

## Detection of Buried Pipes and Soil Classification Using Remote Sensing

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### ABSTRACT

The research aims to employ microwave remote sensing techniques to classify soil with the traditional classification method and to detect buried pipes in soil and compare the results. The three- band IKONOS image and the one band QUICK BIRD image for the study area were used in this study; in addition a topographic map for Baghdad city was used also in this study. followed by field investigations including activities such as survey operations in the area using the GPS device and collecting soil samples from certain positions. Then the properties of soil are determined, this includes determination the physical properties of soil to be used according to the (USCS), Microwave experimental setup has been operated to work with x band for studying the reflection coefficient of these waves from the moisture content and the texture change of soil. Also an experiment has been done to detect the pipes in soil by using (iron, plastic) pipes material with different diameters to determine and study the changes in reflection coefficient The main results of the study that the spatial merge between the three- bands image (IKONOS) and the one band image (QUICK BIRD) produces a new color image with high resolution for the study area which is considered the best in giving explanation to visual sensing of the kind of soil and it has been found that the soil of the study area is predominated by silt and clay.

### الكشف عن الانابيب المدفونة وتصنيق التربة باستخدام تقنيات التحسس الناب

#### الخلاصة

هدف البحث الى استخدام وتوظيف تقنيات التحسس الناب والميكروفي في تصنيف التربة بالطريقة التقليدية والكشف عن الانابيب المدفونة فيها. حيث استخدمت صورة (QUICK BIRD) ذات حزمة واحدة وكذلك صورة (IKONOS) بثلاث حزم لمنطقة الدراسة وايضاً خارطة طبوغرافية لمدينة بغداد. ثم اجريت التحريات الحقلية التي تضمنت عمليات المسح باستخدام جهاز (GPS) وجمع عينات التربة من المناطق المحددة. ومن ثم اجراء الفحوصات المختبرية من ضمنها فحوصات فيزيائية للتربة تضمنت تصنيف التربة تبعاً الى نظام تصنيف التربة (USCS) ومن ثم اجراء الفحوصات المايكروفي حيث تم استخدام منظومة قياس مايكروفي (Microwave) تعمل ضمن الحزمة (X) وذلك لدراسة معامل الانعكاس من التربة وكذلك دراسة المحتوى الرطوبي والتغير النسيجي لهذه المواد على الانعكاس. وكذلك اجراء تجربة يتم فيها الكشف عن وجود

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الانابيب في التربة بـدفن انابيب مختلفة المعادن (حديد و بلاستيك ) وبأقطار مختلفة ودراسة التغيرات التي تحصل في الانعكاسية.من اهم الاستنتاجات التي توصلت اليها الدراسة توضح ان عملية الدمج الحيزي بين الصورة المتعددة الاطيف مع الصورة ذات الطيف الواحد انتجت صورة ملونة وذات دقة وضوح عالية لمنطقة الدراسة والتي تعد الامثل في عملية التفسير البصري لتحسس نوع التربة حيث وجد ان تربة المنطقة يطغى عليها الطين والغرين.

## INTRODUCTION

**R**emote sensing is the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter. The primary objective of subsoil investigation in civil engineering is to determine the geotechnical properties of the soil underlying the site. One of the applications of the remote sensing is to investigate some soil properties and detect materials in soil. Thus remote sensing data can be analyzed and integrated with the field investigated data to determine the some soil properties for design.

### Aim of Study

The basic purpose of this study is to utilize active and passive Remote sensing techniques for soil classification then explain the capabilities of microwave remote sensing for detection the buried objects such as (pipes)in the soil by performing experimental tests about buried pipes and conducting a comparison between different diameters of buried pipes and their depths. Besides, the study aimed to construct digital geotechnical maps through employing GIS techniques represent by geographic database with the integration of remote sensing data represented by digital satellite image this map contains the geotechnical information about the study area (such as soil classification ,elasticity, plasticity ,allowable bearing capacity ,and moisture content) .

### Study Area

The study area is the Southern West part of Baghdad city known as Al-Nuhrain University site. The area is surrounded from the West by the Tigris River, from the North and East by the Al-Jadiriyy city, and from the South by Baghdad University. The study area is bounded by the coordinates (from 441300.49 to 3682038.60) easting and (from 441297.57 to 3682794.03) northing in zone (38°N) according to UTM geographic coordinate system. The study area has an about (177400.75) m<sup>2</sup>, as illustrated by Figure (1).



**Figure (1) Study Area /Al-Nuhrain University Site**

### **Experimental Work**

The experimental work is including 2 steps which are (Field measurements, Laboratory tests) .

Field measurements are also divided into:

- a) Point selection of soil samples by GPS.
- b) Spectral reflectance and microwave reflection measurements.
- c) Pipes detection

Laboratory tests are also divided into:

- a) Soil analysis.
- b) GIS techniques.

### **Field Measurements**

#### **A) GPS Observation**

The field measurements, GPS (Germen GPS10) observations were presented by acquiring the locations of 13 soil samples in the study area, their coordinates are listed in Table (1), also illustrated in Figure (2).

Table (1) The coordinates of soil samples location.

Point	Easting	Northing
1	441983	3682314.26
2	442034	3682263.60
3	441870	3682322.44
4	441693	3682418.21
5	441864	3682482.60
6	442012	3682339.12
7	441990	3682461.21
8	441948	3682535.15
9	441718	3682341.01
10	441815	3682271.78
11	441699	3682269.26
12	441799	3682212.31
13	441781	3682143.08

**B) Spectral Reflectance and Microwave Reflection Measurements**

Radiometer is a very important device for studying the objectives of field work represented by the field investigations, reconnaissance of the study area and acquiring of soil samples. Multiband radiometer with 3 channels used to measure the spectral reflectance and 1 channel to measure the radar reflection for soil and materials. Radiometer records this radiation as electrical signal, which must be transferred to radiation by using following equations:

$$L = C_1 V_1 \quad \dots \quad (1)$$

$$\text{Spectral reflectance (R\%)} = \frac{\text{Radiance (volt)*Calibration factor}}{\text{Irradiance (volt)*Calibration factor}} \quad \dots(2)$$

$$R_{ch} = P_t/P_r \quad \% \quad \dots(3)$$

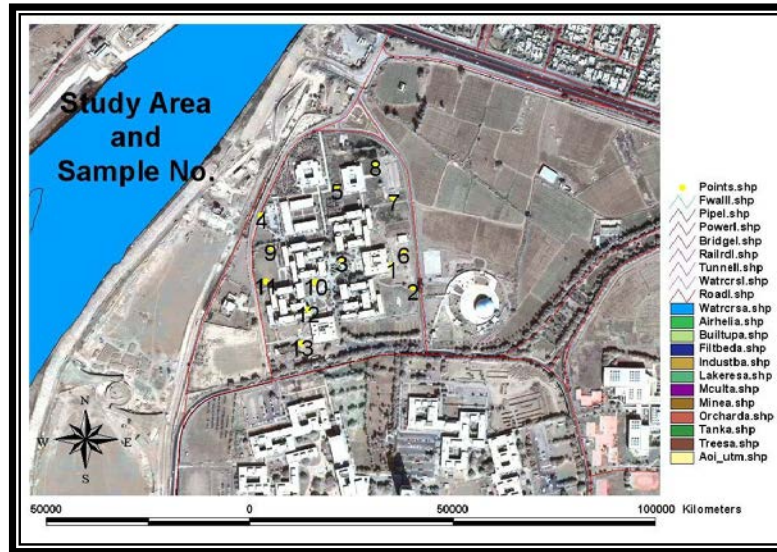


Figure (2) The distribution of soil samples in the study area.

**C) Pipes Detection**

Various materials may be tested with more than one measurement method to improve the spectral behavior of these materials spectral reflectance, Emittance and reflection coefficient for them with microwave detection.

Different pipes made of materials (iron, plastic) with different diameters (0.5in, 1in, and 2in) were used in this experiment. This experiment included two stages; first was recording the reflection of each pipe that is buried in soil at different depths (4, 6, 8, 10cm) and second was making a comparison between them. Then other experimental was made to detect any leak that can happen in pipes underground and also made a compression between the leaked and in leaked pipe. Figures(3),(4) show the buried pipes.

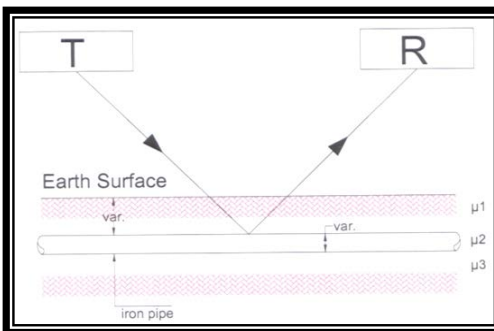


Figure (3) iron pipes buried in soil

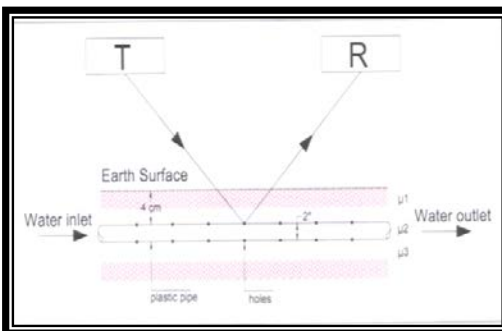


Figure (4) Plastic Pipe with holes in soil

### **laboratories Work**

Laboratory work includes lab tests and application of remote sensing and GIS techniques to soil classification as follow:

#### **Laboratory Tests**

Many tests were executed to determine some of physical properties in the laboratory of the Soil Mechanics Laboratory in the University of Technology as follows:

#### **A) Moisture Content**

The soil moisture content is the characteristic which is most frequently determined, and applied to all types of soils [12]. The moisture content test of soil samples were performed directly after samples collection.

#### **B) Grain Size Distribution**

The distribution of grain sizes in soil samples was determined, to identify the nature of soils that are generally encountered. Soils of study region consist of coarse and fine-grained (fine gravel, sand, silt and clay). Sieve analysis test was executed using the sieves No.4 (94.76mm), No.10 (2mm), No.40 (0.42mm), No.100 (0.194mm) and No.200 (0.075mm) and hydrometer analysis test for less than(0.075mm) or for very fine clay.

#### **C) Liquid and Plastic Limits**

Liquid Limit test was carried out using a Casagrandi apparatus. Plastic Limit test was carried out to evaluate the plasticity of a given soil sample according to [7].

#### **D) Plasticity Index (PI)**

The differences between LL and PL of a soil are defined as the plasticity index (PI or IP) [7].

### **Digital image processing**

Using a computer and specialized software, digital images can be manipulated and interpreted to accomplish one or more of the following:

1. Image processing (Geometric and Radiometric).
2. Image enhancement.
3. Image classification.

## **Results and Discussion**

### **Field Survey**

The coordinates of the 13 points was fixed and determined with the aid of the GPS instrument. The locations of the points are stated earlier in chapter four.

### **Laboratory Tests**

The results of laboratory tests for 13 soil samples are listed in Table (2) as follows:

**Table (2) Classification of soil according to USCS system**

Sample No.	W.C %	L.L %	P.L %	P.I %	Clay %	Silt %	Sand %	Gravel %	Name	Description
1	1.29	26	20	7	18	32.3	49.55	0.15	CL-ML	Inorganic clays, sandy clays, silt clays
2	4.01	13	10	3	12.5	35.9	51	0.6	ML	Inorganic silt, very fine sands, rock flour
3	9.2	37	23	14	29.65	50.9	19.4	0.05	CL	Inorganic clays, (low to medium plasticity)
4	17.01	38	22	16	15.90	71.2	12.4	0.5	CL	Inorganic clays, (low to medium plasticity)
5	11.16	35	20	14	26.08	51.47	22.15	0.3	CL	Inorganic clays, (low to medium plasticity)
6	7.0	31	17	14	18.80	49.55	30.35	1.3	CL	Inorganic clays, (low to medium plasticity)
7	1.39	30	28	2	20.10	53.55	25.55	0.8	ML	Inorganic silts, very fine sands, rock flour
8	2.33	34	22	11	27.35	60.25	11.55	0.85	CL	Inorganic clays, (low to medium plasticity)
9	17.37	40	23	17	29.5	52.1	18.35	0.05	CL	Inorganic clays, (low to medium plasticity)
10	3.30	41	24	17	26.05	52.65	21.15	0.15	CL	Inorganic clays, (low to medium plasticity)
11	25	42	24	19	25.20	54.45	19.85	0.5	CL	Inorganic clays, (low to medium plasticity)
12	19.05	32	26	6	28	63.05	7.95	1.0	ML	Inorganic silts, very fine sands, rock flour
13	24.16	34	19	15	29.90	51.25	18.3	0.55	CL	Inorganic clays, (low to medium plasticity)

### Applying Remote Sensing Techniques

The results of applying remote sensing techniques (reflectance and reflection measurements, pipes detection, enhancement and classification) are presented as follows:

### Experimental test to the materials buried in the soil

Features such as (pipes) were tested with X-band portion of microwave. To identify the spectral behavior of the pipes a field test bench was prepared for this goal and the tests results are explained in microwave curves in figures (31) and (32). Figure (31) that show the reflection coefficient of pipe (2in) is low as compare with pipe (0.5in). For that the reflection coefficient increases as the diameter decreases. The figure (32) shows that high reflection of the leaked pipe in compared with the same pipe without any leak due to the reflection of water that leaked from the pipe.

### Results of GIS Techniques

One of the advantages of using GIS software (Arc Map 9.1) which is able to perform operations that relate values of one location to those at neighboring locations. Geotechnical engineers usually present the interpretation of test results in soil profiles across a section (or sections) for the area in question. With the facilities of GIS, it is possible to present a digital geotechnical map that shows the distribution of any property across the study area as a new layer, and various layers can be produced which can show graphically the distribution of any property. Physical and some geotechnical properties can be arranged through the GIS software Arc Map9.1 by producing the layers which show the distribution of those properties across the study area. Figure (33) represents the distribution of soil types in the study area that are classified according to USCS. On the other hand, figures (34, 35, 36, 37,38,39,40, and 41) present the distribution of physical tests in the study area.

### Bearing Capacity

The values of bearing capacity in the area vary between (62.79-95.67) KN/m<sup>2</sup> as shown in figure (42). The bearing capacity was measured at a depth of (2-3) meters as set in the investigation reports used in this study. The allowable bearing capacity adopted by the investigation reports was those values evaluated using one of the following methods, than taking the most critical value (minimum) to be the convenient allowable bearing capacity:

- 1- The bearing capacity was calculated according to Terzaghi (Equation4,5,6)

$$q_{ult} = cN_c S_c D_c + qN_q S_q d_q + 0.5\gamma B N_\gamma S_\gamma d_\gamma \quad \dots(4)$$

- 2- Bearing capacity for foundation on undrained saturated clay for  $\Phi=0$ , the general expression will be:

$$q_{ult} = cN_c + \gamma D_f \text{ (i.e. } N_a = 1, N_\gamma = 0) \quad \dots(5)$$

- 3- The net allowable bearing capacity of clay or plastic silt is approximately equal to the unconfined compressive strength .

- 4- The bearing capacity calculated from SPT results using the equation which is suitable for cohesion less soil for (25 mm) settlement:

$$q_{ult} = N/0.008((B + 0.3)/B)^2 (1 + 0.33 D_f/B) \quad \dots (6)$$



## **CONCLUSIONS**

The main conclusions that can be drawn from this research are summarized as follows:

- 1- The digital geotechnical maps produced for the study area which employed the geotechnical properties in GIS techniques are representative, easy to use, and save time and cost since they represent the ground truth in a simple manner.
- 2- The spectral reflectance and reflection coefficients of soil are influenced by the differences in surface composition texture (grain size distribution of soils) and moisture content.
- 3- In the first experimental work the microwave reflection for buried pipes in soil depends on their diameter, the decrease in diameter gives high reflection due to increase in diameter, but in the second experimental the reflection coefficient for pipe with leak increases due to the reflection of water.
- 4- Joining of traditional data (the soil classification according to USCS) with RS techniques are very important and essential for soil thematic mapping, especially when there is a difference between acquiring space images date and soil investigations date (samples collecting).

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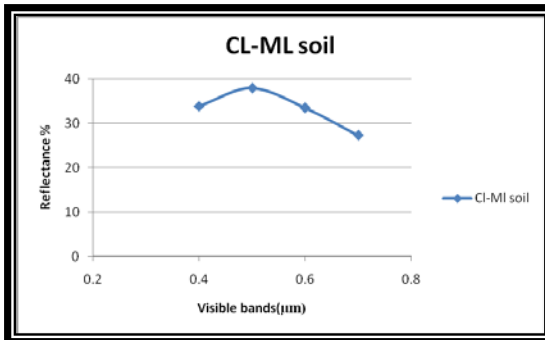


Figure (5) The reflectance of Sample 1

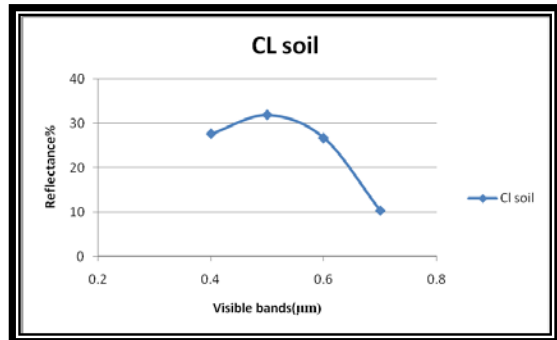


Figure (6) The reflectance of Sample 2

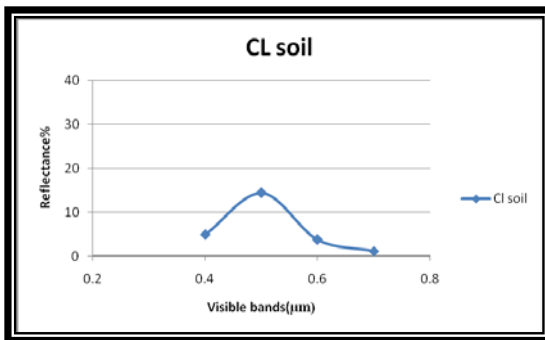


Figure (7) The reflectance of Sample 3

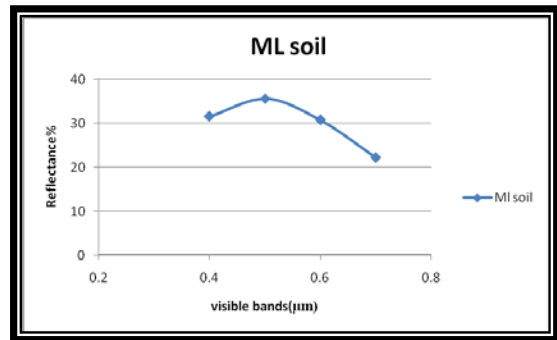


Figure (8) The reflectance of Sample 7

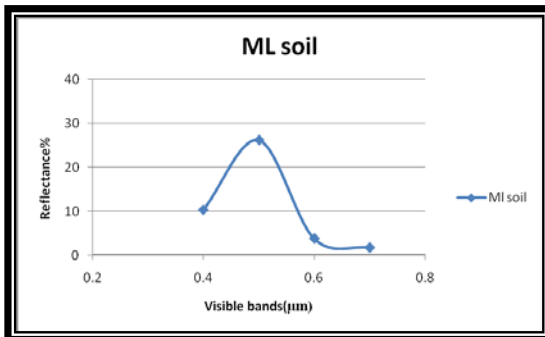


Figure (9) The reflectance of Sample 12.

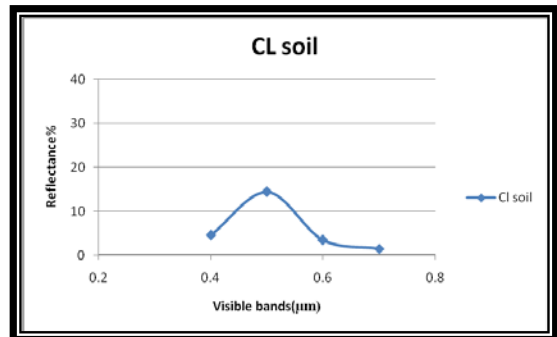


Figure (10) The reflectance of Sample 13.

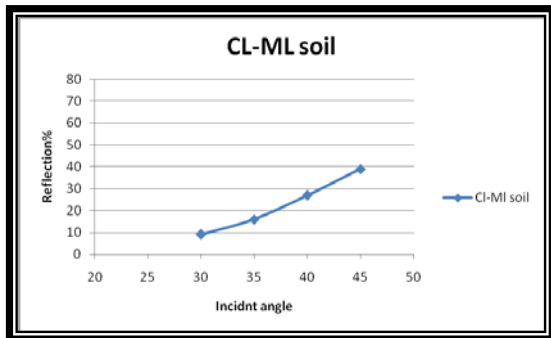


Figure (11) The reflection of Sample 1

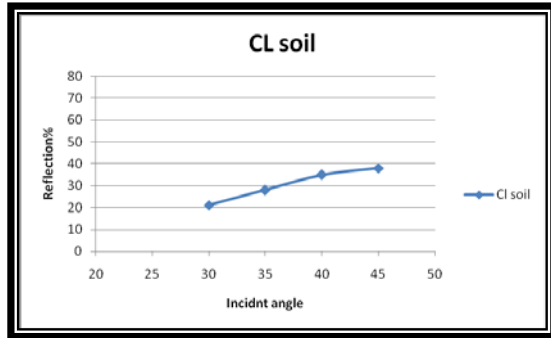


Figure (12) The reflection of Sample 2

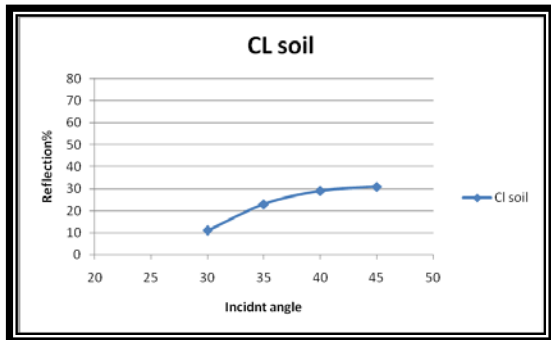


Figure (13) The reflection of Sample 3

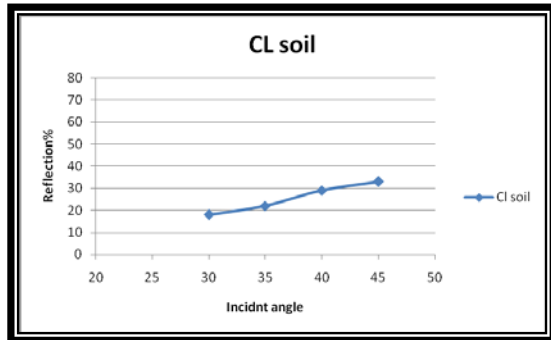


Figure (14) The reflection of Sample 4

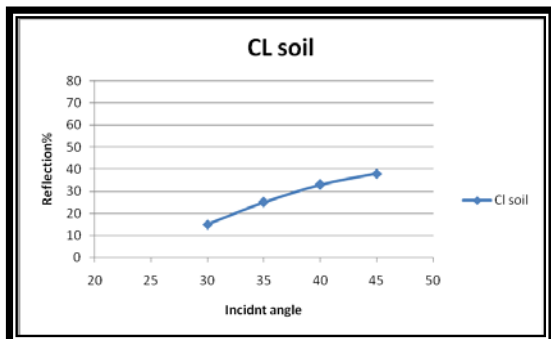


Figure (15) The reflection of Sample 5

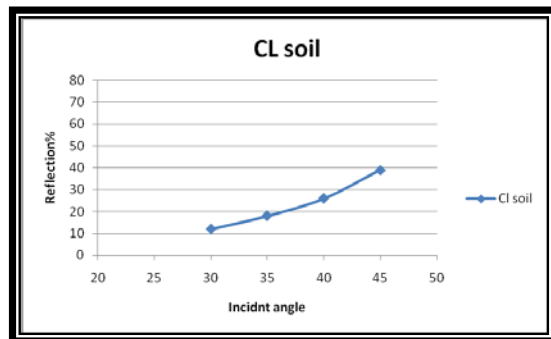


Figure (16) The reflection of Sample 6

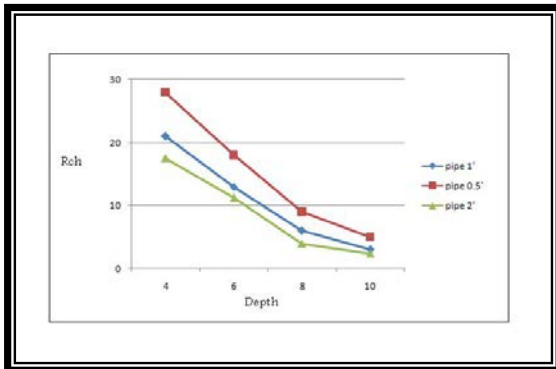


Figure (17) The reflection of pipes

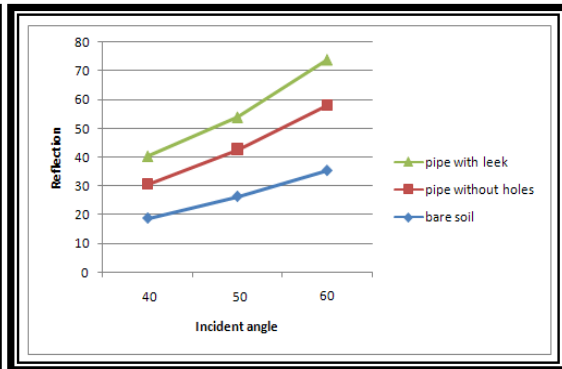


Figure (18) The reflection of leaked pipe

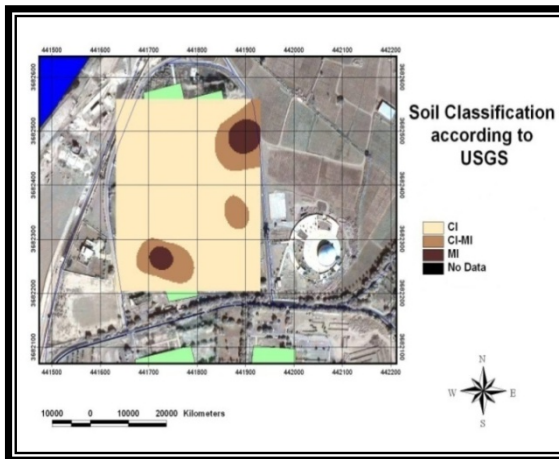


Figure (19) Soil classification according to USCS across the study area

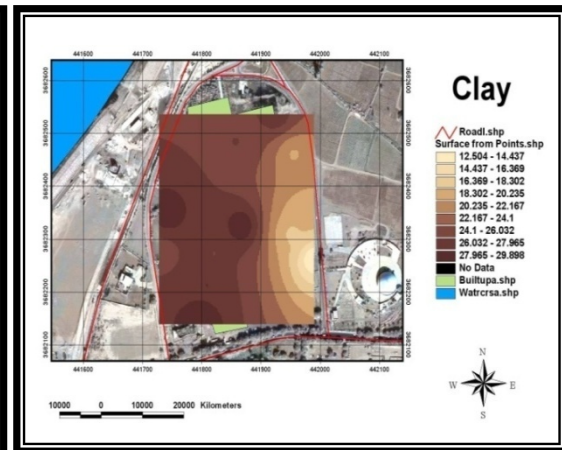


Figure (20) The distribution of Clay % across the study area

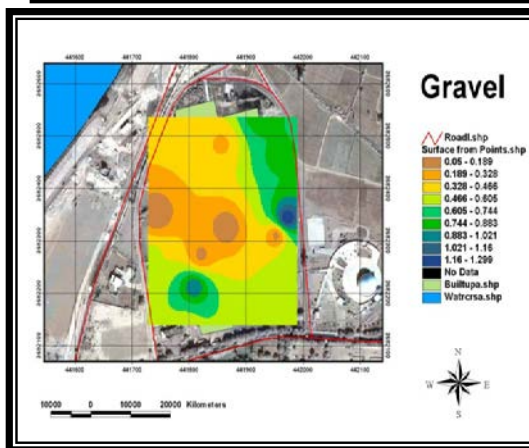


Figure (21 )The distribution of Gravel % across the study area

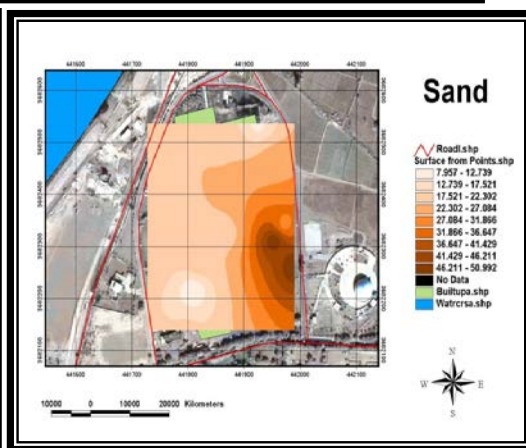


Figure (22 )The distribution of Sand % across the study area

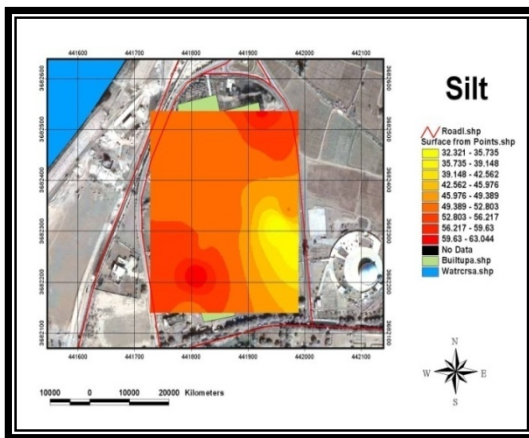


Figure (23 )The distribution of Silt % across the study area

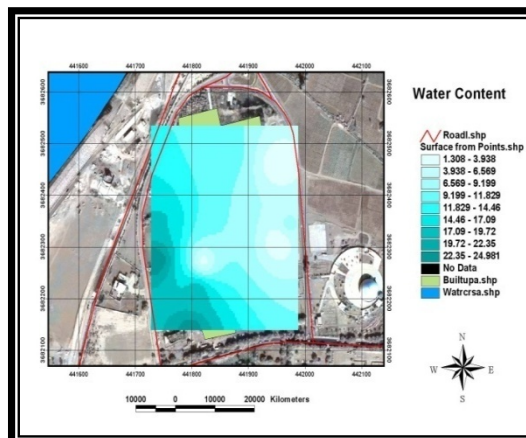


Figure (24 )The distribution of Water Content % across the study area

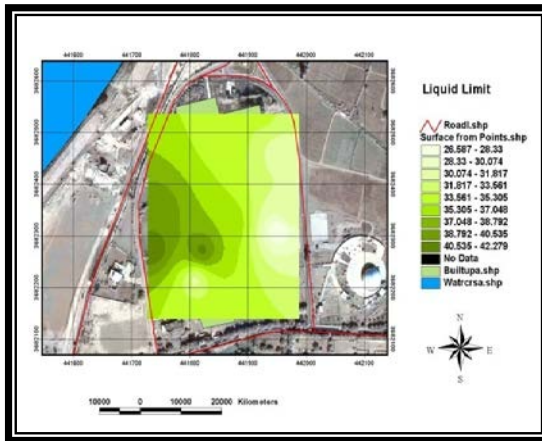


Figure (25) the distribution of Liquid Limit % across the study area

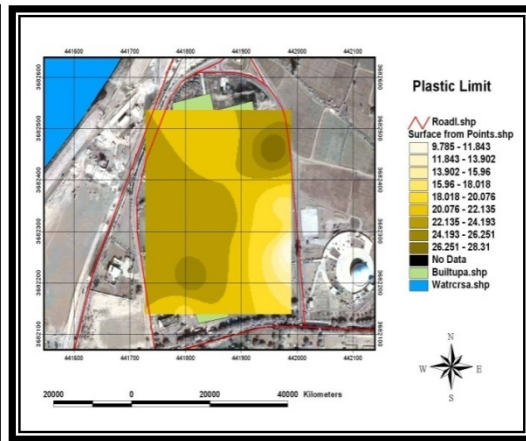


Figure (26) The distribution of PI % across the study area

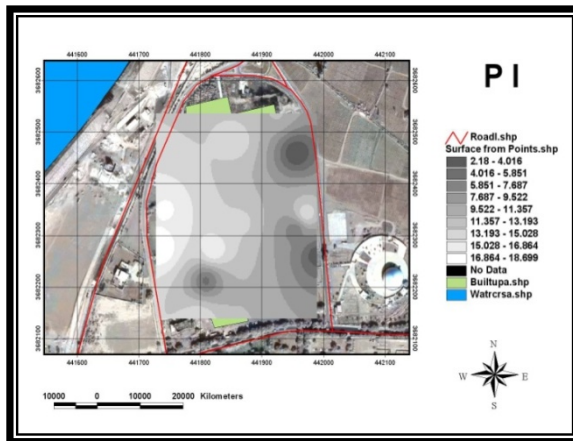


Figure (26) The distribution of Plastic Limit % across the study area

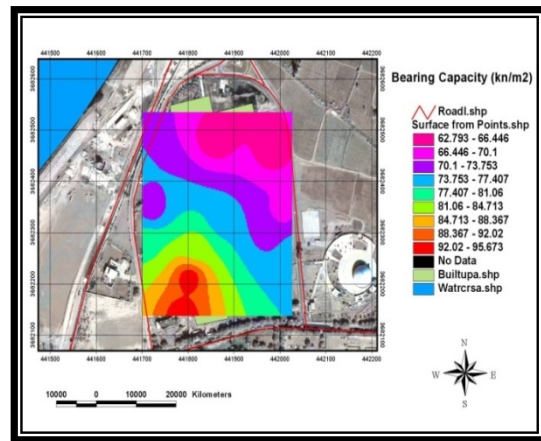


Figure (27) The distribution of Bearing Capacity across the study area