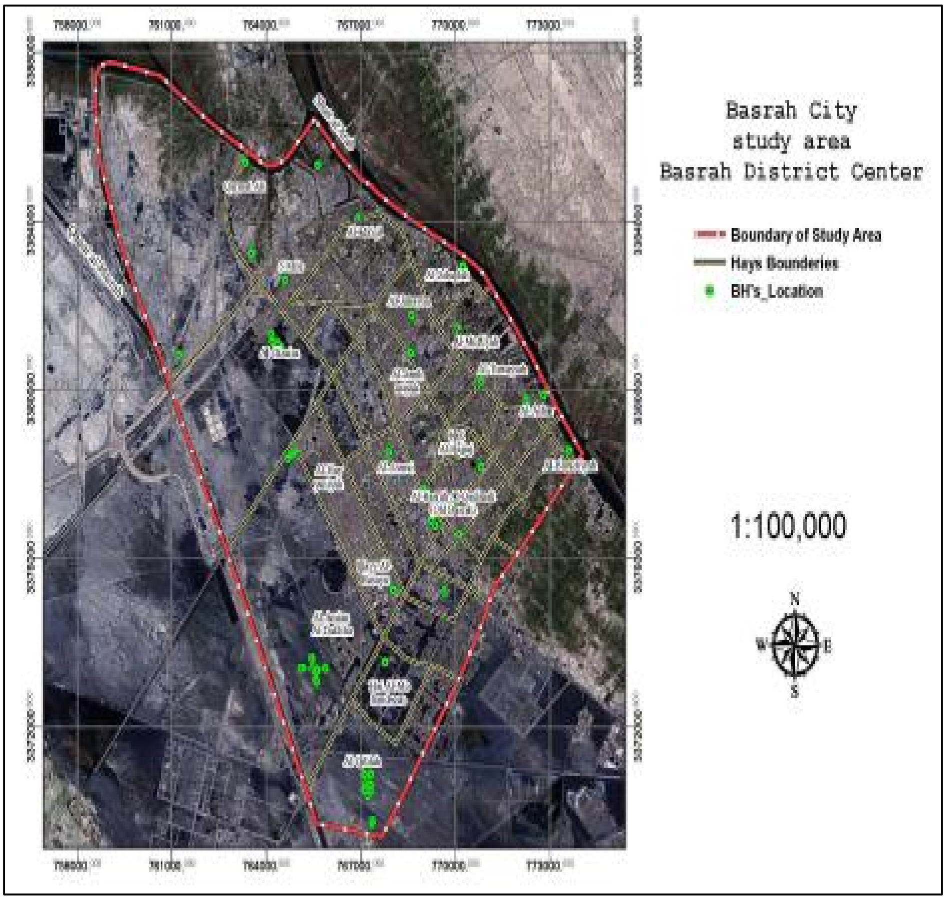

Figure (2) Digital photo map of Borehole locations in the study area.

Borehole locations are projected on the corrected image and attribute table of the geotechnical properties recorded in each borehole of the various points in the study area constructed in ArcMap9.2 software to build a GIS database for the study area. Figure (2) shows the distribution of borehole locations in the study area. The boundaries of each district (Hays) in the study area are also shown in the Figure.

DATA ANALYSIS

Satellite image processing has been done by using ERDAS 9.2 software, which include geometric corrections and image enhancement on the collected image of the study area.

Four enhancement techniques were applied to the raw-collected satellite image of the study area. For radiometric enhancement, the histogram equalization technique was applied. This technique develops many features that do not appear to the observer in a raw image. For spatial enhancement, the convolution filtering and the crisp techniques were used. The former uses a matrix to average small sets of pixels across an image, while the later sharpens the overall scene luminance without distorting the thematic content of the image. For spectral enhancement, the principal component analysis technique was adopted, this technique compresses redundant data values into fewer bands, which are often more interpretable than the source data.

The principal advantages of using spatial data analysis in GIS software's (such as ArcMap9.2) are they able to perform operations that relate values of one location to those at neighboring locations. And since the geotechnical properties do change, not only with depth (vertically), but also across the area (horizontally), then using capabilities of GIS to represent the variation in the geotechnical properties across the area, at a particular depth, can be produced as thematic maps that show the variation in values as graduated colors which will help in understanding the distribution in a better way, since a quick glance at such a map will generate the impression of how the property is distributed across the area.

RESULTS AND DISCUSSIN

Remote Sensing Technique

The raw image of the study area before implementing any processing and the results of applying enhancement techniques are shown in Figures (3) to (7).

The results of image enhancements show that the histogram enhancement has the best results in clarifying the areas of bare soil that are distributed within the study area. Other enhancements used had less effect when compared to the previously mentioned method.

Figure (3): The raw image of the study area.

Figure (4): The histogram equalization enhancement.

Figure (5): The convolution filtering enhancement.

Figure (6): The crisp enhancement.

Figure (7): The principal component analysis.

GIS TECHNIQUE

Several geotechnical properties have been manipulated (using inverse distance weighted method) for borehole points of the study area with GIS software ArcMap 9.2 through its generation and its transformation from its dot shape to the grid shape by submitting it to the counting processing to achieve the purpose of this research to produce digital geotechnical maps that shows the distribution of any property across the study area as new layer.

BEARING CAPACITY

The ultimate bearing capacity of soil beneath a foundation load depends primarily on the shear strength. The working, or allowable, value for design will take into consideration both strength and deformation characteristics.

The values of bearing capacity in the study area vary between (30–60) kN/m^2 as shown in Figure (8). Most of the area has a value of bearing capacity around

(30 – 50) kN/m^2 except for the Hai Al-Mohandseen where it rises to (60) kN/m^2. The bearing capacity is measured at a depth of (2-4) meters as set in the investigation reports used in this study.

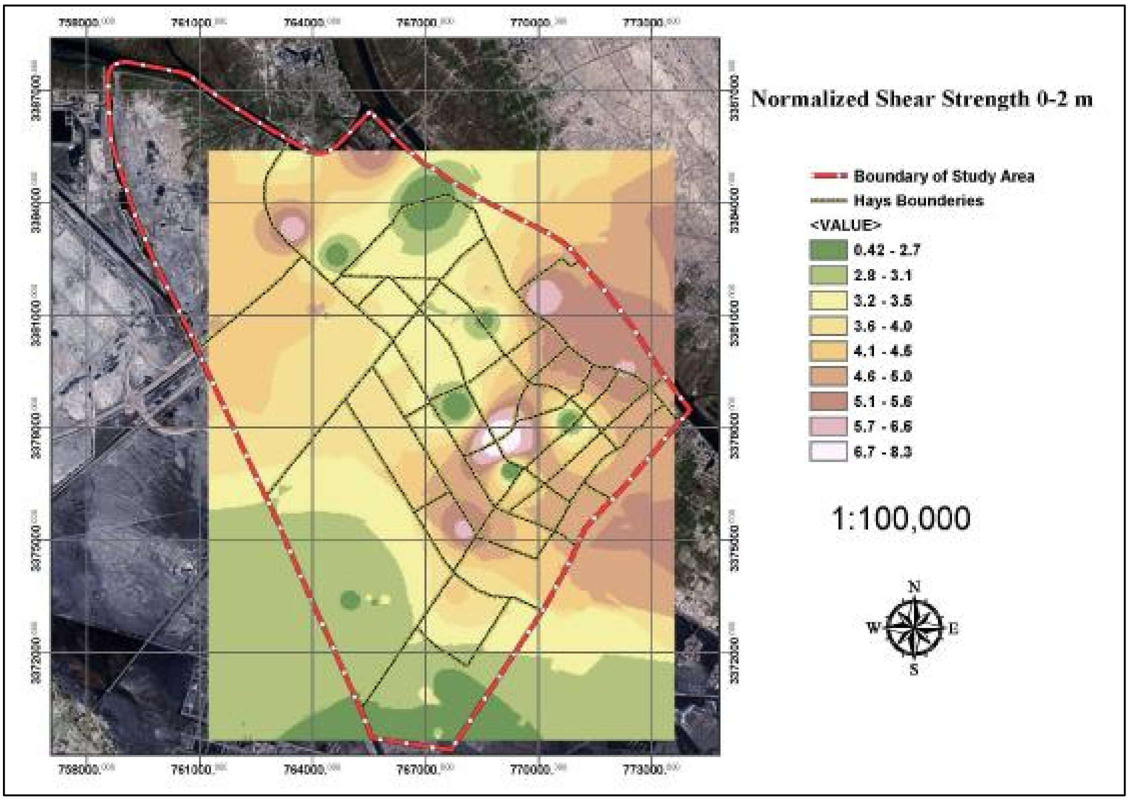

Figure (8) Bearing capacity distribution across study area.

In order to represent the variation of a single property with depth across the study area, the soil profile was divided into five layers, each layer 2 meter thick. Then the distribution of each property studied across the study area was constructed by the software for each of the five layers, and the variation of the property with depth at different places can be noticed by studying the thematic maps of the five layers in consecutive manner.

DISTRIBUTION OF NORMALIZED SHEAR STRENGTH

The distribution of normalized shear strength (c_u / P'_o) across the study area, for each 2 meters depth interval, is shown in Figures (9) to (13). The study of each map by itself will give an impression of how the property is distributed at that depth interval. Studying all maps together and comparing values of the property at the same location but with different depth can give the distribution profile of that property.

Comparing the values of (c_u / P'_o) at different depths shown in the figures show that there is a pronounced change in the upper 4 meters as shown in Figures (9) and (10). The southern west parts of the study area (Al-Amin Al-Dakhlia and Al-Qiblah) and some locations (Al-Ma'qil, 5 Mile, Al-Asmai and Al-Basrah Al-Qadimah) have a low (c_u / P'_o) value in those depths (0-2 and 2-4m) comparing with the remaining of study area.

The soil change dramatically between the second and third layers (2-4 and 4-6m). The remaining three layers (4-6, 6-8, and 8-10m) shown in Figures (11), (12), and (13) respectively, have a same trend of upper 4 meters with decrease in (c_u / P'_o) with maximum value of (1.1, 0.57, 0.40) at depths (4-6, 6-8, and 8-10m) respectively.

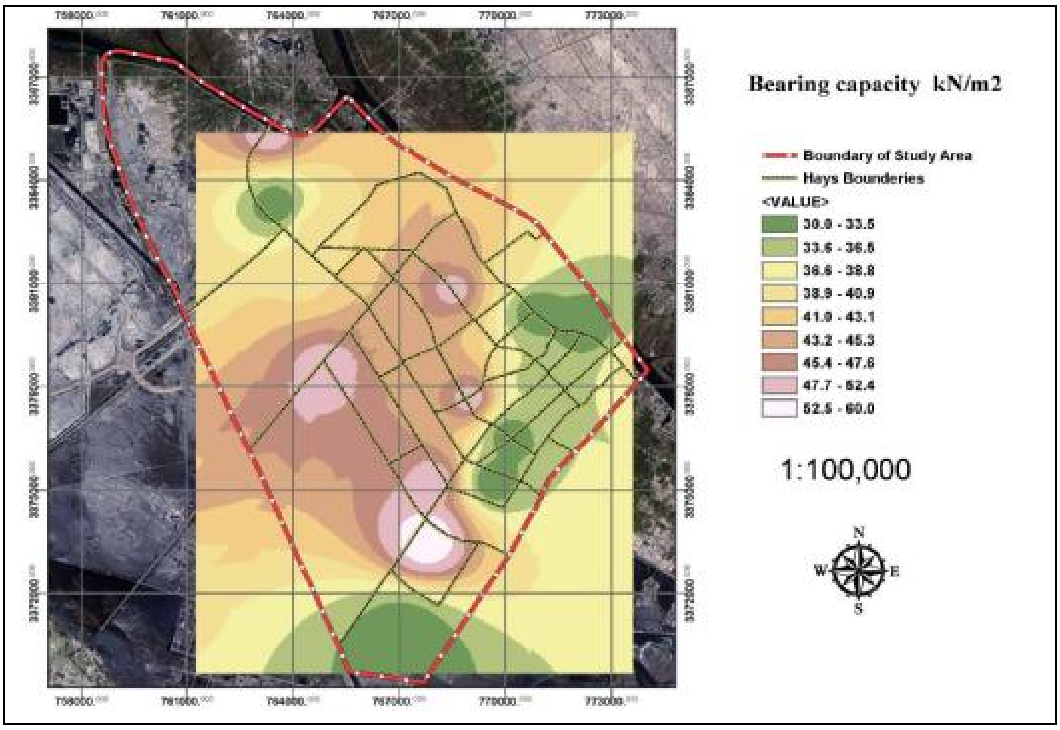

Figure (9) Distribution of normalized shear strength at depth 0-2 m across study area.

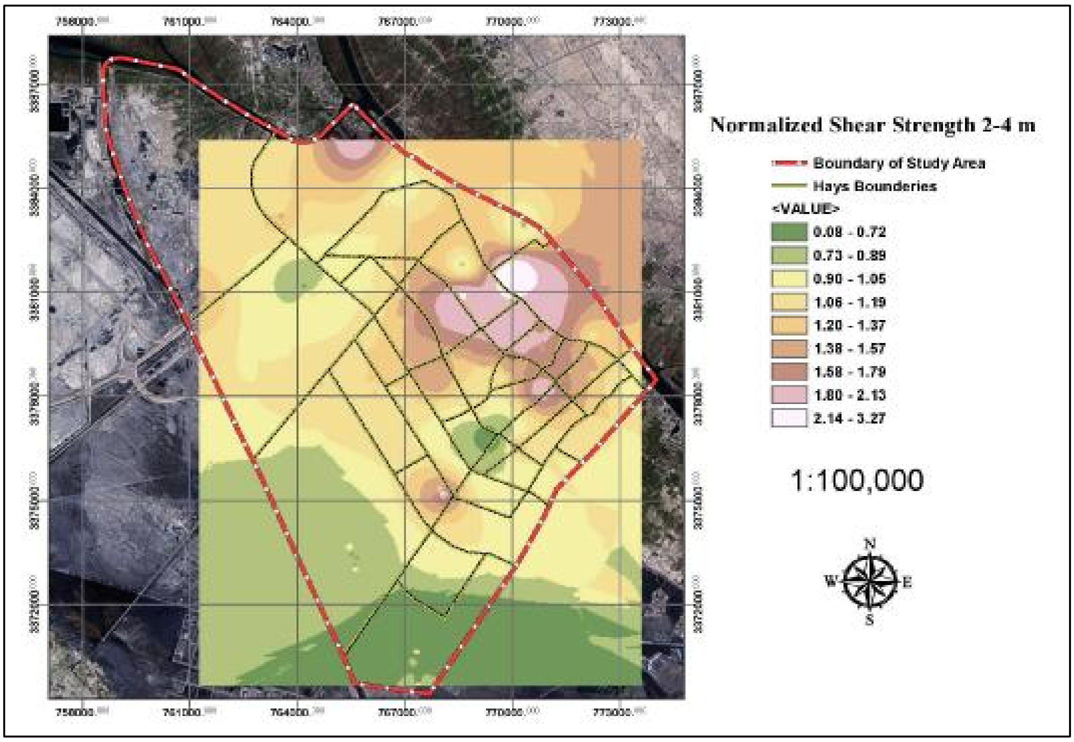

Figure (10) Distribution of normalized shear strength at depth 2-4 m across study area.

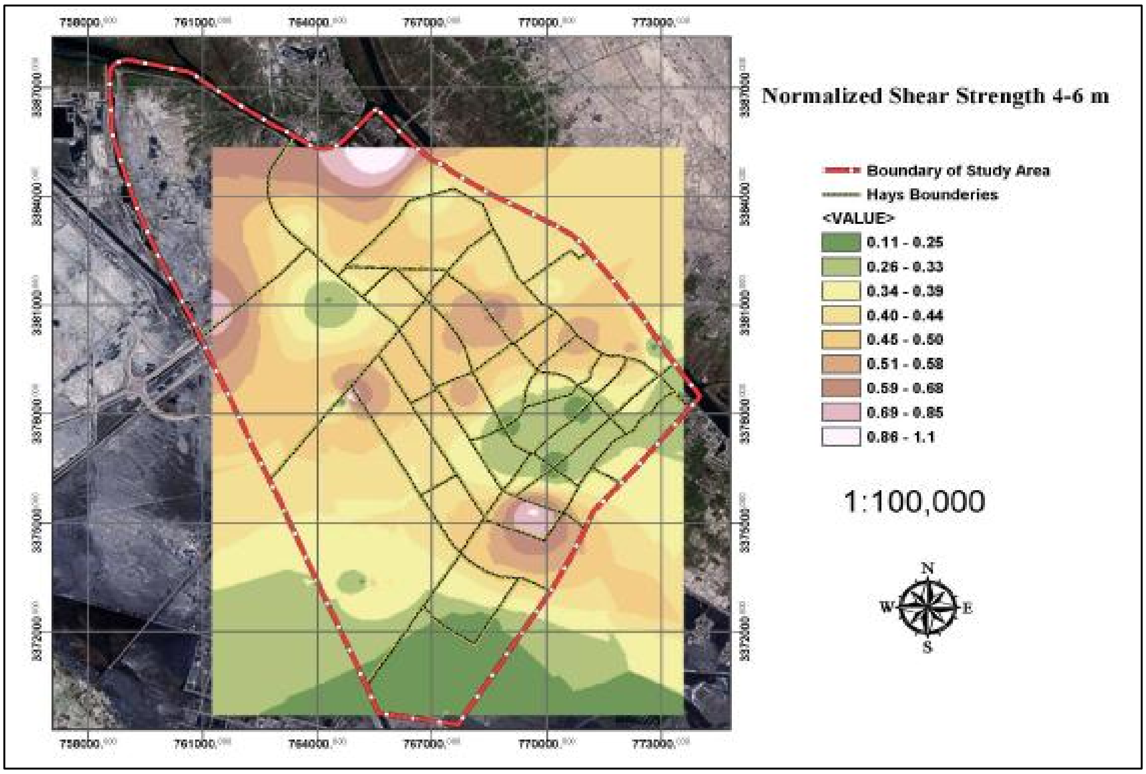

Figure (11) Distribution of normalized shear strength at depth 4-6 m across study area.

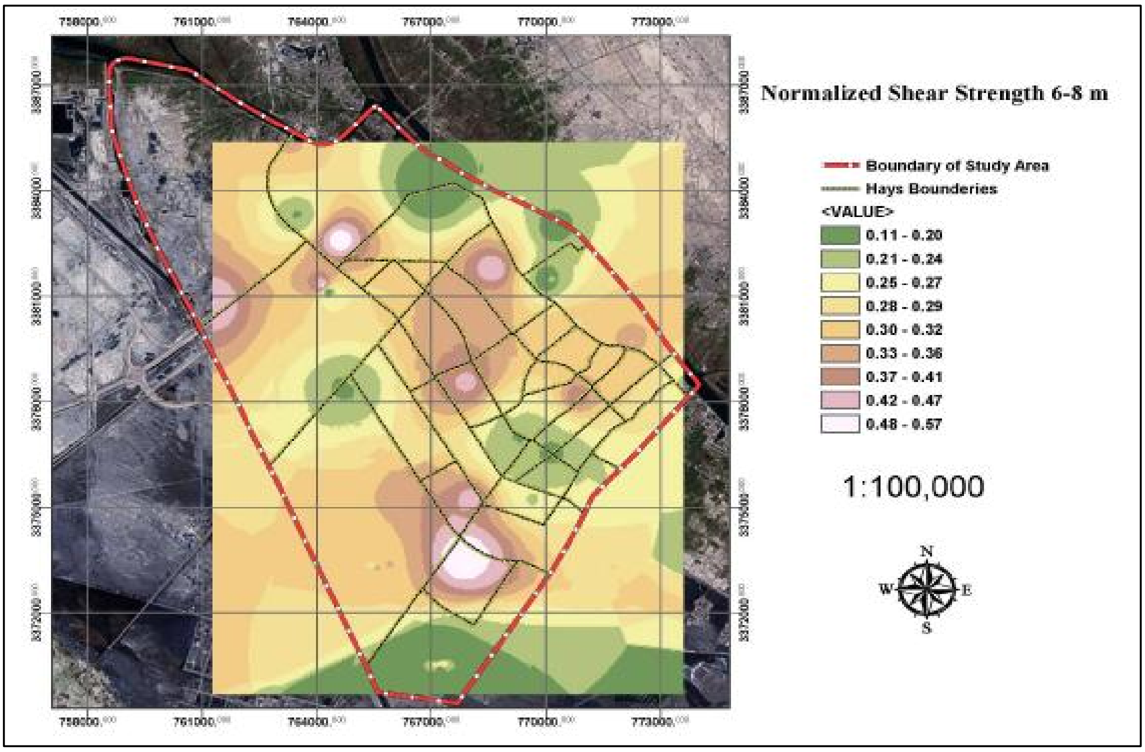

Figure (12) Distribution of normalized shear strength at depth 6-8 m across study area.

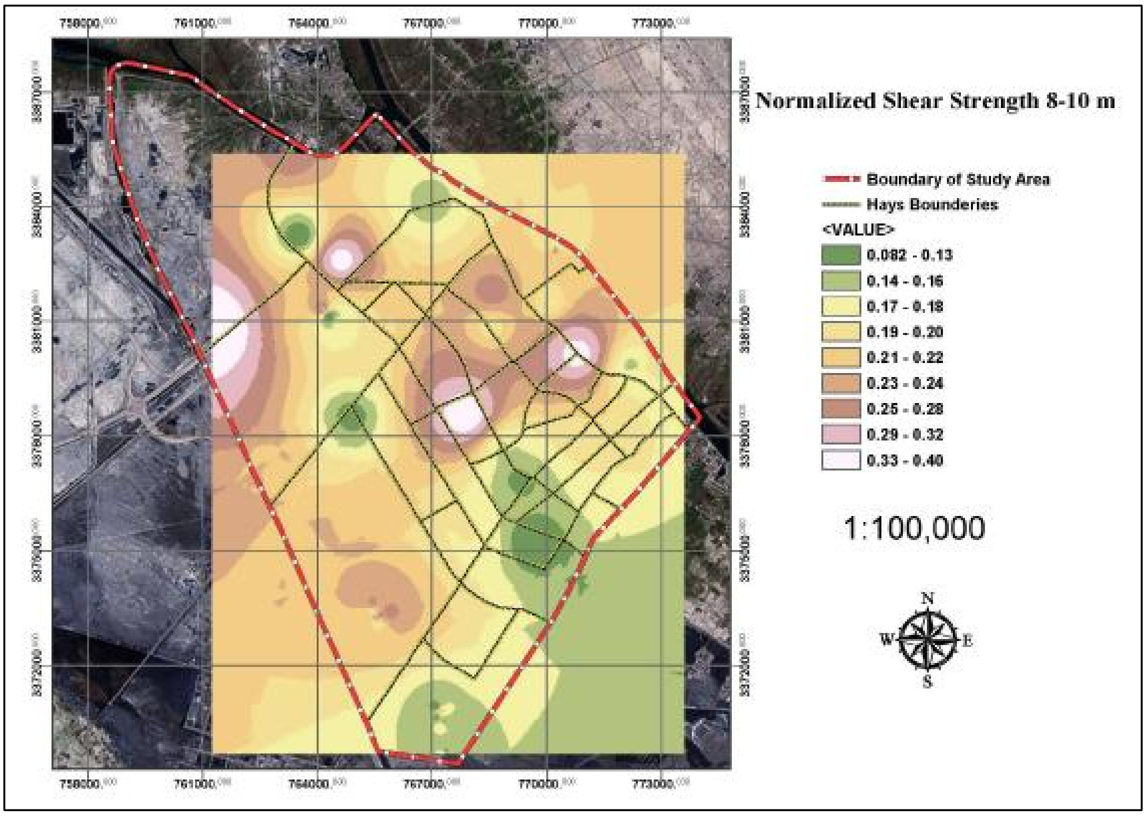

Figure (13) Distribution of normalized shear strength at depth 8-10 m across study

DISTRIBUTION OF LIQUIDITY INDEX VALUES

Figures (14), (15), (16), (17), (18) show the variation of the liquidity index values across the area at depths (0-2, 2-4, 4-6, 6-8, 8-10 m) respectively. The distribution across the area at each depth can be seen directly from each figure. But vertical variation in the property must be concluded from all the figures. The upper 2 meters has liquidity index values more than zero at northern and northern east of study area except for a few spots in the Al-Muftiyah, 5 Mile and Al-Najebiah while the remaining area has liquidity index value close or less than zero. The second layer with a depth (2-4 m) had nearly the same distribution of liquidity index of the upper layer (0-2 m) with increasing the area having liquidity index values more than zero to include southern parts of study area, which means that there are no major variations in the upper four meters.

The following three layers (4-6, 6-8, 8-10 m) show that the liquidity index starts to increase with depth for most of the areas where it becomes greater than zero which means that the soil in plastic state.

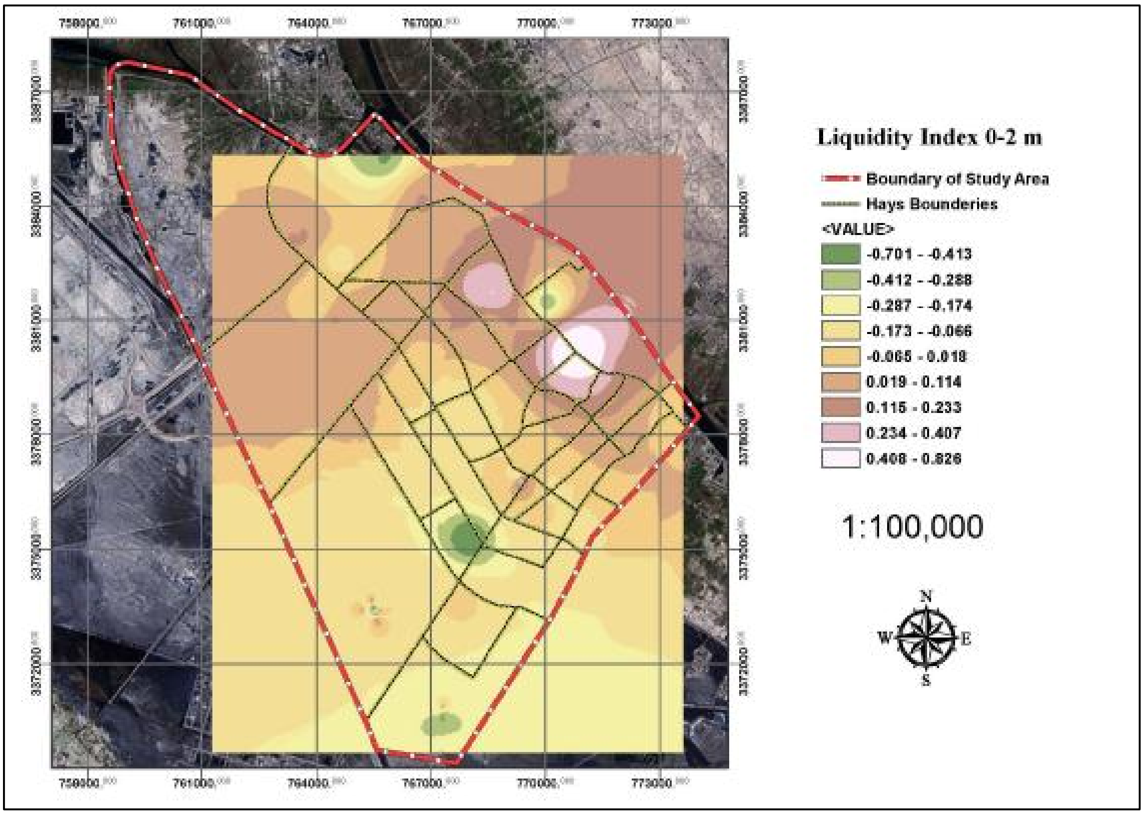

Figure (14) Distribution of liquidity index at depth 0-2 m across study region

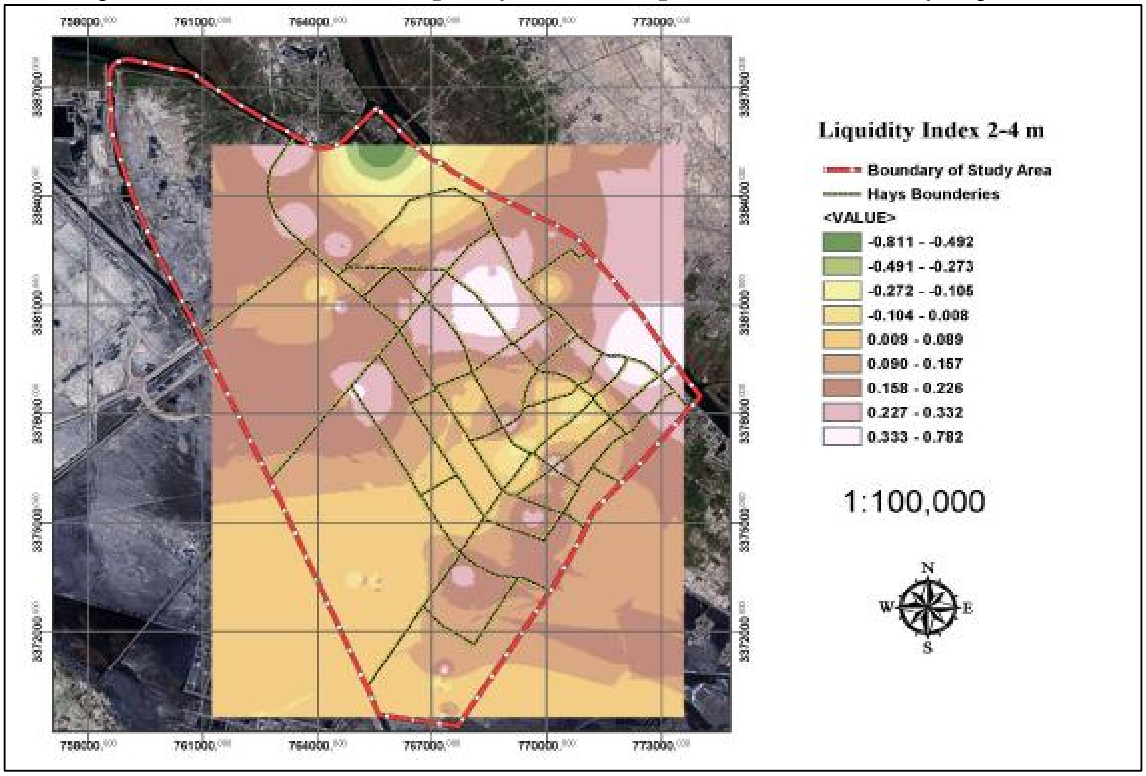

Figure (15) Distribution of liquidity index at depth 2-4 m across study region

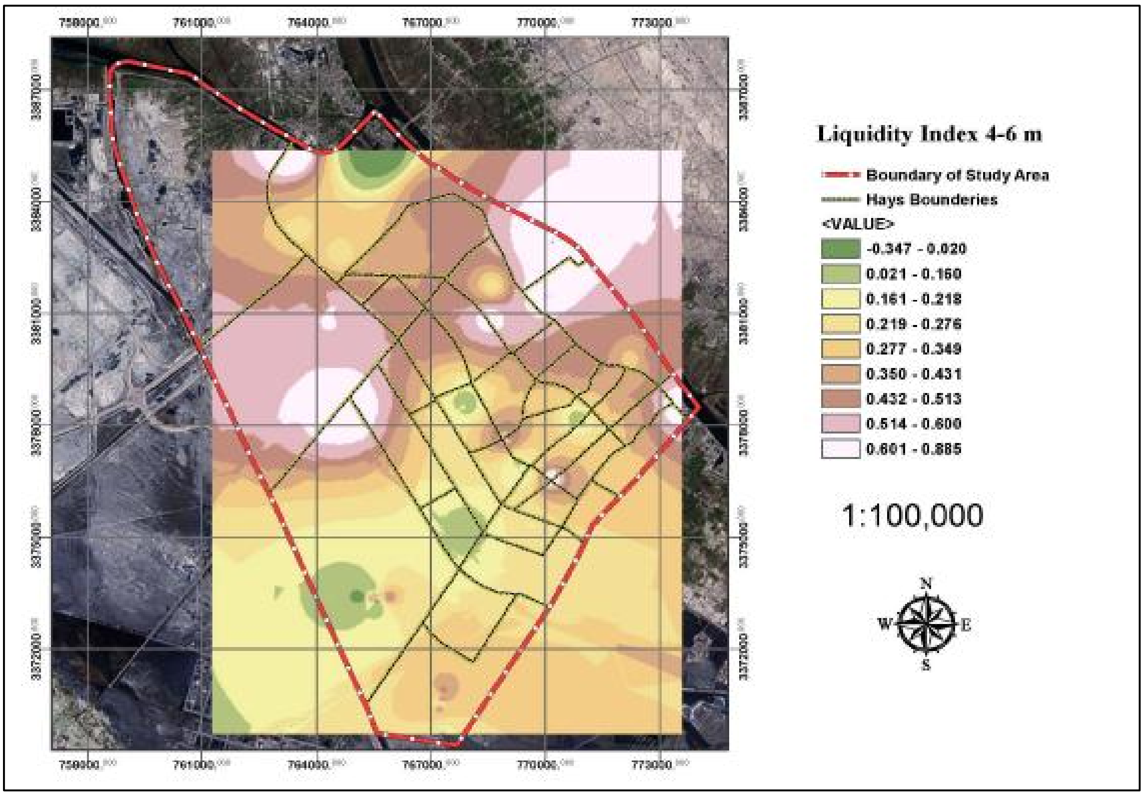

Figure (16) Distribution of liquidity index at depth 4-6 m across study region

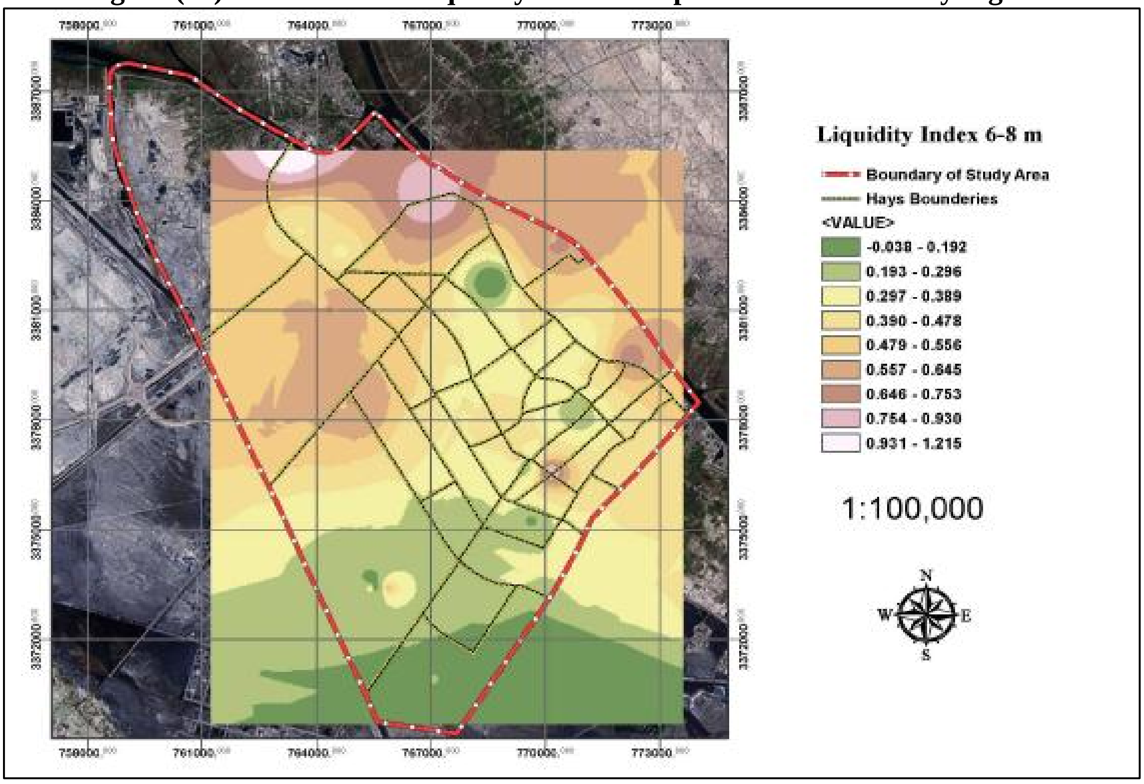

Figure (17) Distribution of liquidity index at depth 6-8 m across study region.

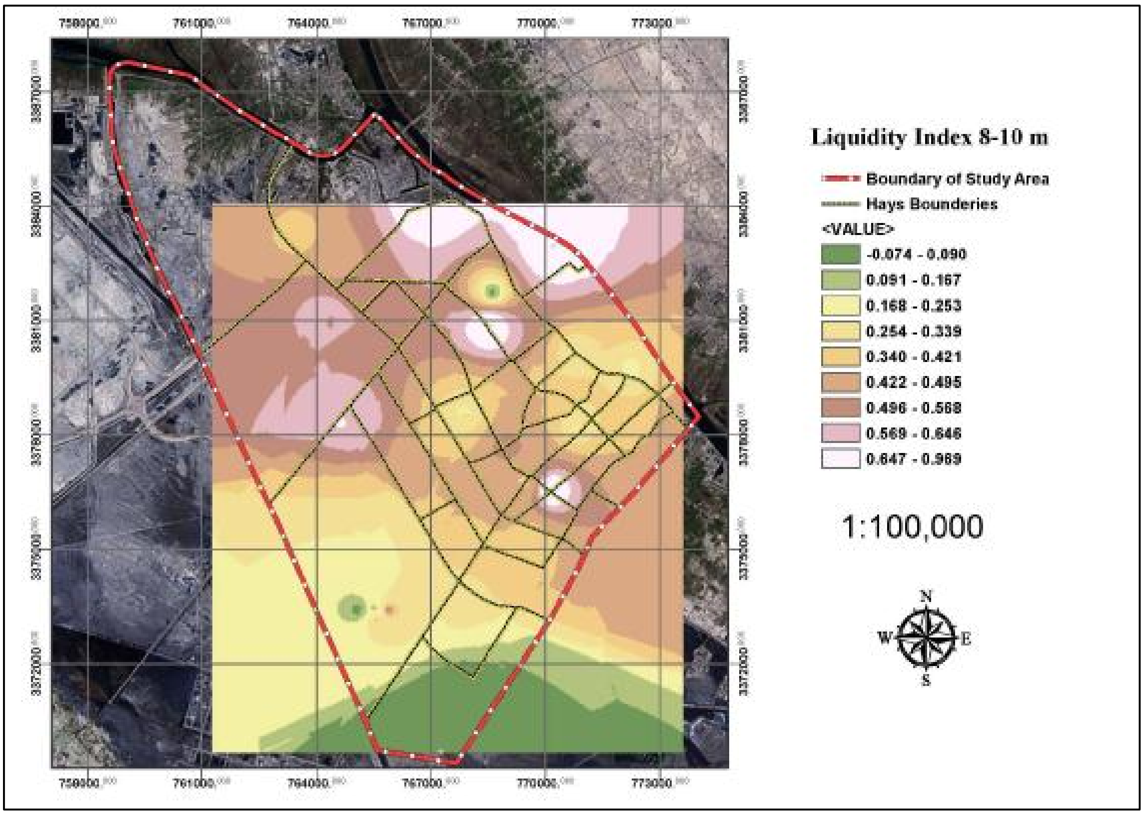

Figure (18) Distribution of liquidity index at depth 8-10 m across study region

DISTRIBUTION OF COMPRESSION INDEX VALUES

The compression characteristics of a fine grained soil can be evaluated by its compression index. High value of compression index indicates that the soil has a tendency to undergo considerable volume change under stresses.

The values of compression index encountered in the study region range between (0.011) and (0.310). The change in values with depth for each zone in the study area can be deduced from the Figures (19), (20), (21), (22), and (23), and would lead to the conclusion that at old Basrah the level of compression index values is low (less than 0.011) for all the layers. Other low values of compression index occurring at third and forth layers at Al-Ashar. For the three upper layers (0-2, 2-4 and 4-6) meters compression index values are moderate at most study area except at three locations show high values (Al-Gizaiza and 5 Mile at north, Al-Qiblah at southern west and Al-Baradi'iyah at east). At depths (6-8 and 8-10) meters high values of compression index extended to include central part of study area at Al-Asmaee and Al-Jumhuriyah, while remaining area keeps moderate values.

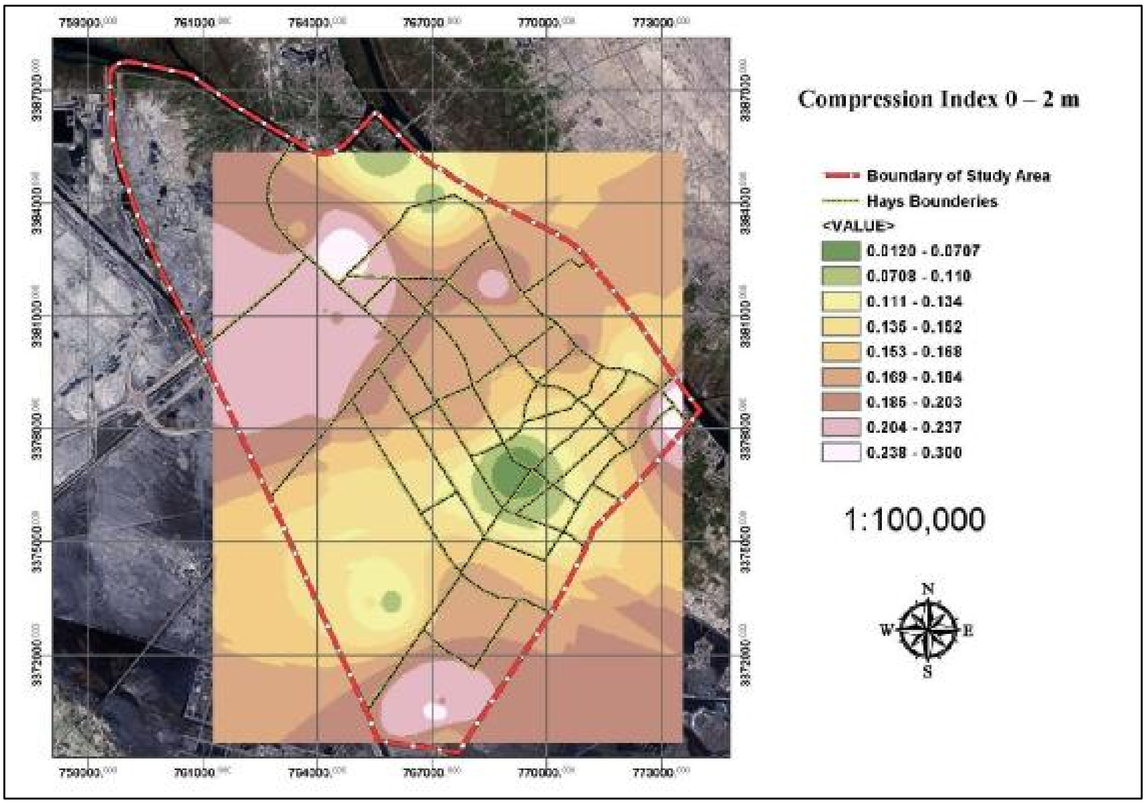

Figure (19) Distribution of compression index at depth 0-2 m across study area.

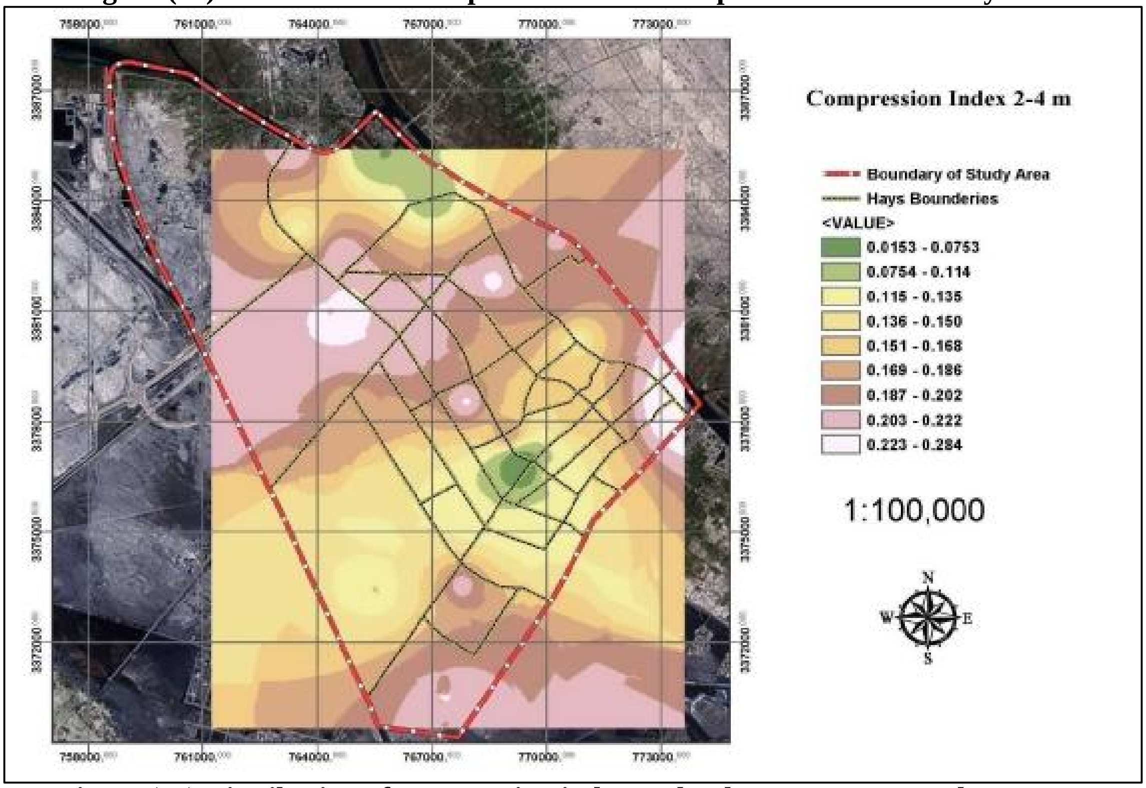

Figure (20) Distribution of compression index at depth 2-4 m across study area.

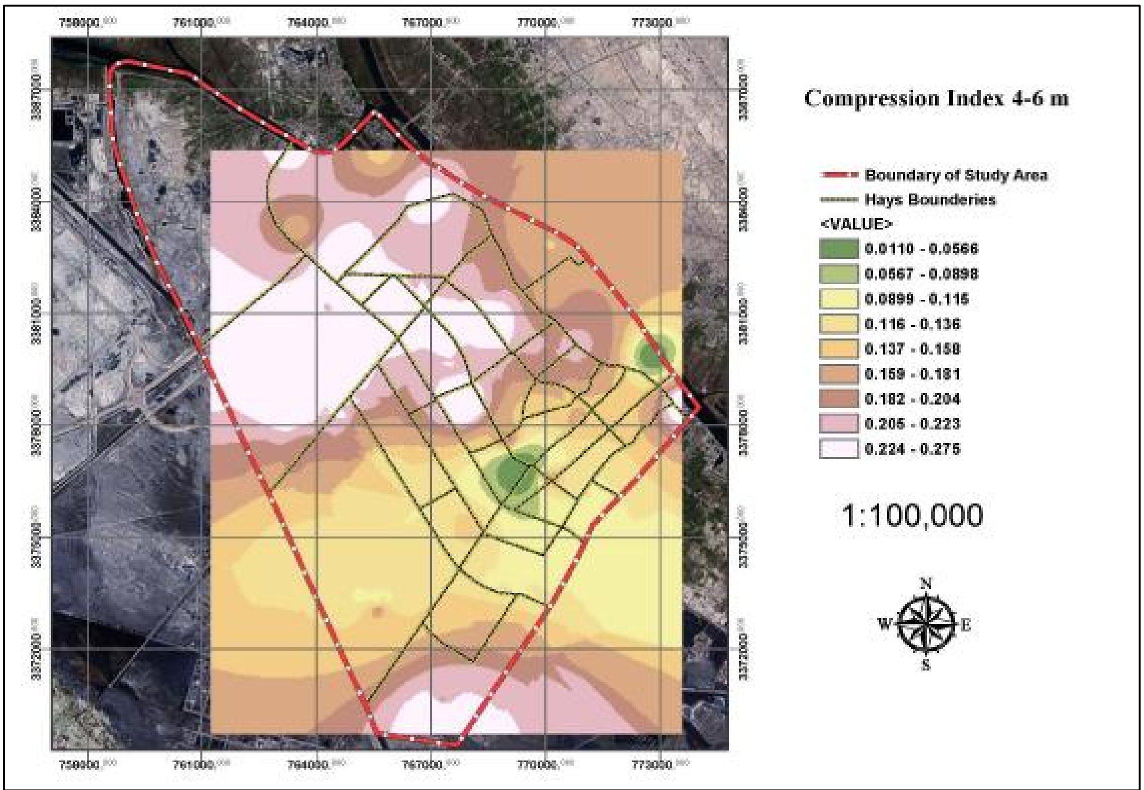

Figure (21) Distribution of compression index at depth 4-6 m across study area

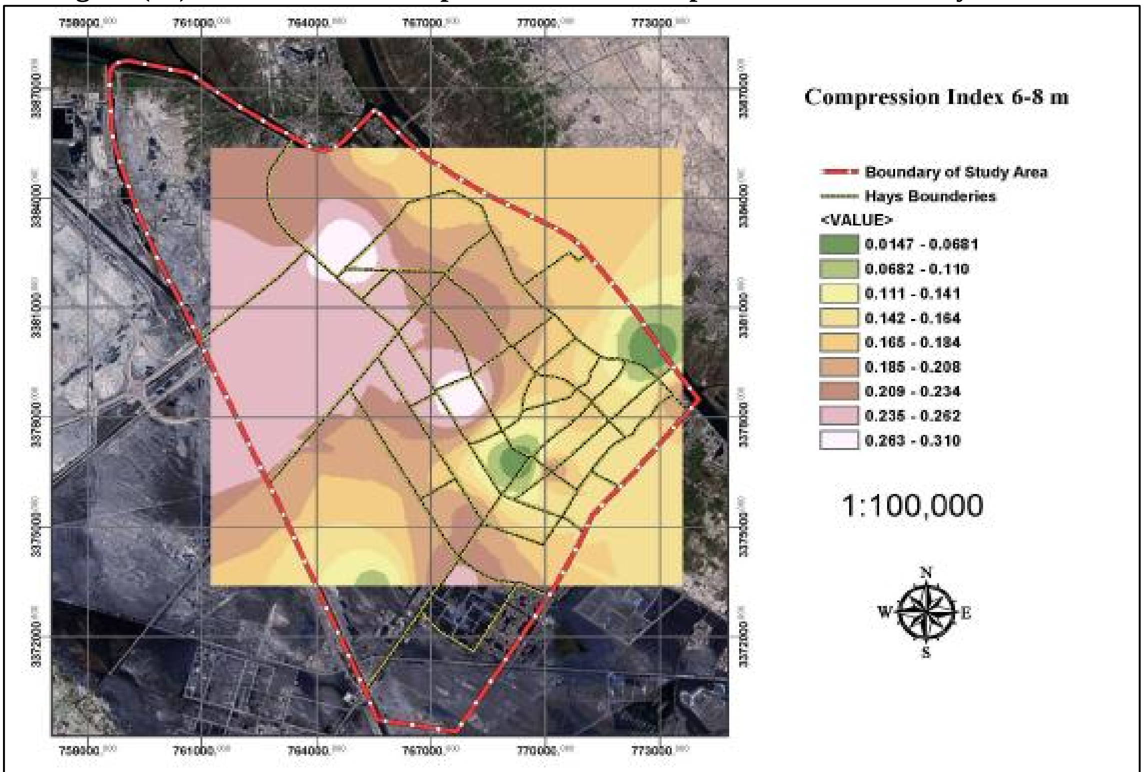

Figure (22) Distribution of compression index at depth 6-8 m across study area.

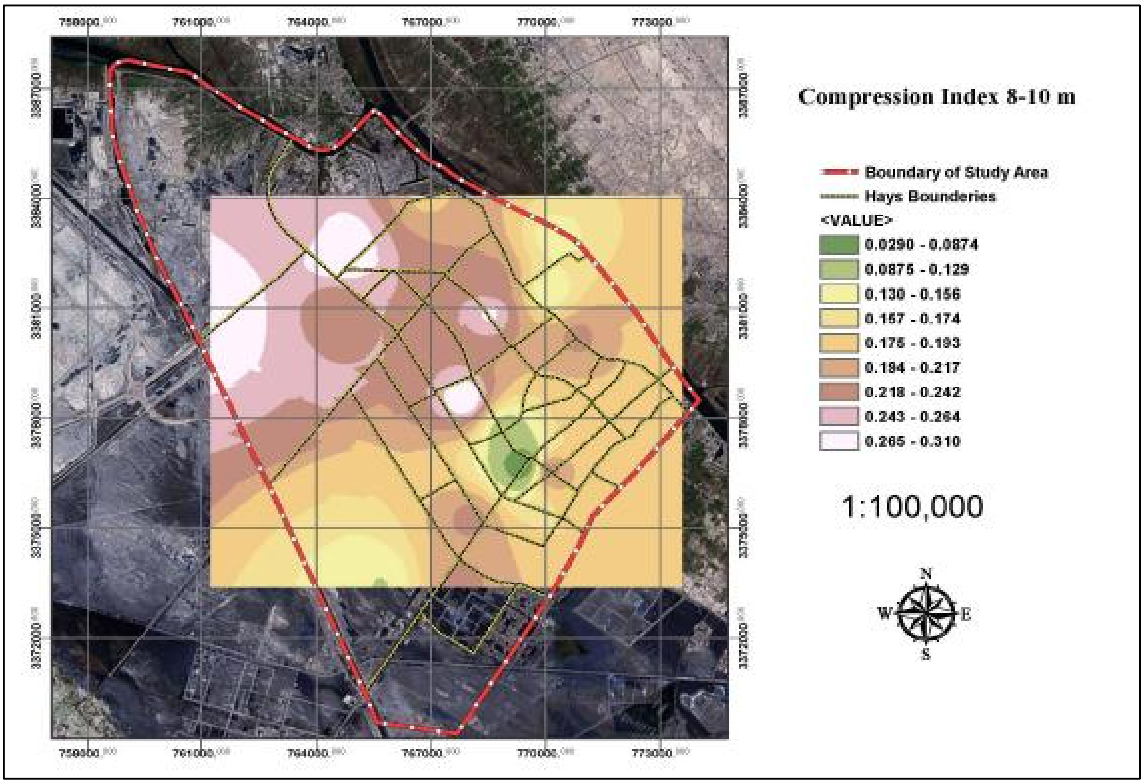

Figure (23) Distribution of compression index at depth 8-10 m across study area.

CONCLUSIONS

Based on the analysis of the collected data from soil investigation reports and on the results and discussion presented above, the following conclusions are drawn:-

1. Basrah soil stratification is erratic in nature and consists of different layers and lenses as a result of its geological history and depositions conditions.
2. The application of digital image enhancement techniques, especially the histogram equalization enhancement, would greatly enhance the images through clarifying the areas of bare soil found in different parts of the study region.
3. The utilization of the geographic information system (GIS) in the work concerning geotechnical engineering helped in linking the geotechnical properties to known and specific locations, and this can be served the geotechnical engineer as very effective tools for non-spatial data area prediction.
4. The digital geotechnical maps, which produce for the study region, presented the distribution of several geotechnical properties; provide a powerful

database and strong visual presentation of the data collected form investigation reports. And use of such maps will save time, cost, effort and easy to use since they represent the data graphically based on their values and their geographic location.

5. Studying the geotechnical properties of the soil in the study region (*Basrah District Center*), which are reported in site investigation reports to 10m depth, showed that there are some imported ranges for some of the properties such as allowable bearing capacity (30-60) kN/m^2, normalized shear strength (c_u/P'_o) (0.08-8.3), liquidity index (-0.811-1.215) and compression index between (0.011) and (0.310).

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