CERTIFICATION OF APPROVAL

Spatial Variability of Soil Engineering Properties at UTP Campus

by

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

RODZLEANA BT ABDUL RAZAK

ABSTRACT

Soil engineering properties spatial characterization are important for several form of analysis such as to determine the optimum size of spatial grids for distributed parameter hydrological models, estimating point or spatially averaged values of soil properties using kriging technique, and also in designing sampling networks and improving their efficiency. The primary objectives of this study are to characterize spatial structure of soil properties under tropical climate in terms of semivariogram parameters, to map the variation in soil properties in Universiti Teknologi Petronas, and to evaluate the effect of land use changes on the variability of soil properties. Laboratory analysis was done on two samples from each location. For each soil sample, five soil engineering properties are determined in the laboratory: bulk density, moisture content, specific gravity, particle size distribution, and the organic content. The results of the laboratory tests on soil engineering properties were subjected to two types of analysis: normal statistical and geostatistical analysis. All of the soil properties in the study area have a moderate spatial dependency since the ratio is within 25% and 75% but fine content has the lowest ratio which is 3.48%. Large spatial variability of moisture content was found exist in the study area and the degree of variability was heterogeneous among different soil properties. These various degrees of heterogeneity observed between different soil properties examined clearly indicate the highly complex and variable nature of tropical soils within a relatively small area. The variation in soil properties in the study area is produced in the form of maps, and the effect of land use changes on the variability of soil properties is evaluated. Land disturbances, forest clearance and topographic conditions all contributed to the variability of soil properties.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

Soils are characterized by a high degree of spatial variability due to the combined action of physical, chemical, or biological processes that operate with different intensities and at different scales (Goovaerts, 1998)

Soil properties vary spatially even within homogeneous layers as a result of depositional and post depositional processes that cause variation in properties (Lacasse and Nadim, 1996). Nevertheless, most geotechnical analyses adopt a deterministic approach based on single soil parameters applied to each distinct layer.

Spatial variability of soil physical properties within or among agricultural fields is inherent in nature due to geologic and pedologic soil forming factors, but some of the variability may be induced by tillage and other management practices. These factors interact with each other across spatial and temporal scales, and are further modified locally by erosion and deposition processes.

Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response. One of the major issues in distributed parameter hydrological modeling is how to estimate attributes of spatially varying soil properties.

This proposed project will allow understanding and characterization of small scale spatial variability nature of physical and hydraulic properties of tropical soil in the Universiti Teknologi Petronas, Tronoh area in Perak State, Malaysia. This will also allow identifying effect of land disturbance and catchment characteristics in Tronoh area. Apart from that, this study will also enhance the understanding of the spatial variability in soil engineering properties and its effects on the hydrological processes.

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

Geotechnical engineers often face important discrepancies between the observed and the predicted behavior of geosystems. Two conceptual frameworks are hypothesized as possible causes: the ubiquitous spatial variability in soil properties and process-dependent terminal densities inherent to granular materials. The effects of spatial variability are explored within conduction and diffusion processes. Mixtures, layered systems, inclusions and random fields are considered, using numerical, experimental and analytical methods. Results include effective medium parameters and convenient design and analysis tools for various common engineering cases. In addition, the implications of spatial variability on inverse problems in diffusion are numerically explored for the common case of layered media.

Spatial variability causes difficulty in representing a soil with a deterministic or precisely defined set of characteristics and precludes characterization of soil hydrological response. Recently, there has been increasing concern about how to estimate attributes of spatially varying soil properties

Soil engineering properties spatial characterization are important for several form of analysis such as to determine the optimum size of spatial grids for distributed parameter hydrological models, estimating point or spatially averaged values of soil properties using kriging technique , and also in designing sampling networks and improving their efficiency. Therefore, spatial variability of soil properties should be monitored and quantified.

Lastly, geostatistical characterization of soil engineering properties from the humid tropics particularly, the south-east Asia has been scanty. Most previous studies from this region, particularly Malaysia have focused on geostatistical characterization of spatial variability of soil nutrients in relation to farming practices (e.g. Swapan et al., 2001; Eltaib et al., 2002; 2003). It also appears that no geostatistical study has been reported on evaluation of spatial variability of soil engineering properties at small and regional scale. Hence this study is required in order to obtain such data.

1.2.2 Significance

The variability of soil engineering properties has significant impact on many hydrological processes. For example, the spatial distribution of soil moisture content effects infiltration of water into the soil, lateral soil moisture redistribution as well as determines rainfall-runoff responses in many catchments (Anctil et at., 2002). The heterogeneity and variability of soil properties has important influence on processes such as erosion (Western et al., 1998), solute transport (Netto et al., 1999), soil-water retention, soil swelling, shrinking, seepage (Mapa, 1995; Guan and Fredlund, 1999), CO2 emission from soil (Scala et al., 2000), various soil-inhabiting biota (Brukner et al., 1999), and soil fertility (Delcourt, et al., 1996). Properties of soils under tropical climates exhibit more spatial variability due to their greater exposure to harsh climatic conditions (Mapa and Kumaragamage, 1996).

Characterization of spatial structure of soil engineering properties are important for several form of analysis: (i) to determine the optimum size of spatial grids for distributed parameter hydrological models (Anctil et al., 2002), (ii) estimating point or spatially averaged values of soil properties using kriging technique (e.g. Bardossy and Lehmann, 1998), (iii) in designing sampling networks and improving their efficiency (e.g. Prakash and Singh, 2000). Therefore, spatial variability of soil properties should be monitored and quantified. It also appears that no geostatistical study has been reported on evaluation of spatial variability of soil engineering properties at small and regional scale.

The proposed project will allow understanding and characterization of small scale spatial variability nature of physical properties of tropical soil in the Tronoh area in Perak State, Malaysia.

1.3 OBJECTIVES

The primary objectives of this study are

i. To characterize spatial structure of soil properties under tropical climate in terms of semivariogram parameters
ii. To map the variation in soil properties in the study area, and
iii. To evaluate the effect of land use changes on the variability of soil properties.

1.4 SCOPE OF STUDY

For this project, the scope of study will be determining the spatial variability of soil engineering properties within UTP campus.

1.5 FINDINGS

Results from this project are expected to contribute to the understanding and characterization of small scale spatial variability nature of physical properties of tropical soil.

CHAPTER 2

LITERATURE REVIEW

Many physical systems in general and soil materials in particular exhibit relatively large variability in their properties, even within so called homogeneous zones. Deterministic descriptions of this spatial variability are not feasible due to prohibitive cost of sampling and to uncertainties induced by measurement errors. A more rational approach to geotechnical design is made possible by use of stochastic field based techniques of data analysis, which rely more on analytical methods when dealing with various uncertainties related to soil properties.

The probabilistic characteristics of spatial variability of soil properties are studied based on two sets of in-situ measurement results. The first case study uses the results of a two dimensional measurement array consisting of 24 standard penetration test profiles, performed in a natural soil deposit in the Tokyo Bay area, Japan. The second case is based on the results of a series of cone penetration tests performed at an artificial island in the Canadian Beaufort Sea. Though measured in a supposedly homogeneous man-made soil deposit, the recorded cone tip resistance shows significant spatial variations.

The soil properties are modeled as the components of a multi-dimensional, multi-variate, non-Gaussian stochastic field, and the probabilistic characteristics of the stochastic field are estimated based on the in-situ soil test results, using the method of moments and a nonlinear regression procedure. The probability distributions, coefficients of variation, and correlation distances exhibited by the soil properties in the two cases analyzed (a natural and a man-made soil deposit), can be used as guidelines for stochastic analysis of similar soil deposits.

The spatial variation of productivity across farm fields can be classified by delineating site-specific management zones. Since productivity is influenced by soil characteristics, the spatial pattern of productivity could be caused by a corresponding variation in certain soil properties. Determining the source of variation in productivity can help achieve more effective site-specific management.

Based on study by Mzuku Et Al. (2005), Spatial Variability of Measured Soil Properties, the objectives of this study were to characterize the spatial variability of soil physical properties across irrigated corn production fields and to determine if soil physical properties could explain the variability in productivity between site-specific management zones. The study was conducted over three study sites in northeastern Colorado. The soil properties measured were bulk density, cone index, surface soil color, organic C, texture, sorptivity, and surface water content. A multi response permutation procedure was used to test for significant differences among soil properties between management zones.

Box plots of soil physical properties were created for each management zone within each study site to determine if trends in soil physical properties corresponded to the productivity potential of the management zones. Overall, this study showed that soil physical properties exhibited significant spatial variability across production fields. The trends observed for the measured soil physical properties corresponded to the productivity potential of the management zones. Utilizing site-specific management zones could help manage the in-field variability of yield- limiting soil physical properties.

CHAPTER 3
METHODOLOGY

3.1 THE STUDY AREA

The study was conducted in the Universiti Teknologi Petronas (UTP) campus area located on a flat plain in Tronoh. The campus area is 400 hectare (1,000 acre). Tronoh is a small tin-mining town located some 30 km south of the Perak state capital Ipoh in Malaysia hence there are many ponds around campus due to abandon tin mines. UTP is situated between longitude of 100° 57' 28.18" E and 100° 58' 34.21" E and latitude 4° 22' 16.91" N and 4° 23' 25.72" N.

The climate at the study area is typical of the humid tropics and is characterized by year-round high temperature and seasonal heavy rain. Daily temperature ranges from 25°- 32°C and the annual rainfall varies between 1700 to 2500 mm. (Tourism Malaysia Portal, 2008)

3.2 SAMPLE POINT / COORDINATE

To determine the point/coordinate of sample collections, Global Positioning System (GPS) is used. Longitude and latitude of two points was established, one near the Multi Purpose Hall with 100°58'15.29499E longitude and 4°23'03.05825N latitude and another point is at the helicopter pad with 4°22'48.28137N latitude and 100°57'57.28015E longitude. With the introduction of GPS and GIS, the spatial variability of soil properties was measured and analyzed using traditional statistics method and geo-statistics. The system is used because it has been developed so that a user at any point on or near Earth can obtain three-dimensional coordinates instantaneously. These fixes can be taken at any time of the day or night and in any weather conditions.

3.3 STUDY AREA TOPOGRAPHIC MAP

A topographic map of UTP is required before commencement of work. After the map is obtained and scanned, the map is digitized using CorelDraw9 software. The map is traced with different layers according to different requirement such as buildings, contour line, ponds, roads and etc.

This map is used to divide the campus area by a number of regular geo-grids based on the longitudes and latitude obtained from GPS. Soil samples were collected at each grid-node. During field sampling the grid-node locations were established by a portable Global Positioning System (GPS) unit with an error of ±1m. Fifty soil samples were collected during the sampling program. The soil sampling locations is shown on the map.

The usage of the map is more significant during the statistical and geostatistical analysis to show the spatial variability of data obtained. Spatial distribution maps and semivariogram was drawn based on the maps and tracings.

Figure 1: Plan View of Study Area

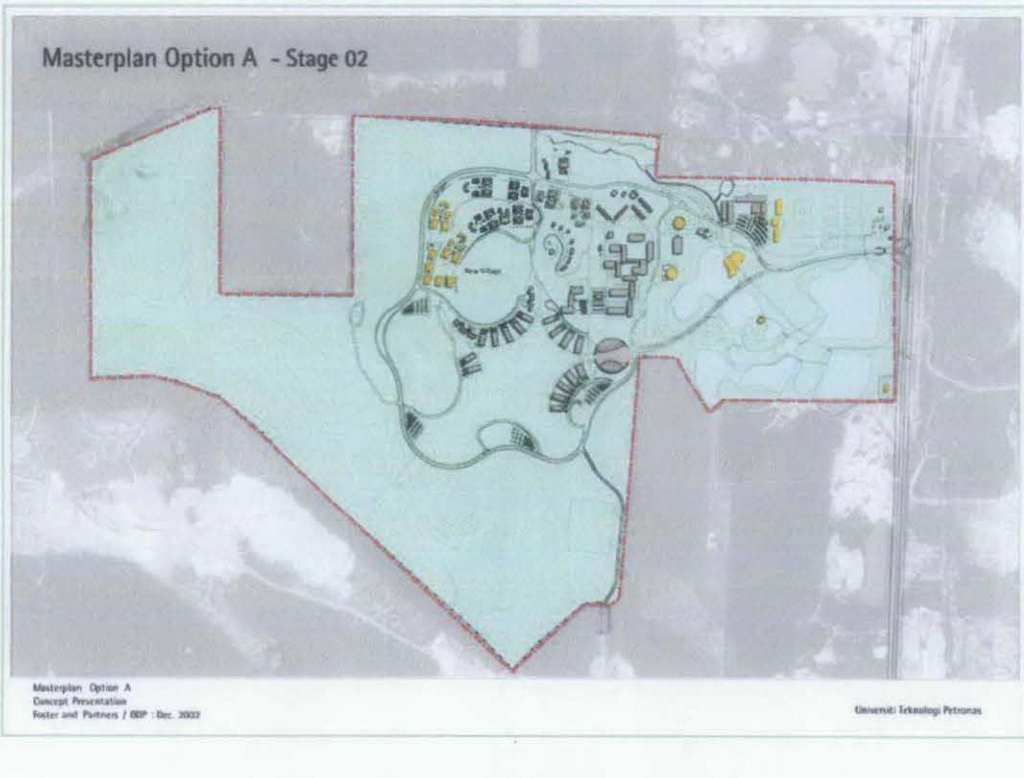


Figure 2: Map of Study Area

3.4 SAMPLE COLLECTION

The grid-sampling method was used for this study on the premise that grid-sampling reduces the possibility of uneven or clustered samples. The campus area was divided by a number of regular geo-grids. Sampling location which fell on paved area or on buildings or where the sampling location was inaccessible (wet areas) were omitted. In certain occasion where the sampling location fell at the corner of a paved area or at the corner of a building, soil samples were collected from the adjacent ground.

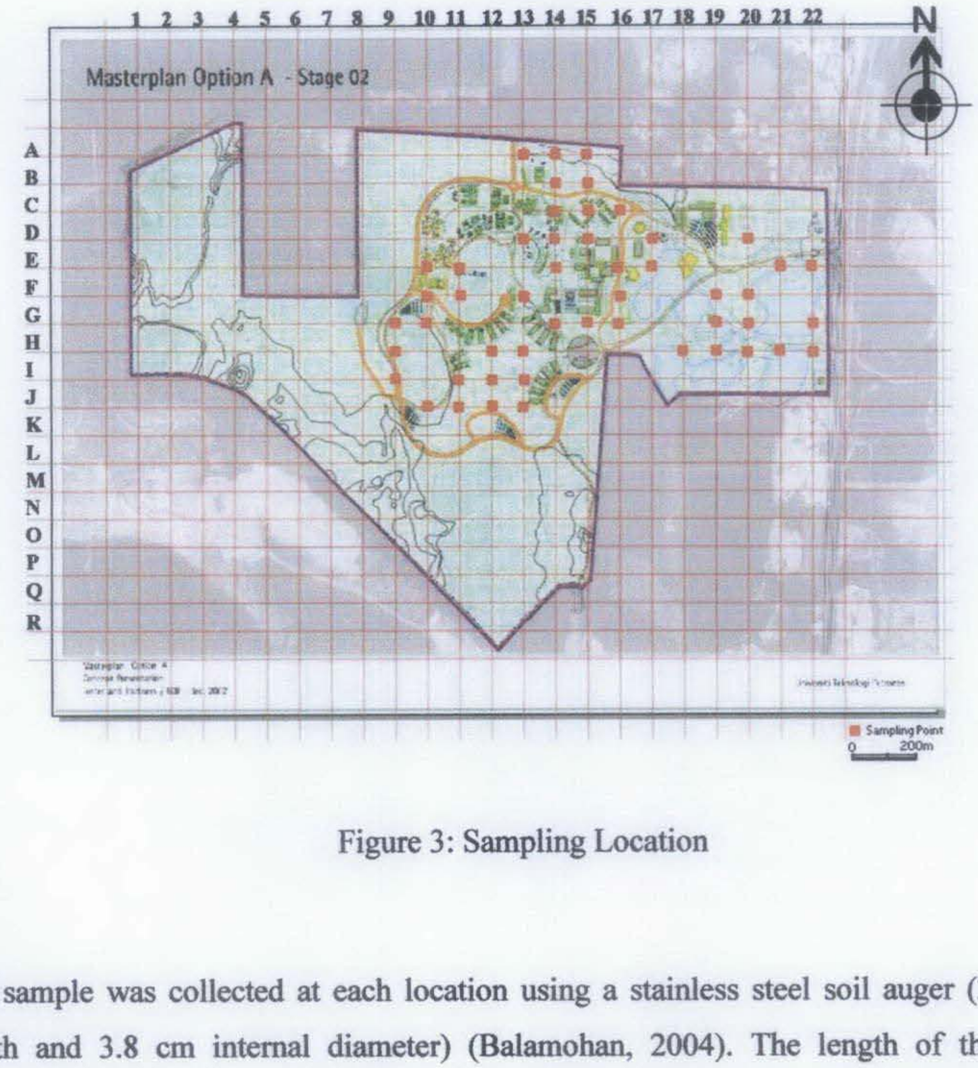


Figure 3: Sampling Location

Soil sample was collected at each location using a stainless steel soil auger (23 cm length and 3.8 cm internal diameter) (Balamohan, 2004). The length of the soil samples collected was about 20 cm. Each core sample, after extrusion from the sampler was divided into two sub-samples to represent two samples from each location. The soil samples was sealed into plastic bags and transferred to the laboratory for analysis.

3.5 LABORATORY ANALYSIS

Laboratory analysis was done on two samples from each location and the mean result is used for analysis. For each soil sample, five soil engineering properties are determined in the laboratory: bulk density, moisture content, specific gravity, particle size distribution, and the organic content. All laboratory tests are performed in accordance with BS 1377 (1990).

3.5.1 Bulk Density

Soil bulk density was determined from the ratio of sample mass and sample volume. The sample volume was calculated by measuring sample length and cross sectional area and the sample mass was obtained from the dry weight of the sample subjected to oven drying at 110°C for 24 hours.

3.5.2 Moisture Content

Water is present in most naturally occurring sol. The amount of water, expresses as a proportion by mass of the dry solid particles, known as the moisture content, has a profound effect on soil behaviour. In this context a soil is 'dry' when no further water can be removed. Soil moisture content was determined from the difference between the wet weight (field sample) and dry weight (subjected to oven drying at 110°C for 24 hours) of the sample and expressed as a percentage of the dry weight of the sample.

Procedure:

1. Two sub-samples were taken from the top and bottom of the original samples to get an average value of the soil moisture content as the soil moisture content varies with depth.
2. The container is cleaned and dried and weigh it to the nearest 0.01g. The weight is recorded.

3. The samples are placed in the container. Each container with wet soil is weighted and the weight is recorded. The weighing process must be done immediately to avoid loss of water due to evaporation.
4. The container with wet soil was then dried in oven at 110°C for 24 hours. The weight of the container and the dried samples is recorded.
5. The changes in weight of the sample are the weight of water or moisture content in the sample. The moisture content of soil is expressed as a percentage of its dry mass:

$$\text{Moisture content, } W = \frac{\text{Moisture loss} \times 100\%}{\text{Dry mass}}$$

6. The average value of both samples is used for the computer analysis.

3.5.3 Specific Gravity

Sample specific gravity was determined by the gas-jar method. Sample specific gravity data was used in hydrometer analyses but were not intended for spatial variability analysis.

Procedure:

1. 500g of the soil sample is taken and sieved. All coarse particle retained on a 20mm test sieve have to be broken down
2. 400 g of sieved specimens is taken and oven dried at 110° C and then stored the specimen in an airtight containers until required
3. The pyknometer is cleaned and dried and the whole assembly is weighted to the nearest 0.5 g (m1).
4. The screw top is removed and the specimen is transferred from its sealed container directly into the jar.
5. The jar, the screw-top and its content assembly is weighted to the nearest 0.5g (m2).

6. Water at a temperature of within ± 2°C of the average room temperature is added during the test to about half fill of the jar. The mixture is stirred thoroughly with the glass rod to remove air rapped in the soil.
7. The screw cap assembly is fitted and tightened so that the reference marks coincide. Then, the pyknometer is filled with water.
8. The pyknometer is agitated by shaking it. Air is allowed to escape and froth is allowed to disperse. The pyknometer is leaved standing for at least 24 hour at room temperature content within ± 2°C.
9. The pyknometer is top up with water so that the water surface is flush with the hole in the conical cap. Must make sure there are no air bubbles or froth trapped under the cap.
10. Outside of the pyknometer is dried and weigh to nearest 0.5g (m3).
11. The pyknometer is then emptied, washed thoroughly and filled completely with water at room temperature. The reference marks on the screw cap must coincide, no air bubbles are entrapped and the water surface must flush with the hole in the conical cap.
12. Outside of the pyknometer is dried and weigh to nearest 0.5g (m4).
13. The specific gravity is calculated from equation below,

$$\rho s = \frac{m2 - m1}{(m4 - m1) - (m3 - m2)}$$

3.5.4 Particle Size Distribution

The particle size distribution was determined using both, mechanical sieving and hydrometer analysis. 100 grams of the oven dried (at 110°C for 24 hours) soil sample was soaked in distilled water for 24 hours to remove soil clods. Wet sieving with distilled water was then performed with a 0.063 mm sieve. Water and soil particles passing 0.063 mm sieve was collected and subjected to hydrometer analysis. Soil particles retained in the 0.063mm sieve were oven dried and subjected to dry sieving.

The results of the two analyses will be combined to produce the complete particle size distribution of the soil samples. The fine contents is used for statistical and geostatistical analysis.

Hydrometer Analysis

1. 200g of the soil sample is oven dried at 110°C for 24 hours. After the sample cools down, 100g is taken and soaked in distilled water for another 24 hours to remove the soil clods.
2. Then, using a 63μm sieve and distilled water, wet sieving is performed on the soaked sample.
3. The water and soil particles finer than 63μm passed through the sieve is collected and poured into a 1000ml sedimentation cylinder without losing any soil. Appropriate amount of water is used to wash the sample to make sure a suitable level of water in the cylinder is obtained.
4. The remaining soils in the 63μm sieve are oven dried for dry sieving analysis.
5. The rubber bung is inserted into the cylinder containing the soil suspension. The cylinder is then shakes and placed in the constant-temperature bath so that it is immersed in water at least up to the 1000 ml graduation mark.
6. 100ml of sodium hemosphate solution is added to the second 1000 ml sedimentation cylinder and diluted to exactly 1000ml with distilled water. The rubber bung is inserted and places in the constant temperature bath alongside the first cylinder.
7. After at least one hour, the cylinder containing the dispersing solution is taken out, shakes thoroughly and replaced it in the bath. Then, the cylinder containing the soil suspension is also taken out, shake vigorously end over end about 60 times in 2 minutes and then immediately replace it in the bath.

8. At the instant the cylinder with the soil suspension is replaced upright in the bath, the timer is started. The rubber bung is carefully removed from the cylinders.
9. The hydrometer is immersed in the suspension to a depth slightly below its floating position and it is allowed to float freely.
10. The hydrometer readings are taken at the upper rim of the meniscus after periods of 1, 2 and 4 minutes.
11. The hydrometer is slowly removed, rinsed in distilled water and placed in a cylinder of distilled water with dispersion at the same temperature as the soil suspension. The top of the meniscus reading, R0 is observed and recorded.
12. The hydrometer is reinserted in the soil suspension and readings after periods of 8 min, 30 min, 2 hours, 8 hours and 24 hours from the start of the sedimentation is taken and recorded. The temperature is monitored and recorded whenever reading from hydrometer is obtained.
13. The particle size, percentage finer is calculated using the following formula:

The effective depth (mm),

$$H_r = H + \frac{1}{2}\left(h - \frac{V_h}{900}L\right)$$

The equivalent particle diameter (mm),

$$D = 0.005531\sqrt{\frac{nH_r}{(\rho_s - 1)t}}$$

Percentage finer than D,

$$K = \frac{100\rho_s}{m(\rho_s - 1)}R_d\%$$

True hydrometer reading (mm)

$R_h = R_h' + C_m$

Modified hydrometer reading,

$R_d = R_h' - R_o'$

Length from the neck of the bulb to graduation R_h (mm),

$H = N + d$

$d = (30 - R_h) \times 4.0$

Sieve Analysis

1. Soil retained in 63μm from the wet sieve is oven dried and used for dry sieve analysis.
2. A stack of test sieves consist of 2mm, 1.18mm, 600μm 425μm, 300μm, 212μm, 150μm, 75μm and 63μm are used. Each empty and clean sieve is weighted and the weight is recorded.
3. Then, the sieves are stacked on the mechanical shaker with the largest size test sieve appropriate to the maximum size of the material present at the bottom of the stack followed by the smaller size test sieves and a receiver at the bottom of the stack.
4. The sample is placed on the top sieve and the sieve is covered with a lid. The test sieve is agitated on the mechanical shaker for 5 minutes.
5. The amount retained on each of the sieves is weighted to 0.01% of its total mass. Samples that passed through 63μm test sieve is added to the hydrometer analysis.
6. The percentage finer is calculated using:

$$\text{Percentage finer} = 100 - \frac{100W_s}{W_{tw}}\%$$

Where W_s = sample weight retained on specific sieve

W_{tw} = the total weight of the soil sample.

3.5.5 Organic Content

Sample organic content is to be determined from the difference between the weight of the oven dried (at 110°C for 24 hours) sample and the weight of the sample subjected to ignition in a muffler furnace at 440°C for 4 hours and expressed as a percentage of the oven dry weight of the sample.

Procedure:

1. The sample from moisture content experiment is used for this test.
2. The sample which is oven dried for 24 hours was weighted and is put into a crucible.
3. The crucible with the sample is burned in a muffler furnace at 440°C. When it has cooled slightly, the crucible is placed in desiccators and allowed to cool fully before it is weighted.
4. The percentage of the dry weight lost on ignition is calculated using:

$$OC = \frac{W_s - W_b}{W_s - W_c} \text{ x } 100\%$$

Where;

OC = percentage of organic content

W_s = weight of crucible + oven-dried soil

W_b = weight of crucible + ignited soil

W_c = weight of crucible

3.6 STATISTICAL AND GEOSTATISTICAL ANALYSIS

The results of the laboratory tests on soil engineering properties were subjected to two types of analysis: normal statistical and geostatistical analysis. Normal statistical analysis included determination of maximum, minimum, mean, standard deviation, and coefficient of variation of soil engineering properties over the study area. Geostatistical analysis included examining spatial variability nature of the soil engineering properties by determining semivariogram parameters namely the sill, nugget and range, establishing best fitted semivariogram models for the soil properties, and computing maps of distribution of soil engineering properties over the study area using the method of kriging.

Geostatistical characterization of the data is performed using GS+ (Gamma Design Software, Plainwell, MI, USA). Semivariogram is a function describing the spatial variance structure of soil properties. The semivariance will be estimated for all the four soil engineering properties. The semivariance is defined as (Goovaerts, 1997):

$$\gamma(h)=\frac{1}{2N(h)}\sum_{i=1}^{N(h)}\left[z(x_i)-z(x_i+h)\right]^2$$

where γ(h) is the semivariance, h is the lag, N(h) is the total number of sample couples separated by the lag interval h; z(xi) is the measured sample value at point (xi), and z(xi+h) is the measured value at point (xi+h).

A property is called spatially dependent or auto correlated if the probability of similar data values is higher for neighboring sample points than for points far from each other (Warrick et al., 1986). Thus, z(xi) correlates to the neighboring z(xi+h), with h being the lag, between z(xi) and z(xi+h). The correlation between z(xi) and z(xi+h) expresses the spatial structure of a variable of interest (Isaaks and Srivastava, 1989).

The semivariogram displays the change in semivariance between sample points with increasing lag. The semivariance rises with increasing lag then levels off. The lag, at which the plateau is achieved, is called the 'range' β, and the semivariance value of the plateau is called the 'sill' (λo+λ). Points within the range are considered to be spatially or temporally auto-correlated, while points outside the range are spatially independent. Empirical semivariograms seldom pass the origin, but intersect with the ordinate.

This discontinuity is the 'nugget' λo, and consists of two parts; the spatial variance of scales less than the minimum sampling distance (if present), and measurement and sample location error. The nugget represents all unaccounted spatial variability at distances smaller than the smallest lag while the semivariogram models the structural spatial dependence (Goovaerts, 1997). Therefore, the ratio of the nugget-to-sill gives a measure of the spatial or temporal dependence of the data. The smaller the ratio the stronger is the spatial dependence.

Calculation of semivariance assumes stationarity. The existence of a sill in a semivariogram is an indication that the process is stationary (Western et al., 1998). Five different models will be examined to fit the semivariance data. These include the spherical, linear, linear-sill, exponential, and gaussian model. Optimal models were determined by examining the fit of the model to the semivariogram as judged by the coefficient of determination r2 and RSS (residual sums of squares) values.

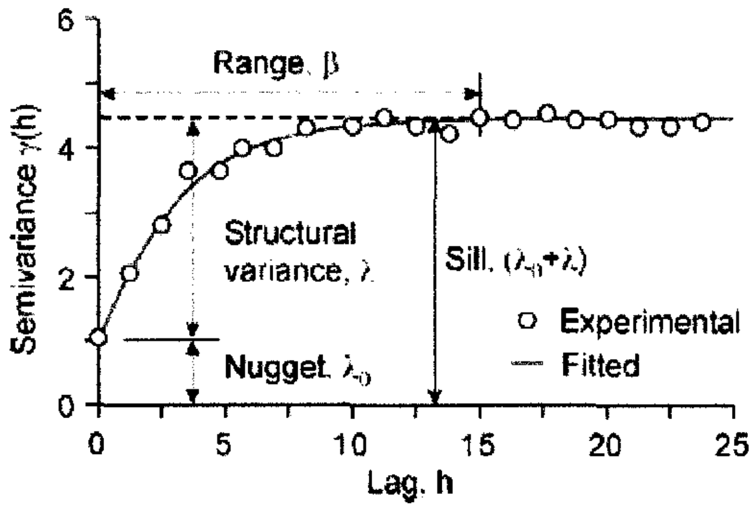


Figure 4: Schematic Diagram of a Semivariogram and Its Parameters

3.7 ANALYSIS OF SPATIAL VARIABILITY OF SOIL ENGINEERING PROPERTIES IN TERMS OF CONTOUR MAP

Soil engineering properties for each soil sample was determined from the laboratory tests. Thus the laboratory test results provide a database of soil engineering properties of UTP campus. From this database and the geo-grid reference location of the sampling point, contour map for each soil engineering properties was prepared by using Surfer software. This software interpolated the locations with known soil properties to estimate the soil properties at the unsampled locations. The results of the interpolation provided maps on variation of soil engineering properties (bulk density, moisture content, particle size analysis and organic content) over the study area.

3.8 JOB SAFETY ANALYSIS

Table 1: Job Safety Analysis

Job Steps	Potential Hazards	Who Might Injured (Person / Equipment)	Risk Rating	Controls
1. Geogrid positioning	1.1 Trip and fall	Student, equipment	Low	• Proper shoes are worn during handling the equipment. • The GPS receiver tools are hold tightly to avoid it from falling. • Supervisor to assist the students during the work execution.
2. Soil sampling	2.1 Sharp edge and heavy equipment	Student	Medium	• Proper shoes are worn during handling the equipment • Hand glove is worn during the work execution. • The equipment is hold tightly. • The equipment should be use as stated in the procedure.

				• Supervisor to assist the student during work execution.
3. Soil analysis	3.1 Fall	Student, equipment	Low	• Proper shoes and lab coat should be worn during working in the laboratory • The test equipment must not be placed at the edge of the table. • Handling equipment in congested area must be avoided.
	3.2 Burn	Student	Medium	• Hand gloves must be worn during handling hot equipment.
	3.3 Dust, Noise	Student	Low	• Protective glasses, mask, apron, hand gloves, ear-plug and proper shoes during handling sample must be worn.
4.Computer Analysis	4.1 Eye fatigue	Student	Medium	• Staring at the screen for a long duration should be avoided • Work should be done under sufficient lighting
	4.2 Wrist/ Neck Strain	Student	Medium	• Work in a neutral position utilizing good posture • Ergonomic keyboard and mouse should be use.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 RESULTS FROM LABORATORY ANALYSIS

Data obtained from field sampling and laboratory analysis are presented as below. The results are arranged according to longitude and latitude of the sample point.

Table 2: Results from Lab Analysis

No.	Point	Longitude	Latitude	Moisture Content %	Bulk Density (g/cm^3)	Organic Content %	Fine Content %
1	15A	100° 58' 11.65555E	4° 23' 21.49137N	26.68	1.4561	1.69	12.33
2	14A	100° 58' 08.06170E	4° 23' 21.49137N	27.30	1.4064	2.92	10.33
3	13A	100° 58' 04.46785E	4° 23' 21.49137N	24.72	1.3995	2.18	7.84
4	15B	100° 58' 11.65555E	4° 23' 17.80137N	25.99	1.4344	2.24	9.79
5	14B	100° 58' 08.06170E	4° 23' 17.80137N	35.83	1.4632	2.08	16.32
6	16C	100° 58' 15.24940E	4° 23' 14.11137N	20.44	1.4307	1.22	11.35
7	15C	100° 58' 11.65555E	4° 23' 14.11137N	20.94	1.4235	1.59	4.92
8	14C	100° 58' 08.06170E	4° 23' 14.11137N	17.11	1.4389	1.16	5.62
9	20D	100° 58' 29.62480E	4° 23' 10.42137N	18.72	1.5221	1.02	9.65
10	17D	100° 58' 18.84325E	4° 23' 10.42137N	23.18	1.4429	2.62	13.45
11	15D	100° 58' 11.65555E	4° 23' 10.42137N	18.67	1.4480	1.37	12.81
12	14D	100° 58' 08.06170E	4° 23' 10.42137N	27.32	1.4396	3.53	16.72
13	13D	100° 58' 04.46785E	4° 23' 10.42137N	25.69	1.3156	4.88	5.67
14	22E	100° 58' 36.81250E	4° 23' 06.73137N	18.69	1.4226	0.81	6.37
15	21E	100° 58' 33.21865E	4° 23' 06.73137N	36.95	1.4434	4.83	17.68

No.	Point	Longitude	Latitude	Moisture Content %	Bulk Density (g/cm^3)	Organic Content %	Fine Content %
16	17E	100° 58' 18.84325E	4° 23' 06.73137N	34.66	1.3298	4.65	4.98
17	16E	100° 58' 15.24940E	4° 23' 06.73137N	22.58	1.4018	1.07	9.52
18	14E	100° 58' 08.06170E	4° 23' 06.73137N	21.16	1.4284	2.53	8.63
19	11E	100° 57' 57.28015E	4° 23' 06.73137N	27.33	1.2848	5.06	3.45
20	10E	100° 57' 53.68630E	4° 23' 06.73137N	20.44	1.3462	1.95	11.36
21	20F	100° 58' 29.62480E	4° 23' 03.04137N	37.79	1.4018	2.37	3.76
22	19F	100° 58' 26.03095E	4° 23' 03.04137N	28.75	1.3723	2.20	9.56
23	16F	100° 58' 15.24940E	4° 23' 03.04137N	22.81	1.3474	2.44	4.62
24	13F	100° 58' 04.46785E	4° 23' 03.04137N	20.41	1.4809	1.55	9.63
25	11F	100° 57' 57.28015E	4° 23' 03.04137N	36.42	1.3175	8.02	9.61
26	10F	100° 57' 53.68630E	4° 23' 03.04137N	24.08	1.4111	1.83	5.68
27	22G	100° 58' 36.81250E	4° 22' 59.35137N	50.19	1.3215	4.15	27.18
28	20G	100° 58' 29.62480E	4° 22' 59.35137N	27.45	1.4145	4.85	4.85
29	19G	100° 58' 26.03095E	4° 22' 59.35137N	44.27	1.2923	6.81	8.10
30	16G	100° 58' 15.24940E	4° 22' 59.35137N	21.02	1.4134	1.31	14.32
31	15G	100° 58' 11.65555E	4° 22' 59.35137N	30.73	1.4596	2.15	10.52
32	14G	100° 58' 08.06170E	4° 22' 59.35137N	17.88	1.4815	1.40	11.41
33	10G	100° 57' 53.68630E	4° 22' 59.35137N	28.86	1.3924	6.12	3.21
34	9G	100° 57' 50.09245E	4° 22' 59.35137N	27.89	1.3545	4.57	12.87
35	22H	100° 58' 36.81250E	4° 22' 55.66137N	40.74	1.3095	5.01	5.34
36	21H	100° 58' 33.21865E	4° 22' 55.66137N	48.82	1.2760	9.45	11.30
37	20H	100° 58' 29.62480E	4° 22' 55.66137N	30.56	1.4261	2.86	7.85
38	19H	100° 58' 26.03095E	4° 22' 55.66137N	42.34	1.3971	1.65	19.67

No.	Point	Longitude	Latitude	Moisture Content %	Bulk Density (g/cm^3)	Organic Content %	Fine Content %
39	18H	100° 58' 22.43710E	4° 22' 55.66137N	46.34	1.3711	6.38	25.61
40	13H	100° 58' 04.46785E	4° 22' 55.66137N	23.39	1.4362	2.88	3.09
41	12H	100° 58' 00.87400E	4° 22' 55.66137N	34.13	1.3983	1.31	5.46
42	9H	100° 57' 50.09245E	4° 22' 55.66137N	26.01	1.3758	8.43	2.64
43	13I	100° 58' 04.46785E	4° 22' 51.97137N	29.26	1.3139	5.66	10.68
44	12I	100° 58' 00.87400E	4° 22' 51.97137N	27.07	1.3752	3.82	6.45
45	11I	100° 57' 57.28015E	4° 22' 51.97137N	28.80	1.4833	1.61	10.89
46	9I	100° 57' 50.09245E	4° 22' 51.97137N	28.34	1.3495	3.25	12.57
47	13J	100° 58' 04.46785E	4° 22' 48.28137N	14.99	1.5758	0.64	3.54
48	12J	100° 58' 00.87400E	4° 22' 48.28137N	19.96	1.4797	0.75	4.56
49	11J	100° 57' 57.28015E	4° 22' 48.28137N	25.52	1.4573	2.44	8.64
50	10J	100° 57' 53.68630E	4° 22' 48.28137N	31.23	1.3631	1.54	12.45

4.2 EVALUATION OF STATISTICAL CHARACTERISTICS OF SOIL PROPERTIES

The summary of normal statistics; the maximum, minimum, mean, standard deviation and coefficient of variation of the soil engineering properties were obtained from all collected samples as shown in Table 3.

Table 3: Sample size (N), maximum, minimum, mean, standard deviation (SD), and coefficient of variation (CV) of tested soil engineering properties

Soil Properties	N	Max.	Min.	Mean	SD	CV (%)
Fine Content (%)	50	27.18	2.64	9.697	5.337	55.03
Moisture Content (%)	50	50.19	14.99	28.209	8.444	29.93
Bulk Density (g/cc)	50	1.576	1.276	1.403	0.063	4.52
Organic Content (%)	50	9.45	0.64	3.137	2.137	68.13

The coefficient of variation (CV) is an indicator of variability. The range of CVs obtained suggests different degrees of heterogeneity between different soil properties which has been examined in the study area. Among the four soil properties examined the organic content show the highest CV (68.13%), followed by fine content (55.03%) and moisture content (29.23%) while soil bulk density shows the lowest (4.52%) CV. The lower CV for soil bulk densities are expected because the range over which soil density could vary is narrow compared to other soil properties. The large variance in soil properties in a large area could be inked to heterogeneity of land formation, land use pattern and erosion processes (Sun et al., 2003)

The standard deviation value represents the average distance of set of data from the mean value. From the normal statistical analysis, bulk density showed the lowest standard deviation (0.063 g/cm^3), followed by organic content (2.137%) and fine content (5.337%), while moisture content showed the highest value (8.444%). The lowest value of standard deviation (0.063 g/cm^3) shows that the data sets for bulk density from the study area are very close in value to the mean. Therefore, the variation in bulk density is smaller compared with other soil properties in the study area.

4.3 SPATIAL DEPENDENCE OF SOIL PROPERTIES

The best-fitted semivariogram model parameters are shown Table 4. The semivariograms of different soil properties and best-fitted semivariogram models are presented in Figure 5, 6, 7 & 8 below. Having established the semivariogram models and parameters for the soil properties it is now possible to examine the spatial structure and dependencies of the soil properties in terms of semivariogram parameters, the range, sill, nugget and nugget-to-sill ratio.

Table 4: Characteristics Parameters of Fitted Semivariograms of Soil Engineering Properties

Soil Properties	Model	Nugget, (C_o)	Sill, (C_o+C)	Range (A_o)	S_v (%) (C)	Ratio (%)
Fine Content (%)	S	0.980	28.200	0.22	96.52	3.48
Moisture Content (%)	S	26.600	92.900	1.22	71.37	28.63
Bulk Density(g/cc)	E	0.001	0.004	0.14	75.00	25.00
Organic Content (%)	E	3.280	6.5610	1.28	50.00	50.00

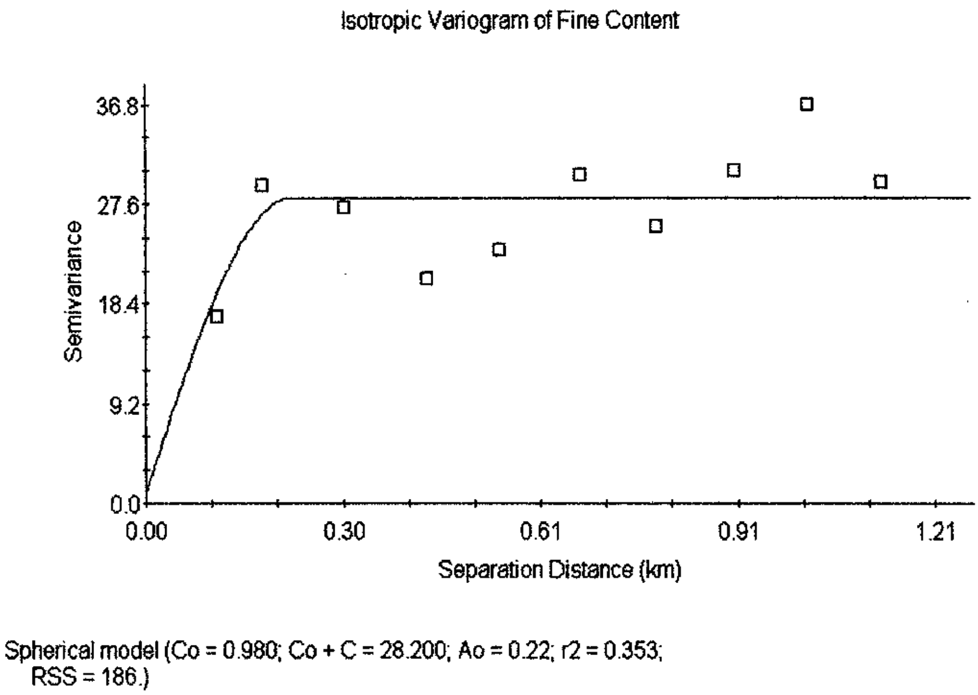


Figure 5: Isotropic Variogram of Fine Content

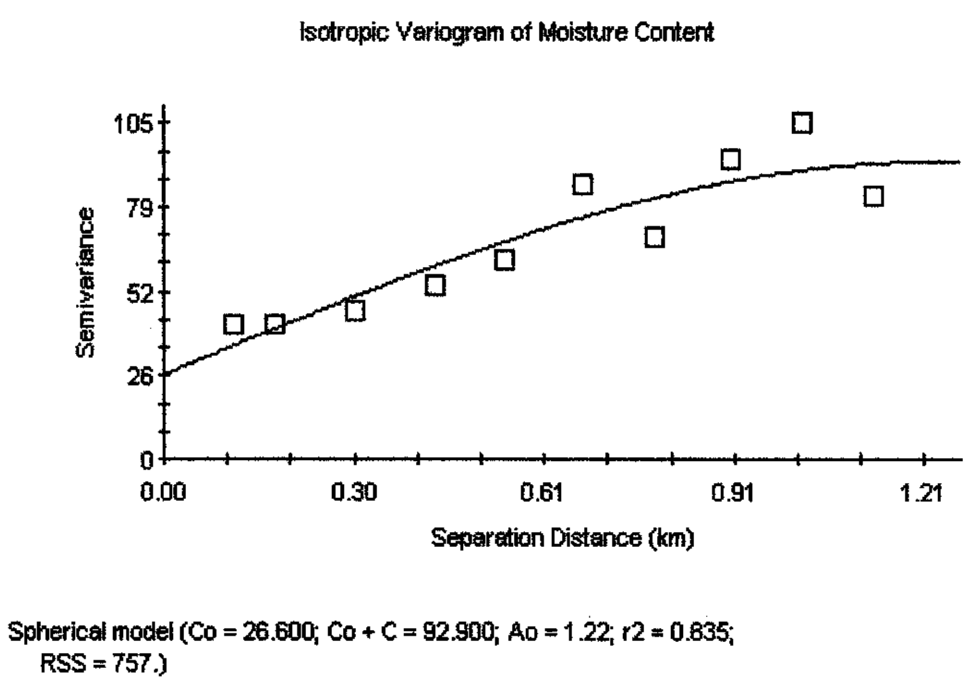
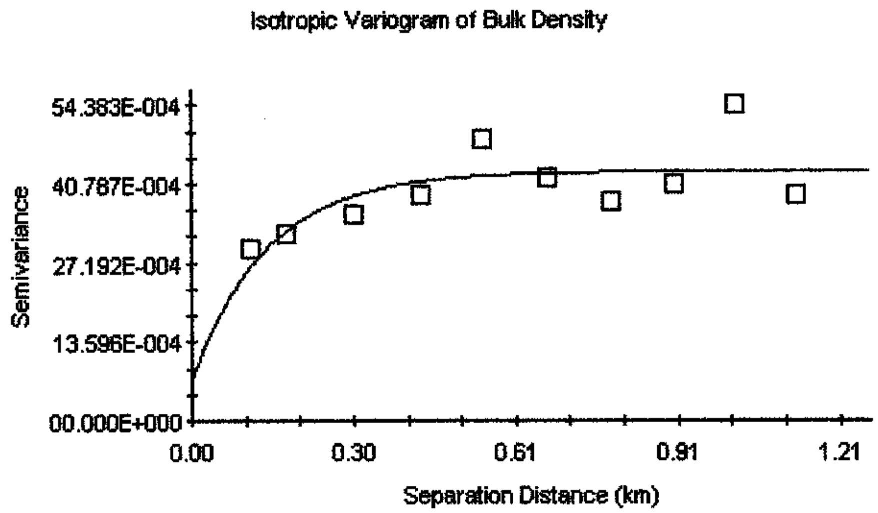
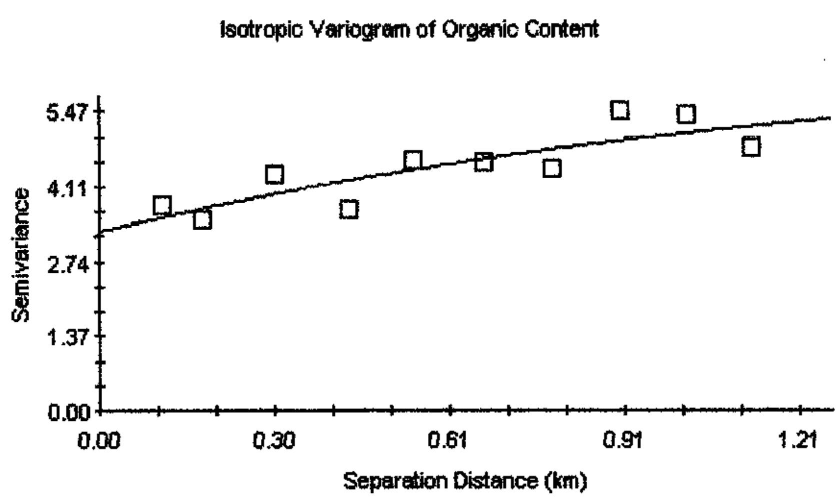


Figure 6: Isotropic Variogram of Moisture Content



Exponential model (Co = 0.001; Co + C = 0.004; Ao = 0.14; r2 = 0.495; RSS = 2.455E-06)

Figure 7: Isotropic Variogram of Bulk Density



Exponential model (Co = 3.280; Co + C = 6.561; Ao = 1.28; r2 = 0.709; RSS = 1.19)

Figure 8: Isotropic Variogram of Organic Content

The nugget is a measure of all unaccounted spatial variability at distances smaller than the smallest while the structural variance accounts for variation due to spatial auto-correlation. The relatively smaller nuggets for soil fine content, organic content and bulk density suggest that less variation existed for these three soil properties at distances shorter than the smallest lag. In contrast, the relatively larger nuggets for moisture content compared to soil fine content, organic content and bulk density suggests that the variation of moisture contents at distances shorter than the smallest lag are more than for fine content, organic contents and bulk densities.

The sill is a measure of the variability in the data. The highest sill was observed for moisture content (92.9) followed by fine content (28.2) and organic content (6.561) while bulk density showed the lowest sill (0.004). Large variability in the study area are associated with moisture content and fine content while relatively low variability are associated with organic content. The soil bulk density indicated the least variability.

The range is considered as the distance beyond which observation are not spatially dependent. It is the separation distance over which sample locations are auto-correlated and there is spatial dependence among the data collected from those sample locations. Organic content has showed the largest range (1.28km) followed by moisture content (1.22km) and fine content (0.22 km), while the bulk density showed the shortest range (0.14 km).

The nugget-to-sill ratio gives an indication of the spatial dependency of the data. A variable is considered to have a strong spatial dependence if the ratio is less than 25%, and a moderate spatial dependence if the ratio is between 25 and 75%, and a weak dependence for ratio >75% (Goderya et al., 1996). The strong spatial dependency of the soil properties provides indication of the influence of intrinsic or extrinsic factors. From Table 4, organic content has the highest ratio of 50% followed by moisture content, 28.63% and bulk density 25%. All of these soil properties have a moderate spatial dependency since the ratio is within 25 and 75% but fine content has the lowest ratio which is 3.48.

The structural variance measures the variations in soil properties due to spatial structure. From Table 4, moisture content and bulk density have nearly similar (71.37% and 75% respectively) but strong spatial auto-correlation whereas while soil organic content exhibited spatial auto-correlation to a lesser extent (50%) than the other soil properties. Soil fine content exhibited spatial auto-correlation to a bigger extent (96.52%).

The relatively larger range and sill for moisture content (Table 3) implies that water contents are spatially dependent over long distances (indicated by large range) and the variability is too high (indicated by large sill) compared to other soil properties. As for the soil fine content, the relatively smaller range and relatively larger sill shows that fine content of the study area are spatially dependent over relatively short distances and the variability is rather high. The largest range and relatively low sill for organic content indicates that in the study area soil organic content are spatially dependent over long distances. However, the variability is much smaller as compared to moisture and fine contents. In contrast, the smallest range and smallest sill for soil bulk density (Table 3) implies soil bulk densities are spatially dependent over relatively short distances and the variability is low.

These various degrees of heterogeneity observed between different soil properties examined clearly indicate the highly complex and variable nature of tropical soils within a relatively small area.

4.4 KRIGING SPATIAL SOIL PROPERTIES

The spatial distribution of soil properties for unsampled locations in the study area were obtained from interpolation between sampled locations by the method of kriging, based on semivariograms of the soil properties at sampled locations. This method will elaborate more on illustration of the spatial distribution of fines, moisture content, organic content and density respectively, over the study area. These maps of spatial distribution of soil properties in conjunction with the site map now allow examining the closeness of association between variation in soil properties and topographic conditions.

4.4.1 Variability in Soil Fine Content

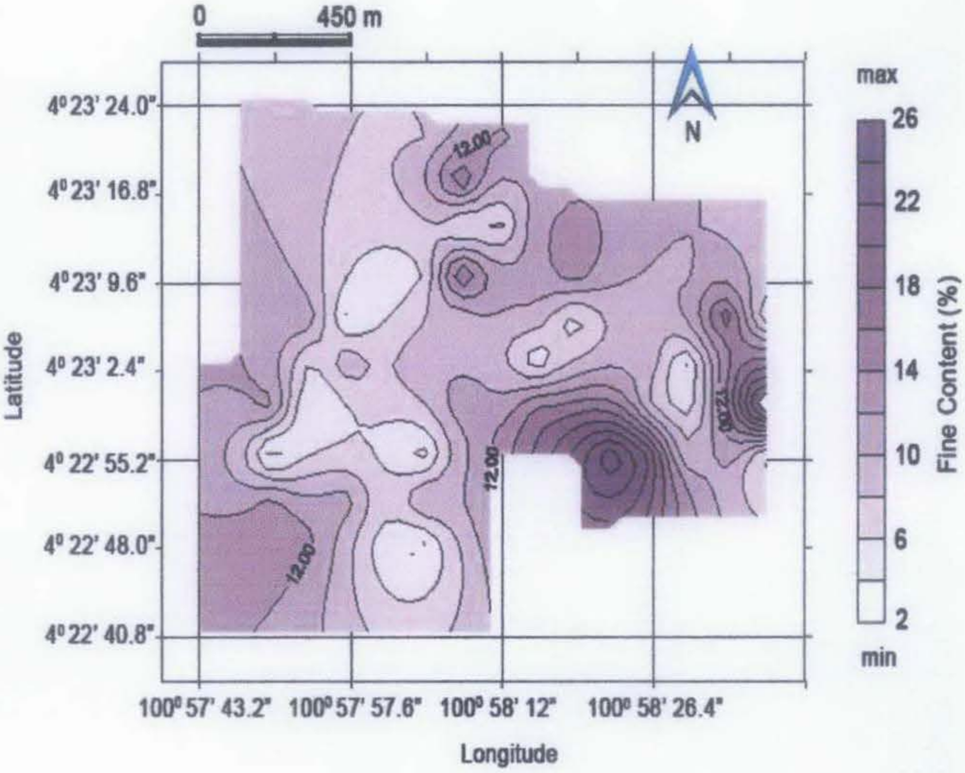


Figure 9: Spatial Distribution of Soil Fine Content

The spatial distribution of soil fine content at the study area is showed in Figure 9. Darker colors indicate high value of fine content while lighter colors indicates lower value.

The soil fine content is varying between disturbed, undisturbed and ponds region. Ponds region have higher percentage of fine content compares with disturbed region. The highest percentage of soil fine content (27.18%) is found at 100° 58' 36.81250"E and 4° 22' 59.35137"N which is located near a pond. High concentration of fine content can be found between 100°58'12"E and 100°58'40.8"E and 4°22'48"N and 4°23'2.4"N. This area has percentage of fines more range between 8 to 27 %. From comparison of Figure 9 and Figure 10, it could be seen that higher soil fine content is associated with higher moisture content. This shows that the region with high fine content will increase the capacity of soil to retain and hold the water.

Meanwhile the lowest soil fine content (2.64%) is found at sampling point 100° 57' 50.09245"E and 4° 22' 55.66137"N which is located near a forest area. Even though the lowest value is obtained at a forest or undisturbed area, from Figure 9, it could be observed that lower percentage of soil fine content is found at disturbed area. This is due to where original soil is replaced by imported soil for construction work. Furthermore, the design of the study area it self where it has forest right in the middle of the campus building makes the data tabulation larger. As conclusion, the spatial variability of soil fine content is greatly influenced by the topography of study area.

4.4.2 Variability in Moisture Content

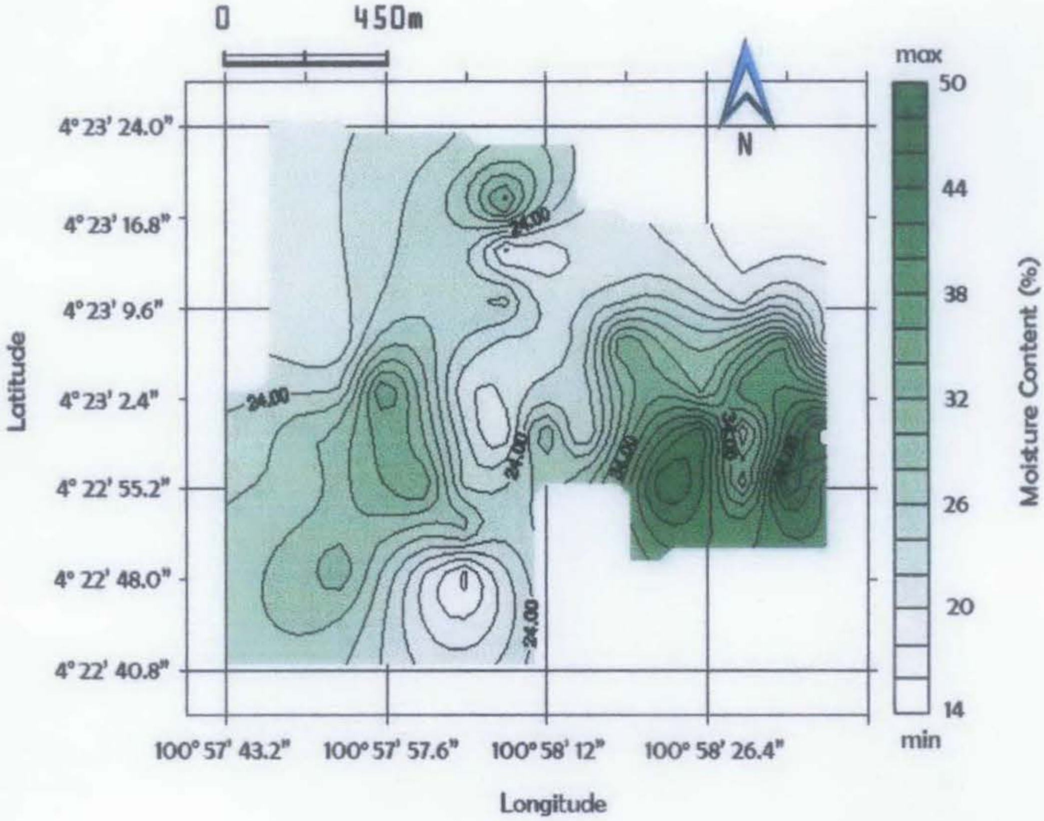


Figure 10: Spatial Distribution of Moisture Content

From the spatial distribution of moisture content map in Figure 8, the tabulation of the soil properties could be observed. Darker colors indicates maximum value of moisture content while lighter colors indicates minimum value

Soil moisture content variability is influenced by a number of factors such as variations in topography, soil properties vegetable type and density, organic content, mean moisture content, depth to water table, precipitation depth, solar radiation and other meteorological factors (Famigluetti et al., 1998).

High value distribution could be seen at closer contour line which consists of undisturbed area with presence of ponds and forest. The highest soil moisture content (50.19%) is obtained near the ponds area at 100° 58' 36.81250E and 4° 22' 59.35137N. the high value distribution is most probably caused from the water from the ponds that has seeped into the soil which makes the soil to have high moisture compared to other area especially at buildings area.

Lower moisture content distribution could be found at disturbed region where there is more development and buildings at that area. The lowest value (14.99%) is found at 100° 58' 04.46785E and 4° 22' 48.28137N which is in a disturbed area. The location is far from any water source and there are no trees. The soil in this area has less water retention ability. The bulk density in this area is also high which indicate the soil is dense where the soil has been compacted to various reason such as constructions work or has been a walking pavement. Hence the moisture content is low.

4.4.3 Variability in Bulk Density

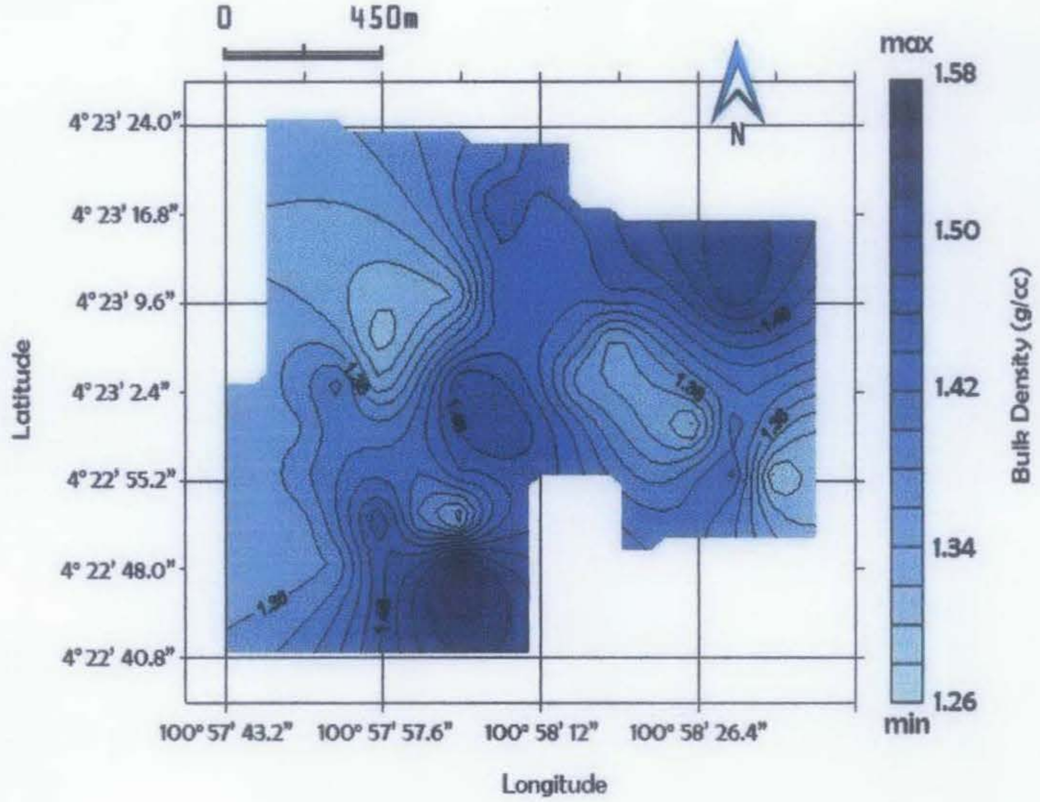


Figure 11: Spatial Distribution of Bulk Density

For bulk density, the variation of data value is low. Form Figure 11, high bulk density value distribution could be observed at disturbed area where more buildings and pavement is presence.

If the bulk density for a soil sample is near 2.0 or greater, it indicates that the area is consists of a very dense soil. Soils become dense if they have been compacted and do not have high organic matter content. This is common in surface soils on which people walk or where machinery has compressed the soil.

The highest bulk density (1.5758 g/cm^3) is found at 100° 58' 04.46785E and 4° 22' 48.28137N where it is located at a construction area of the campus main building. This is most probably due to compaction of soil from the heavy machinery that has been used to move around in that area. The soil there also consists of sandy soil hence soils with massive or single grained structure will have higher densities than soils with granular or blocky structure. The texture of the soil can also affect the bulk density. In general, sandy soils have a higher bulk density than clayey or silty soils, because the porosity is lower although the size of the pores is larger in sandy soils.

The lowest bulk density (1.2760 g/cm^3) is found at 100° 58' 33.21865E and 4° 22' 55.66137N which is located near the pond. Lower bulk density will increase the water infiltration rate and capability of soil to retain water. From comparison of Figure 10 and Figure 11, it could be observed that the soil moisture content is higher at the region with lower bulk density.

As conclusion, bulk density is greatly influenced by the land use at that particular area although it has lower variability.

4.4.4 Variability in Organic Content

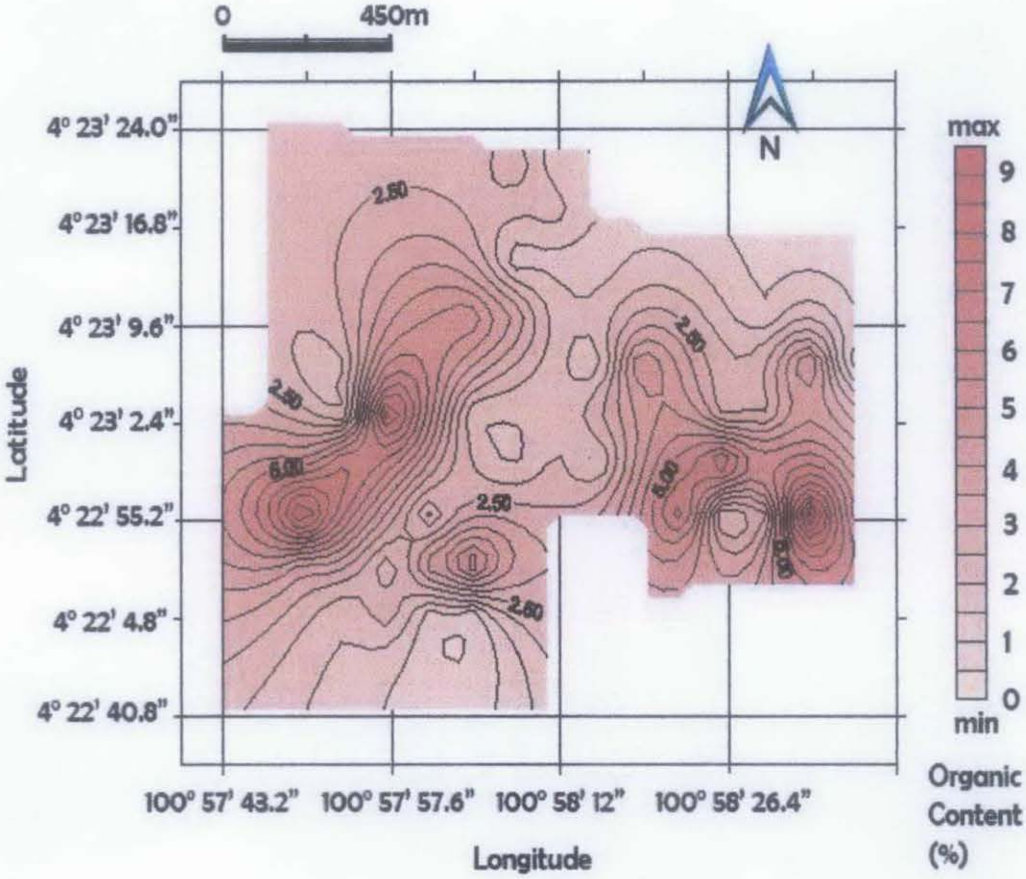


Figure 12: Spatial Distribution of Organic Content

Organic matter is essential to erosion control, water infiltration and conservation of nutrient. From Figure 12, high concentration of organic matter is found at undisturbed and ponds area. Soil organic content is usually high at undisturbed area which consists of forest due to the decomposition of leaves, nutrients used by the trees and also other habitant at the area. The highest value of organic content (9.45%) is determined at 100° 58' 33.21865E and 4° 22' 55.66137N which is located near the ponds. It is most probably caused by the soil that is soaked with water from the ponds which most likely contain high organic matter, eventually also affect the organic content of the soil.

A comparison of Figure 11 and Figure 12 shows an existence of relationship between the soil organic content and the bulk density. As the amount of soil organic content increases, the value of soil bulk density decreases as the presence of organic content in soil would make the soil to have more voids hence the bulk density decreases.

As for relationship between organic content and moisture content, it could be observed from Figure 10 and Figure 12 that the regions with higher organic content tend to have higher moisture content. The higher organic content will increase the available water capacity in soil and affect the water infiltration into soil layer. Therefore, higher moisture content is expected at regions wit high organic content.

From the results, it is also observed that sample on surface horizon have higher value of organic content. This most probably caused by traces of grass and leaf litters at the soil surface.

4.5 VARIATION OF SOIL PROPERTIES ON LAND USE CONDITIONS

Statistical and geostatistical characterization of the soil properties provided strong evidence to the existence of influence from intrinsic or extrinsic factors on the spatial variability of soil properties. To investigate into this aspect, the effect of land use changes was examined.

To examine the effect of land use changes on the variability of soil properties, the study area was categorized by three zones; disturbed zones, forest zones and pond zones as showed in Figure 13.

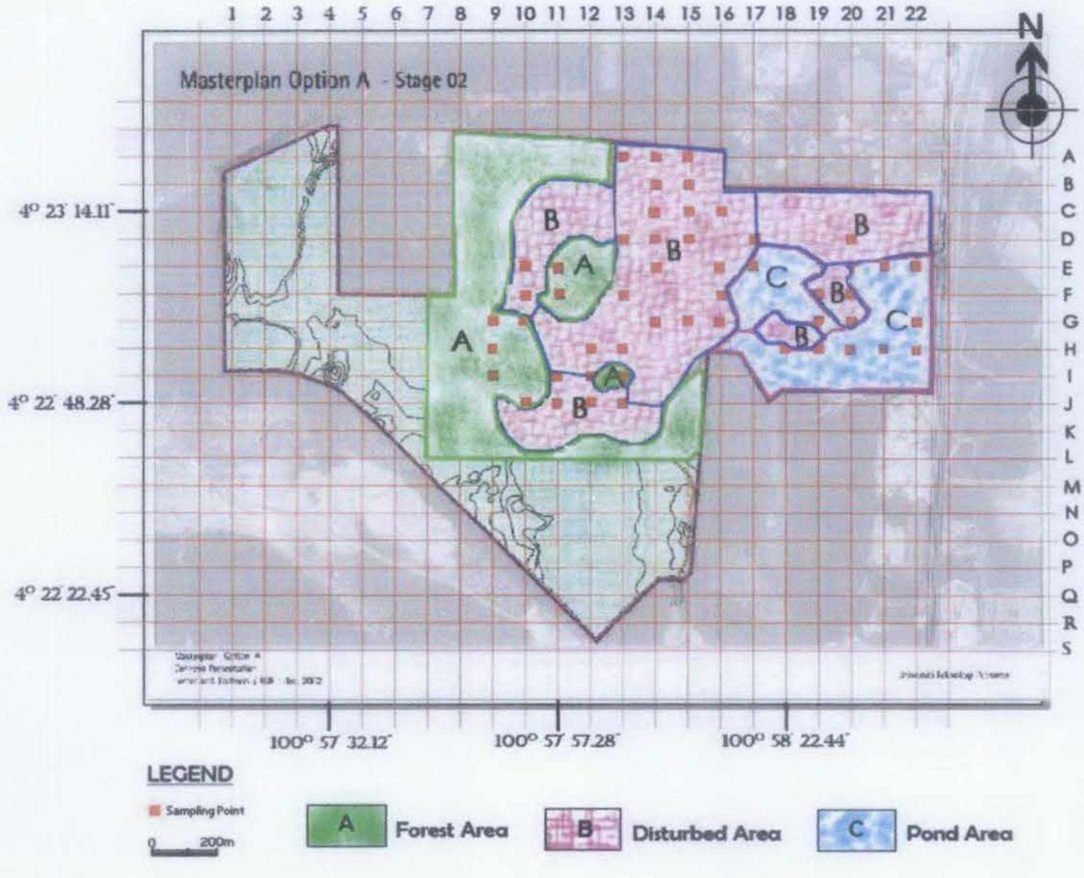


Figure 13: Zone of Disturbed, Forest (Undisturbed) and Pond Area

Figure 14 showed the effect of land use on soil properties. It can be observed that the mean soil moisture content is the highest in ponds zone but also relatively high at undisturbed area. The mean soil organic content is also high at undisturbed zones

The relatively higher moisture and fine contents in the forest and pond zones are probably due to higher organic contents in soils which affect aggregate development and create macro-pores which enhance infiltration. Furthermore, when leaf litters are present, as found in forest soil surface, runoff is delayed and there is more time for infiltration to take place, thus increasing the water intake of soils which contributes to higher moisture contents in the forest zones than in disturbed zones.

The mean for bulk density is higher in disturbed zones compared to the other zones. This could attribute to significant alteration of soil density by compaction induced by construction activities and also the usage of the area.

Thus it appears that the significant differences between soil engineering properties between the disturbed, undisturbed and pond zones are a consequence of disturbances cause by forest clearance and land alteration. The existence of large variability of the soil properties also most probably caused by the land use conditions in the study area.

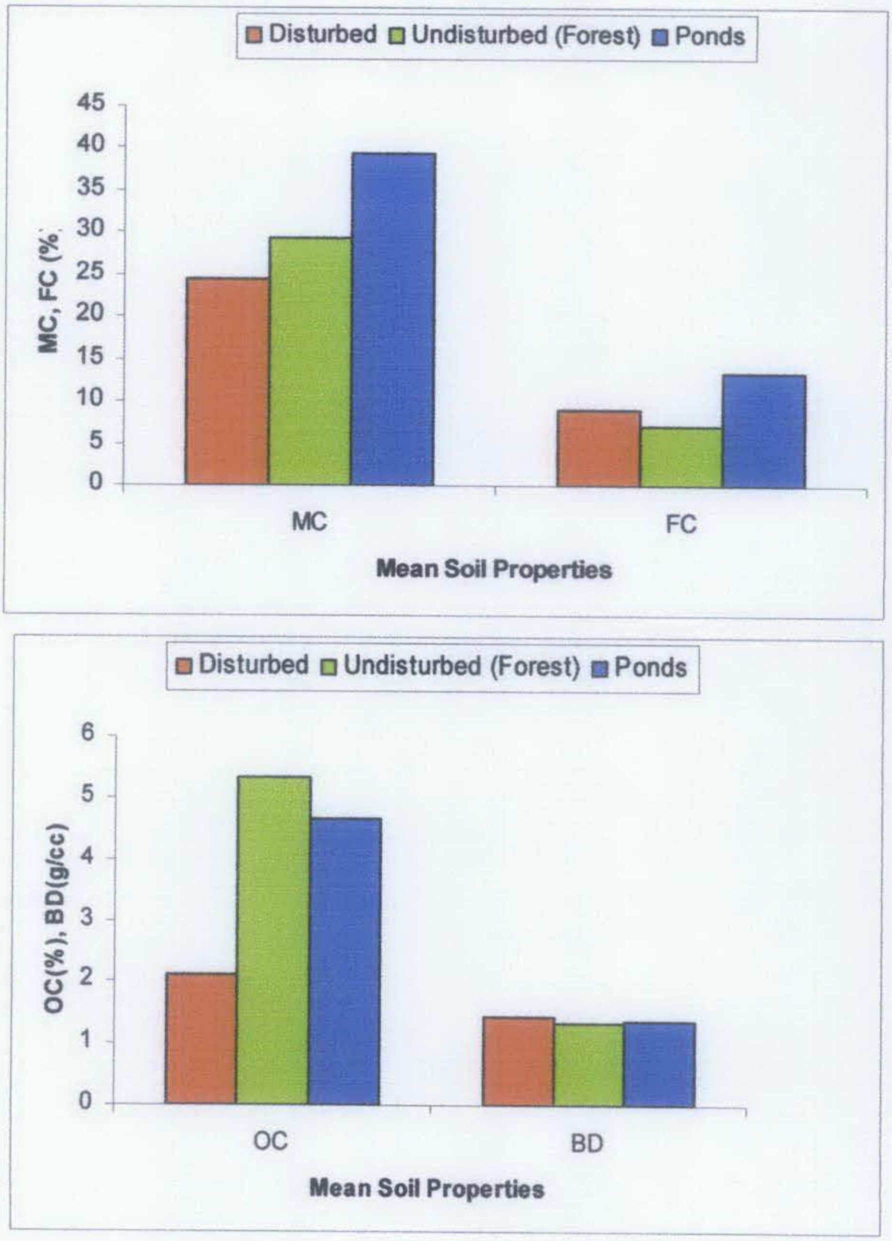


Figure 14: Effect of land use on soil properties (MC: Moisture Content; FC: Fine Content; OC: Organic Content; BD: Bulk Density)

CHAPTER 5
CONCLUSION & RECOMMENDATION

This proposed project is important to obtain the data of characterize spatial structure of soil properties under tropical climate. It also could contribute to the understanding and characterization of small scale spatial variability nature of physical properties of tropical soil. Soil engineering properties spatial characterization are important for several form of analysis such as to determine the optimum size of spatial grids for distributed parameter hydrological models, estimating point or spatially averaged values of soil properties using kriging technique, and also in designing sampling networks and improving their efficiency. Therefore, spatial variability of soil properties should be monitored and quantified.

Fifty samples has been collected around the campus and analyzed in the lab to obtain the value for moisture content, organic content, bulk density and particle size distribution. These results is compiled and analyzed using software such as Surfer and GS+ to characterize spatial structure of soil properties under tropical climate in terms of semivariogram parameters.

The variation in soil properties in the study area is produced in the form of maps, and the effect of land use changes on the variability of soil properties is evaluated. The spatial variability of soil engineering properties has been characterized in terms of semivariogram and statistical parameters and there is significant variation of soil properties exists in the area studied. Land disturbances and topographic conditions both contributed to the variability of soil properties.

In future, more sample points should be collected to produce more precise analysis. Statistical and geostatistical analysis requires larger data to produce a better best-fitted semivariogram models.

Method of sample extraction also should be enhanced for better results. Using hand auger is time consuming hence in order to obtain more samples within the time constraint, more effective sample extrusion method should be used.

As for sample collection, the temperature, weather and rainfall, if possible, at each sampling location should also be recorded. This information is especially important for moisture content analysis since the moisture content of the soil is greatly affected by these factors.

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APPENDIX A

SOIL MOISTURE CONTENT RESULT

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Moisture Content %
1	9G	A	51.22	40.2	27.41
		B	54.94	42.8	28.36
				Average	27.89
2	9H	A	57.48	45.01	27.70
		B	50.52	40.64	24.31
				Average	26.01
3	10F	A	55.21	44.2	24.91
		B	53.12	43.1	23.25
				Average	24.08
4	10G	A	56.23	44.35	26.79
		B	54.85	41.89	30.94
				Average	28.86
5	9I	A	53.4	41.2	29.61
		B	55.4	43.6	27.06
				Average	28.34
6	19G	A	54.6	37.8	44.44
		B	56.2	39	44.10
				Average	44.27
7	10J	A	57.2	43.5	31.49
		B	55.4	42.3	30.97
				Average	31.23
8	11F	A	56.4	41.53	35.81
		B	55.8	40.72	37.03
				Average	36.42
9	15G	A	56.74	43.73	29.75
		B	57.23	43.45	31.71
				Average	30.73
10	11I	A	56.14	43.69	28.50
		B	55	42.6	29.11
				Average	28.80
11	11J	A	53.4	42.5	25.65
		B	55.8	44.5	25.39
				Average	25.52
12	22H	A	56.7	40.2	41.04
		B	52.8	37.6	40.43
				Average	40.74
13	21H	A	55.64	37.35	48.97
		B	56.2	37.8	48.68
				Average	48.82
14	13H	A	53.4	42.67	25.15
		B	51.5	42.34	21.63
				Average	23.39

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Moisture Content %
15	12H	A	52.86	39.5	33.82
		B	54.65	40.65	34.44
				Average	34.13
16	12I	A	56.8	44.58	27.41
		B	55.2	43.56	26.72
				Average	27.07
17	12J	A	53.2	44.5	19.55
		B	52	43.2	20.37
				Average	19.96
18	13A	A	48.5	38.2	26.96
		B	45.62	37.25	22.47
				Average	24.72
19	13I	A	47.35	37.2	27.28
		B	52.1	39.7	31.23
				Average	29.26
20	13J	A	50	43.62	14.63
		B	51	44.21	15.36
				Average	14.99
21	14A	A	49.5	39.7	24.69
		B	45.6	35.1	29.91
				Average	27.30
22	14B	A	46.35	34.5	34.35
		B	46	33.5	37.31
				Average	35.83
23	15A	A	45.5	37.1	22.64
		B	51.5	39.4	30.71
		Average			26.68
24	15B	A	55.7	43.67	27.55
		B	54.5	43.8	24.43
				Average	25.99
25	16F	A	50.3	41.52	21.15
		B	52.4	42.1	24.47
				Average	22.81
26	18H	A	58.73	40.32	45.66
		B	56.85	38.67	47.01
				Average	46.34
27	19F	A	53.4	42.1	26.84
		B	52	39.8	30.65
				Average	28.75
28	19H	A	49	35.2	39.20
		B	46.7	32.1	45.48
				Average	42.34

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Moisture Content %
29	20F	A	48.2	35.6	35.39
		B	45	32.1	40.19
				Average	37.79
30	20G	A	50.38	40.13	25.54
		B	58.47	45.2	29.36
				Average	27.45
31	20H	A	53.4	41.35	29.14
		B	52	39.4	31.98
				Average	30.56
32	21E	A	54	40.13	34.56
		B	52.5	37.68	39.33
				Average	36.95
33	22E	A	45	37.6	19.68
		B	48.5	41.21	17.69
				Average	18.69
34	13D	A	46.5	36.51	27.36
		B	47	37.9	24.01
		Average			25.69
35	14D	A	50	39.61	26.23
		B	52.31	40.74	28.40
				Average	27.32
36	14E	A	44.3	36.08	22.78
		B	45.2	37.81	19.55
				Average	21.16
37	15C	A	48.6	40.21	20.87
		B	50	41.32	21.01
				Average	20.94
38	15D	A	52	43.8	18.72
		B	53.7	45.27	18.62
				Average	18.67
39	16C	A	47.5	39.2	21.17
		B	48	40.1	19.70
				Average	20.44
40	16E	A	50.5	41.64	21.28
		B	53	42.78	23.89
				Average	22.58
41	16G	A	54.2	43.83	23.66
		B	51.2	43.25	18.38
				Average	21.02
42	17D	A	45.6	36.58	24.66
		B	46	37.8	21.69
				Average	23.18

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Moisture Content %
43	17E	A	49.3	36.8	33.97
		B	46.7	34.5	35.36
				Average	34.66
44	14C	A	53.1	44.78	18.58
		B	54	46.7	15.63
				Average	17.11
45	14G	A	50.8	43.2	17.59
		B	54	45.7	18.16
				Average	17.88
46	20D	A	53	44.32	19.58
		B	52.8	44.8	17.86
				Average	18.72
47	11E	A	45.8	36.75	24.63
		B	47.2	36.3	30.03
				Average	27.33
49	10E	A	53.6	44.25	21.13
		B	57	47.6	19.75
				Average	20.44
49	13F	A	54.2	45.4	19.38
		B	55.5	45.7	21.44
				Average	20.41
50	22G	A	47.8	34.21	39.73
		B	49	30.5	60.66
				Average	50.19

APPENDIX B

BULK DENSITY RESULTS

	Point	Sample	Height (cm)	Diameter (cm)	Volume (cc)	Dry Weight (g)	Bulk Density (g/cc)
1	9G	A	4.5	3.5	43.301	58.50	1.3510
		B	4.5	3.5	43.301	58.80	1.3579
						Average	1.3545
2	9H	A	4.4	3.5	42.338	58.10	1.3723
		B	4.4	3.5	42.338	58.40	1.3794
						Average	1.3758
3	10F	A	4.5	3.5	43.301	61.40	1.4180
		B	4.5	3.5	43.301	60.80	1.4041
						Average	1.4111
4	10G	A	4.5	3.5	43.301	60.02	1.3861
		B	4.5	3.5	43.301	60.56	1.3986
						Average	1.3924
5	9I	A	4.4	3.5	42.338	57.34	1.3543
		B	4.4	3.5	42.338	56.93	1.3446
						Average	1.3495
6	19G	A	4.3	3.5	41.376	53.70	1.2978
		B	4.3	3.5	41.376	53.24	1.2867
						Average	1.2923
7	10J	A	4.3	3.5	41.376	56.30	1.3607
		B	4.3	3.5	41.376	56.50	1.3655
						Average	1.3631
8	11F	A	4.5	3.5	43.301	57.10	1.3187
		B	4.5	3.5	43.301	57.00	1.3164
						Average	1.3175
9	15G	A	4.5	3.5	43.301	63.40	1.4642
		B	4.5	3.5	43.301	63.00	1.4549
						Average	1.4596
10	11I	A	4.4	3.5	42.338	63.20	1.4927
		B	4.4	3.5	42.338	62.40	1.4738
						Average	1.4833
11	11J	A	4.5	3.5	43.301	63.40	1.4642
		B	4.5	3.5	43.301	62.80	1.4503
						Average	1.4573
12	22H	A	4.5	3.5	43.301	55.80	1.2887
		B	4.5	3.5	43.301	57.60	1.3302
						Average	1.3094
13	21H	A	4.5	3.5	43.301	54.90	1.2679
		B	4.5	3.5	43.301	55.60	1.2840
						Average	1.2760
14	13H	A	4.2	3.5	40.414	58.00	1.4351
		B	4.1	3.5	39.452	56.70	1.4372
						Average	1.4362

	Point	Sample	Height (cm)	Diameter (cm)	Volume (cc)	Dry Weight (g)	Bulk Density (g/cc)
15	12H	A	4.4	3.5	42.338	59.40	1.4030
		B	4.4	3.5	42.338	59.00	1.3935
						Average	1.3983
16	12I	A	4.3	3.5	41.376	56.80	1.3728
		B	4.3	3.5	41.376	57.00	1.3776
						Average	1.3752
17	12J	A	4.4	3.5	42.338	62.80	1.4833
		B	4.4	3.5	42.338	62.50	1.4762
						Average	1.4797
18	13A	A	4.5	3.5	43.301	60.50	1.3972
		B	4.5	3.5	43.301	60.70	1.4018
						Average	1.3995
19	13I	A	4.2	3.5	40.414	53.20	1.3164
		B	4.2	3.5	40.414	53.00	1.3114
						Average	1.3139
20	13J	A	4.3	3.5	41.376	65.40	1.5806
		B	4.3	3.5	41.376	65.00	1.5710
						Average	1.5758
21	14A	A	4.5	3.5	43.301	61.00	1.4088
		B	4.5	3.5	43.301	60.80	1.4041
						Average	1.4064
22	14B	A	4.4	3.5	42.338	62.00	1.4644
		B	4.4	3.5	42.338	61.90	1.4620
						Average	1.4632
23	15A	A	4.5	3.5	43.301	63.20	1.4596
		B	4.5	3.5	43.301	62.90	1.4526
						Average	1.4561
24	15B	A	4.3	3.5	41.376	59.70	1.4429
		B	4.3	3.5	41.376	59.00	1.4259
						Average	1.4344
25	16F	A	4.3	3.5	41.376	55.50	1.3414
		B	4.3	3.5	41.376	56.00	1.3534
						Average	1.3474
26	18H	A	4.4	3.5	42.338	57.80	1.3652
		B	4.4	3.5	42.338	58.30	1.3770
						Average	1.3711
27	19F	A	4.4	3.5	42.338	58.00	1.3699
		B	4.4	3.5	42.338	58.20	1.3746
						Average	1.3723
28	19H	A	4.4	3.5	42.338	59.00	1.3935
		B	4.4	3.5	42.338	59.30	1.4006
						Average	1.3971

	Point	Sample	Height (cm)	Diameter (cm)	Volume (cc)	Dry Weight (g)	Bulk Density (g/cc)
29	20F	A	4.5	3.5	43.301	60.40	1.3949
		B	4.5	3.5	43.301	61.00	1.4088
						Average	1.4018
30	20G	A	4.5	3.5	43.301	61.50	1.4203
		B	4.5	3.5	43.301	61.00	1.4088
						Average	1.4145
31	20H	A	4.5	3.5	43.301	62.00	1.4318
		B	4.5	3.5	43.301	61.50	1.4203
						Average	1.4261
32	21E	A	4.5	3.5	43.301	62.40	1.4411
		B	4.5	3.5	43.301	62.60	1.4457
						Average	1.4434
33	22E	A	4.5	3.5	43.301	61.70	1.4249
		B	4.5	3.5	43.301	61.50	1.4203
						Average	1.4226
34	13D	A	4.4	3.5	42.338	55.40	1.3085
		B	4.4	3.5	42.338	56.00	1.3227
						Average	1.3156
35	14D	A	4.4	3.5	42.338	61.50	1.4526
		B	4.4	3.5	42.338	60.40	1.4266
						Average	1.4396
36	14E	A	4.3	3.5	41.376	59.20	1.4308
		B	4.3	3.5	41.376	59.00	1.4259
						Average	1.4284
37	15C	A	4.3	3.5	41.376	58.70	1.4187
		B	4.3	3.5	41.376	59.10	1.4284
						Average	1.4235
38	15D	A	4.5	3.5	43.301	62.40	1.4411
		B	4.5	3.5	43.301	63.00	1.4549
						Average	1.4480
39	16C	A	4.5	3.5	43.301	61.80	1.4272
		B	4.5	3.5	43.301	62.10	1.4342
						Average	1.4307
40	16E	A	4.5	3.5	43.301	60.80	1.4041
		B	4.5	3.5	43.301	60.60	1.3995
						Average	1.4018
41	16G	A	4.5	3.5	43.301	61.00	1.4088
		B	4.5	3.5	43.301	61.40	1.4180
						Average	1.4134
42	17D	A	4.3	3.5	41.376	59.40	1.4356
		B	4.3	3.5	41.376	60.00	1.4501
						Average	1.4429

	Point	Sample	Height (cm)	Diameter (cm)	Volume (cc)	Dry Weight (g)	Bulk Density (g/cc)
43	17E	A	4.4	3.5	42.338	55.90	1.3203
		B	4.4	3.5	42.338	56.70	1.3392
						Average	1.3298
44	14C	A	4.2	3.5	40.414	58.30	1.4426
		B	4.2	3.5	40.414	58.00	1.4351
						Average	1.4389
45	14G	A	4.5	3.5	43.301	64.00	1.4780
		B	4.5	3.5	43.301	64.30	1.4850
						Average	1.4815
46	20D	A	4.1	3.5	39.452	59.90	1.5183
		B	4.1	3.5	39.452	60.20	1.5259
						Average	1.5221
47	11E	A	4	3.5	38.490	49.70	1.2913
		B	4	3.5	38.490	49.20	1.2783
						Average	1.2848
49	10E	A	4.3	3.5	41.376	55.40	1.3389
		B	4.3	3.5	41.376	56.00	1.3534
						Average	1.3462
49	13F	A	4.4	3.5	42.338	62.40	1.4738
		B	4.4	3.5	42.338	63.00	1.4880
						Average	1.4809
50	22G	A	4.4	3.5	42.338	55.70	1.3156
		B	4.4	3.5	42.338	56.20	1.3274
						Average	1.3215

APPENDIX C

SOIL ORGANIC CONTENT RESULTS

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Ignited Weight (g)	Organic Content (%)
1	9G	A	51.22	40.2	38.32	4.68
		B	54.94	42.8	40.89	4.46
					Average	4.57
2	9H	A	57.48	45.01	41.56	7.66
		B	50.52	40.64	36.9	9.20
					Average	8.43
3	10F	A	55.21	44.2	43.2	2.26
		B	53.12	43.1	42.5	1.39
					Average	1.83
4	10G	A	56.23	44.35	41.57	6.27
		B	54.85	41.89	39.39	5.97
					Average	6.12
5	9I	A	53.4	41.2	39.7	3.64
		B	55.4	43.6	42.35	2.87
					Average	3.25
6	19G	A	54.6	37.8	35.12	7.09
		B	56.2	39	36.45	6.54
					Average	6.81
7	10J	A	57.2	43.5	42.6	2.07
		B	55.4	42.3	41.87	1.02
					Average	1.54
8	11F	A	56.4	41.53	37.54	9.61
		B	55.8	40.72	38.1	6.43
					Average	8.02
9	15G	A	56.74	43.73	42.5	2.81
		B	57.23	43.45	42.8	1.50
					Average	2.15
10	11I	A	56.14	43.69	43	1.58
		B	55	42.6	41.9	1.64
					Average	1.61
11	11J	A	53.4	42.5	41.67	1.95
		B	55.8	44.5	43.2	2.92
					Average	2.44
12	22H	A	56.7	40.2	38.5	4.23
		B	52.8	37.6	35.42	5.80
					Average	5.01
13	21H	A	55.64	37.35	34.56	7.47
		B	56.2	37.8	33.48	11.43
					Average	9.45
14	13H	A	53.4	42.67	41.35	3.09
		B	51.5	42.34	41.21	2.67
					Average	2.88

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Ignited Weight (g)	Organic Content (%)
15	12H	A	52.86	39.5	39.1	1.01
		B	54.65	40.65	40	1.60
					Average	1.31
16	12I	A	56.8	44.58	42.67	4.28
		B	55.2	43.56	42.1	3.35
					Average	3.82
17	12J	A	53.2	44.5	44.17	0.74
		B	52	43.2	42.87	0.76
					Average	0.75
18	13A	A	48.5	38.2	37.3	2.36
		B	45.62	37.25	36.5	2.01
					Average	2.18
19	13I	A	47.35	37.2	35.1	5.65
		B	52.1	39.7	37.45	5.67
					Average	5.66
20	13J	A	50	43.62	43.4	0.50
		B	51	44.21	43.87	0.77
					Average	0.64
21	14A	A	49.5	39.7	38.57	2.85
		B	45.6	35.1	34.05	2.99
					Average	2.92
22	14B	A	46.35	34.5	33.6	2.61
		B	46	33.5	32.98	1.55
					Average	2.08
23	15A	A	45.5	37.1	36.54	1.51
		B	51.5	39.4	38.66	1.88
					Average	1.69
24	15B	A	55.7	43.67	42.75	2.11
		B	54.5	43.8	42.76	2.37
					Average	2.24
25	16F	A	50.3	41.52	40.35	2.82
		B	52.4	42.1	41.23	2.07
					Average	2.44
26	18H	A	58.73	40.32	37.52	6.94
		B	56.85	38.67	36.42	5.82
					Average	6.38
27	19F	A	53.4	42.1	41.37	1.73
		B	52	39.8	38.74	2.66
					Average	2.20
28	19H	A	49	35.2	34.53	1.90
		B	46.7	32.1	31.65	1.40
					Average	1.65

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Ignited Weight (g)	Organic Content (%)
29	20F	A	48.2	35.6	34.6	2.81
		B	45	32.1	31.48	1.93
					Average	2.37
30	20G	A	50.38	40.13	38.57	3.89
		B	58.47	45.2	42.57	5.82
					Average	4.85
31	20H	A	53.4	41.35	40.1	3.02
		B	52	39.4	38.34	2.69
					Average	2.86
32	21E	A	54	40.13	38.45	4.19
		B	52.5	37.68	35.62	5.47
					Average	4.83
33	22E	A	45	37.6	37.3	0.80
		B	48.5	41.21	40.87	0.83
					Average	0.81
34	13D	A	46.5	36.51	34.68	5.01
		B	47	37.9	36.1	4.75
					Average	4.88
35	14D	A	50	39.61	38.1	3.81
		B	52.31	40.74	39.42	3.24
					Average	3.53
36	14E	A	44.3	36.08	35.24	2.33
		B	45.2	37.81	36.78	2.72
					Average	2.53
37	15C	A	48.6	40.21	39.64	1.42
		B	50	41.32	40.59	1.77
					Average	1.59
38	15D	A	52	43.8	43.06	1.69
		B	53.7	45.27	44.79	1.06
					Average	1.37
39	16C	A	47.5	39.2	38.76	1.12
		B	48	40.1	39.57	1.32
					Average	1.22
40	16E	A	50.5	41.64	41.2	1.06
		B	53	42.78	42.32	1.08
					Average	1.07
41	16G	A	54.2	43.83	43.32	1.16
		B	51.2	43.25	42.62	1.46
					Average	1.31
42	17D	A	45.6	36.58	35.67	2.49
		B	46	37.8	36.76	2.75
					Average	2.62

	Point	Sample	Wet Weight (g)	Dry Weight (g)	Ignited Weight (g)	Organic Content (%)
43	17E	A	49.3	36.8	34.89	5.19
		B	46.7	34.5	33.08	4.12
					Average	4.65
44	14C	A	53.1	44.78	44.25	1.18
		B	54	46.7	46.17	1.13
					Average	1.16
45	14G	A	50.8	43.2	42.57	1.46
		B	54	45.7	45.09	1.33
					Average	1.40
46	20D	A	53	44.32	43.86	1.04
		B	52.8	44.8	44.35	1.00
					Average	1.02
47	11E	A	45.8	36.75	34.67	5.66
		B	47.2	36.3	34.68	4.46
					Average	5.06
49	10E	A	53.6	44.25	43.27	2.21
		B	57	47.6	46.8	1.68
					Average	1.95
49	13F	A	54.2	45.4	44.63	1.70
		B	55.5	45.7	45.06	1.40
					Average	1.55
50	22G	A	47.8	34.21	32.59	4.74
		B	49	30.5	29.41	3.57
					Average	4.15

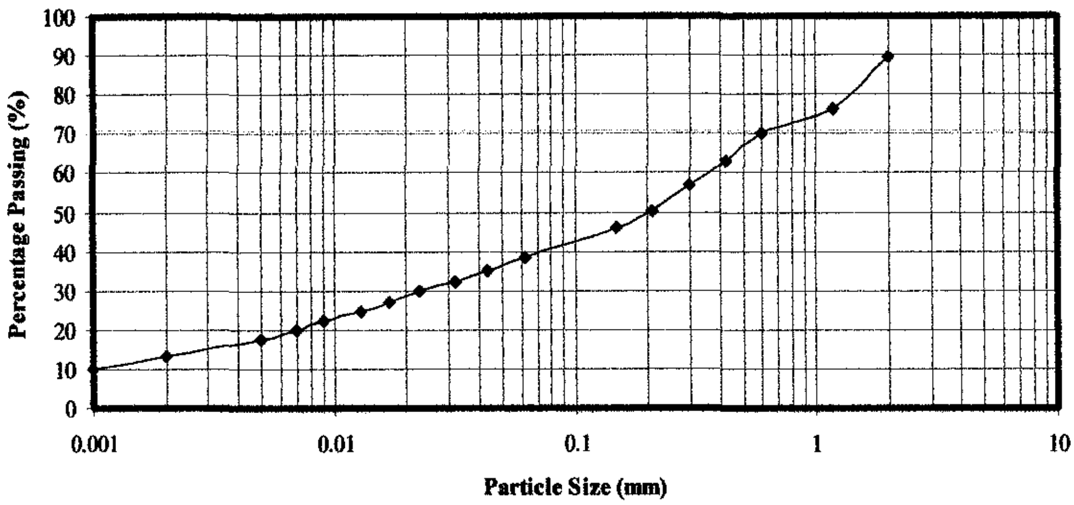
No	Point	Organic Content %	Bulk Density (g/cc)	Moisture Content %	Fine Content %	Specific Gravity (g/cm^3)	**Area**
1	15A	1.69	1.4561	26.68	12.33	2.450	Disturbed
2	14A	2.92	1.4064	27.30	10.33	2.584	Disturbed
3	13A	2.18	1.3995	24.72	7.84	2.511	Disturbed
4	15B	2.24	1.4344	25.99	9.79	2.549	Disturbed
5	14B	2.08	1.4632	35.83	16.32	2.643	Disturbed
6	16C	1.22	1.4307	20.44	11.35	2.603	Disturbed
7	15C	1.59	1.4235	20.94	4.92	2.412	Disturbed
8	14C	1.16	1.4389	17.11	5.62	2.546	Disturbed
9	20D	1.02	1.5221	18.72	9.65	2.614	Disturbed
10	17D	2.62	1.4429	23.18	13.45	2.622	Disturbed
11	15D	1.37	1.4480	18.67	12.81	2.469	Disturbed
12	14D	3.53	1.4396	27.32	16.72	2.510	Disturbed
13	13D	4.88	1.3156	25.69	5.67	2.399	Disturbed
14	16E	1.07	1.4018	22.58	9.52	2.626	Disturbed
15	14E	2.53	1.4284	21.16	8.63	2.557	Disturbed
16	10E	1.95	1.3462	20.44	11.36	2.607	Disturbed
17	20F	2.37	1.4018	37.79	3.76	2.600	Disturbed
18	19F	2.20	1.3723	28.75	9.56	2.590	Disturbed
19	16F	2.44	1.3474	22.81	4.62	2.616	Disturbed
20	13F	1.55	1.4809	20.41	9.63	2.611	Disturbed
21	10F	1.83	1.4111	24.08	5.68	2.515	Disturbed
22	20G	4.85	1.4145	27.45	4.85	2.512	Disturbed
23	16G	1.31	1.4134	21.02	14.32	2.650	Disturbed
24	15G	2.15	1.4596	30.73	10.52	2.487	Disturbed
25	14G	1.40	1.4815	17.88	11.41	2.531	Disturbed
26	13H	2.88	1.4362	23.39	3.09	2.468	Disturbed
27	12H	1.31	1.3983	34.13	5.46	2.541	Disturbed
28	12I	3.82	1.3752	27.07	6.45	2.561	Disturbed
29	11I	1.61	1.4833	28.80	10.89	2.486	Disturbed
30	13J	0.64	1.5758	14.99	3.54	2.508	Disturbed
31	12J	0.75	1.4797	19.96	4.56	2.463	Disturbed
32	11J	2.44	1.4573	25.52	8.64	2.523	Disturbed
33	11E	5.06	1.2848	27.33	3.45	2.470	Forest
34	11F	8.02	1.3175	36.42	9.61	2.425	Forest
35	10G	6.12	1.3924	28.86	3.21	2.676	Forest
36	9G	4.57	1.3545	27.89	12.87	2.482	Forest
37	9H	8.43	1.3758	26.01	2.64	2.440	Forest
38	13I	5.66	1.3139	29.26	10.68	2.558	Forest
39	9I	3.25	1.3495	28.34	12.57	2.410	Forest
40	10J	1.54	1.3631	31.23	12.45	2.430	Forest
41	22E	0.81	1.4226	18.69	6.37	2.547	Pond
42	21E	4.83	1.4434	36.95	17.68	2.400	Pond
43	17E	4.65	1.3298	34.66	4.98	2.495	Pond

No	Point	Organic Content %	Bulk Density (g/cc)	Moisture Content %	Fine Content %	Specific Gravity (g/cm^3)	**Area**
44	22G	4.15	1.3215	50.19	27.18	2.589	Pond
45	19G	6.81	1.2923	44.27	8.10	2.451	Pond
46	22H	5.01	1.3095	40.74	5.34	2.573	Pond
47	21H	9.45	1.2760	48.82	11.30	2.607	Pond
48	20H	2.86	1.4261	30.56	7.85	2.439	Pond
49	19H	1.65	1.3971	42.34	19.67	2.639	Pond
50	18H	6.38	1.3711	46.34	25.61	2.493	Pond

APPENDIX E

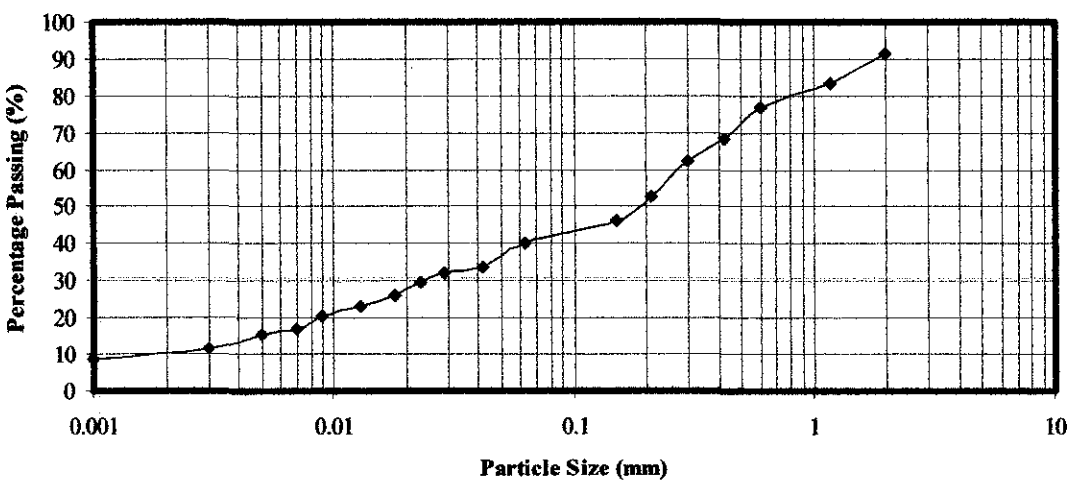
PARTICLE SIZE DISTRIBUTION CHART

Sampling Location: 15A



<table>
<tr><td rowspan="2">Clay</td><td>Fine</td><td>Medium</td><td>Coarse</td><td>Fine</td><td>Medium</td><td>Coarse</td><td rowspan="2">Cobbles</td></tr>
<tr><td colspan="3">Silt</td><td colspan="3">Sand</td></tr>
</table>

Sampling Location: 14A



<table>
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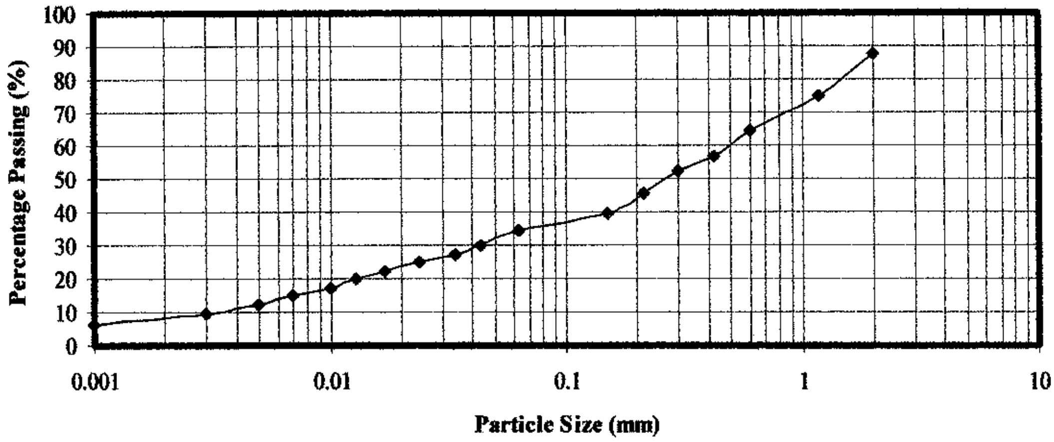
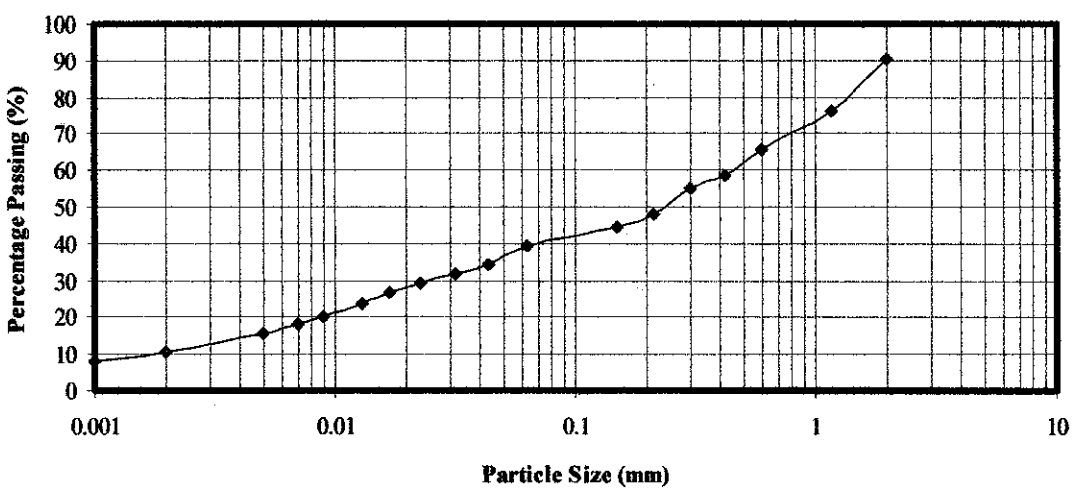
<tr><td colspan="3">Silt</td><td colspan="3">Sand</td></tr>
</table>

Sampling Location: 13A



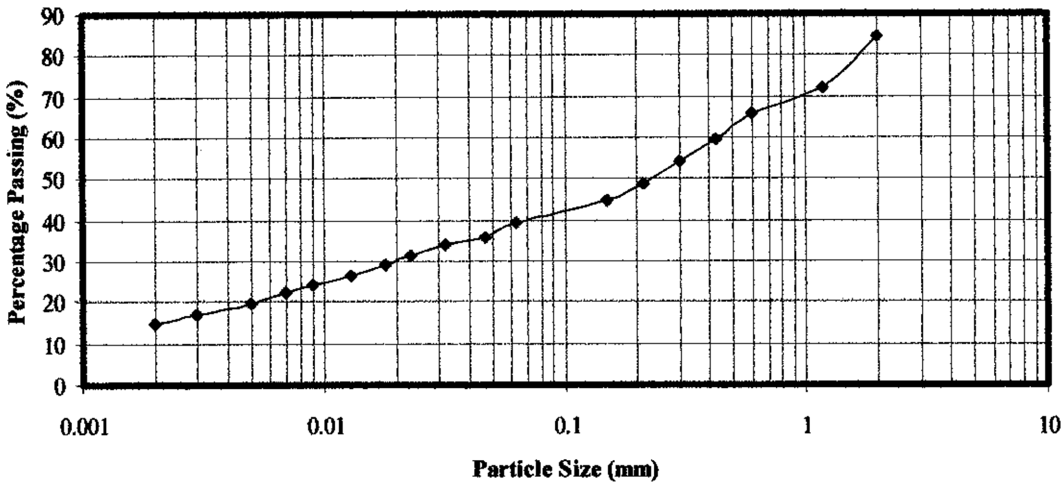
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 15B



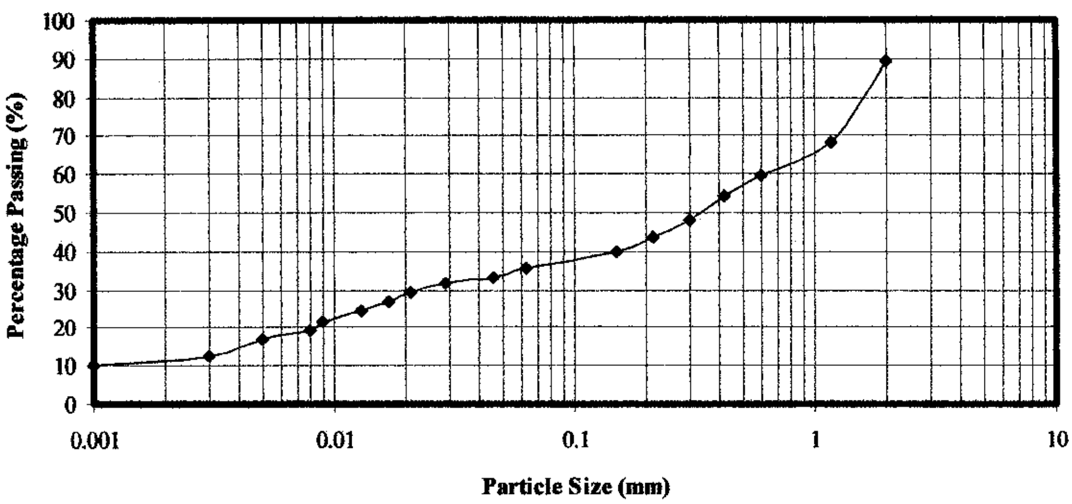
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 14B



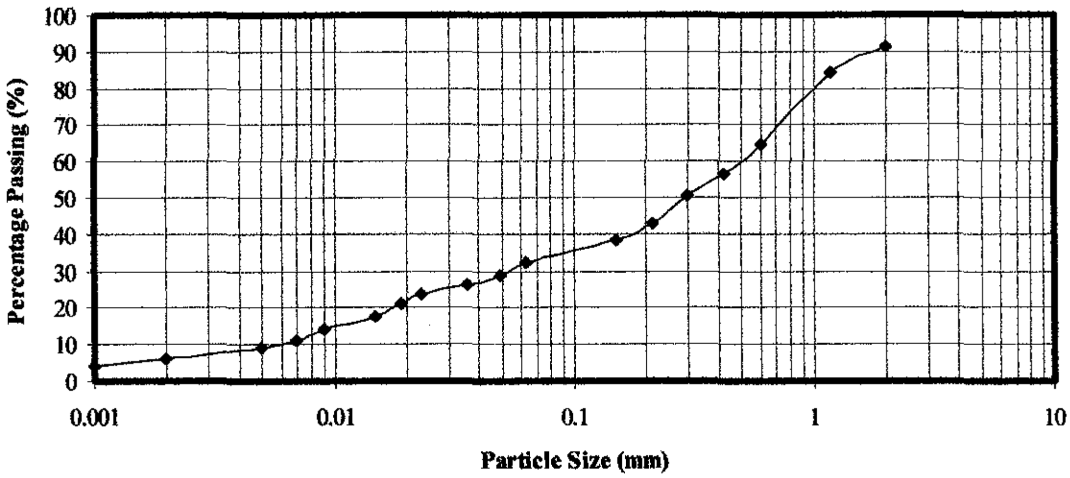
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 16C



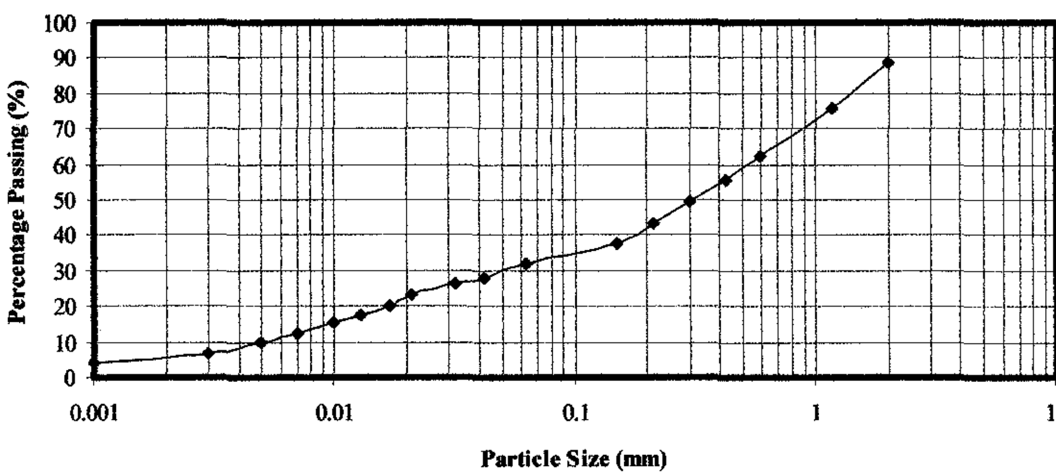
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 15C



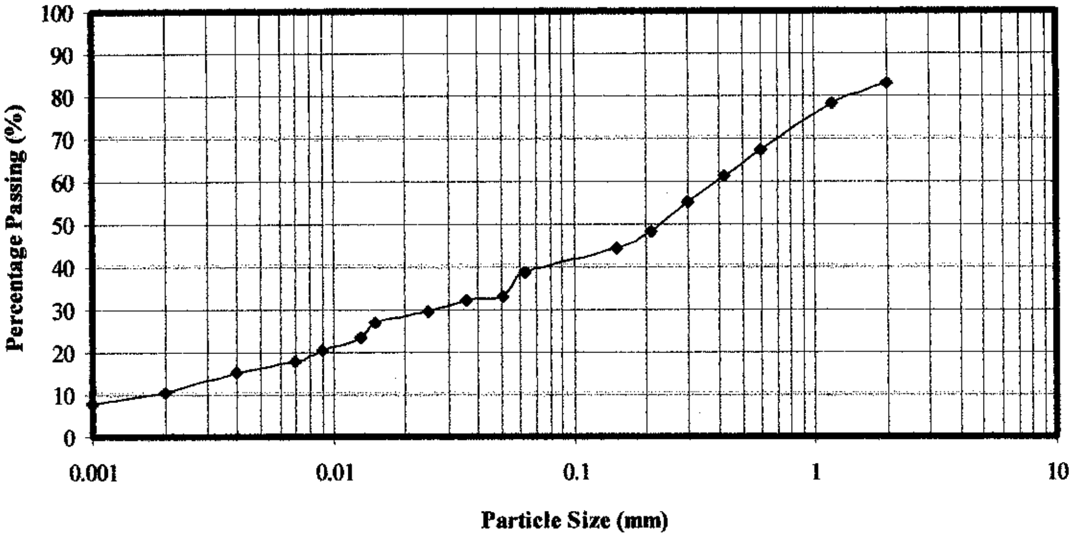
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 14C



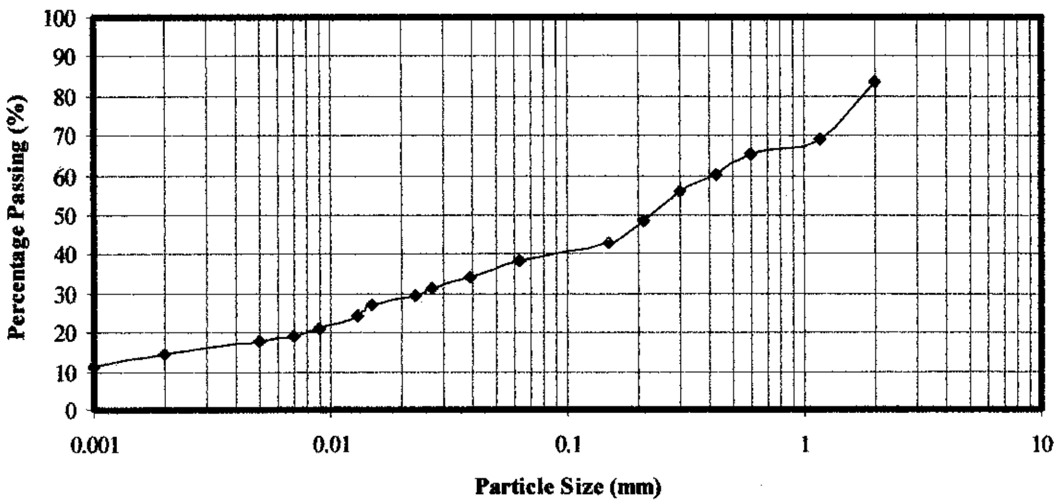
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 20D



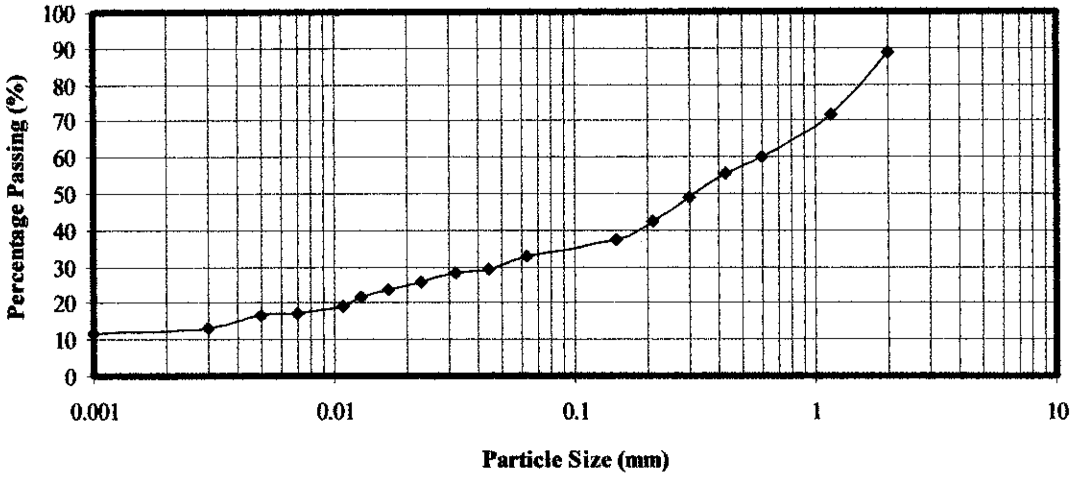
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 17D



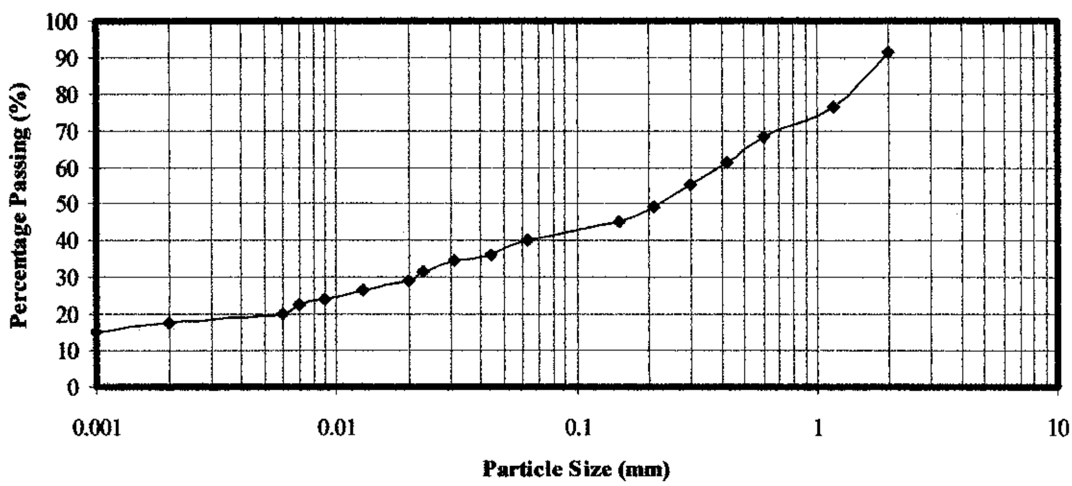
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 15D



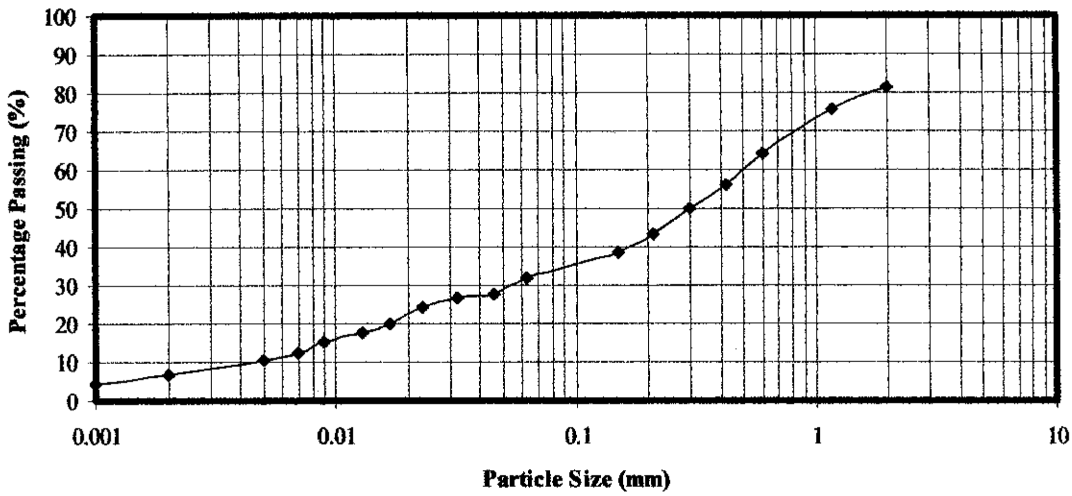
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 14D



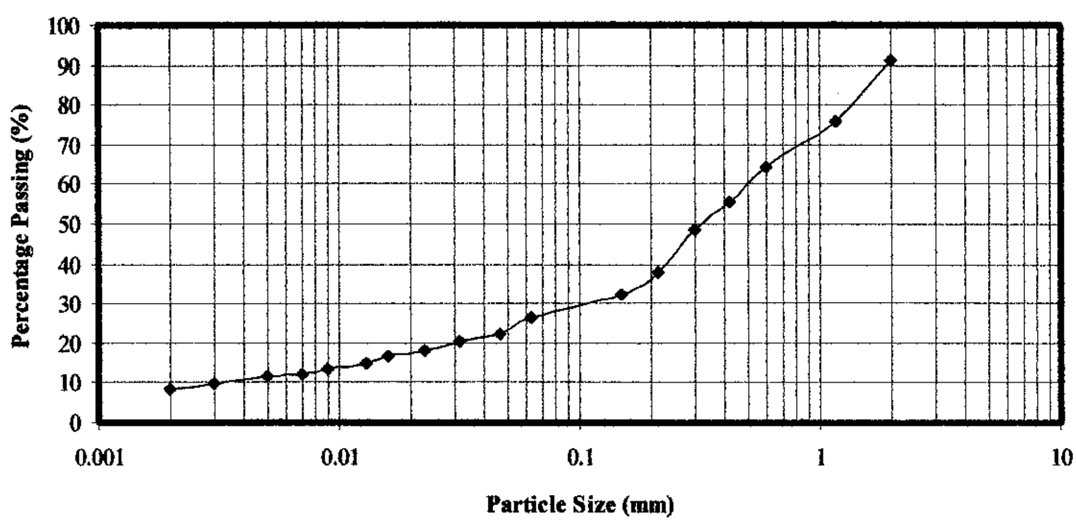
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 13D



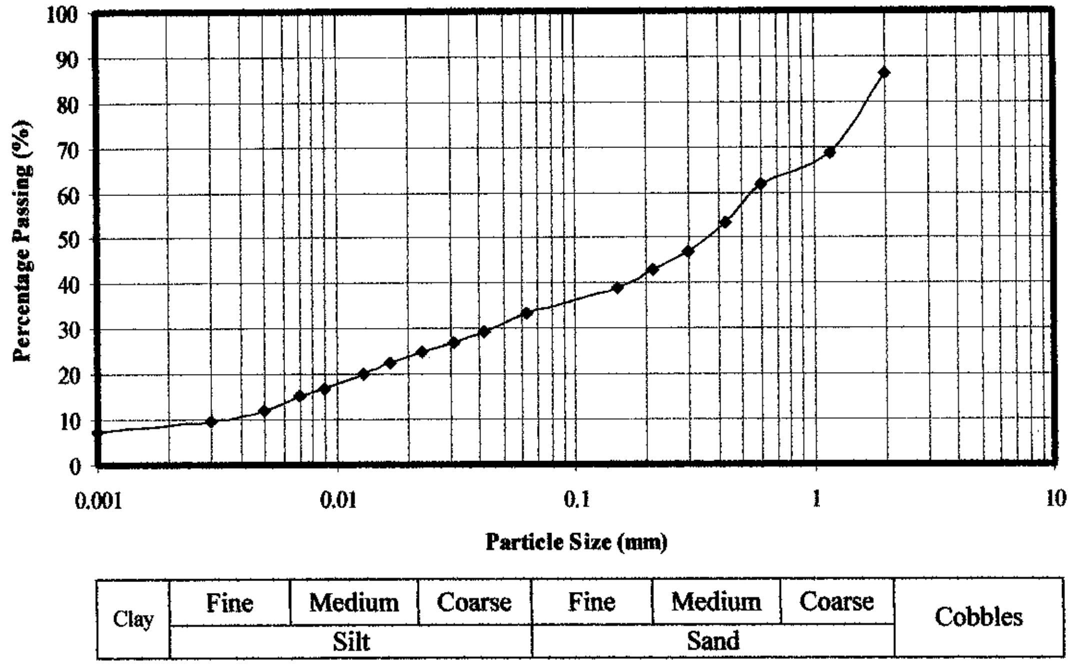
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 16E

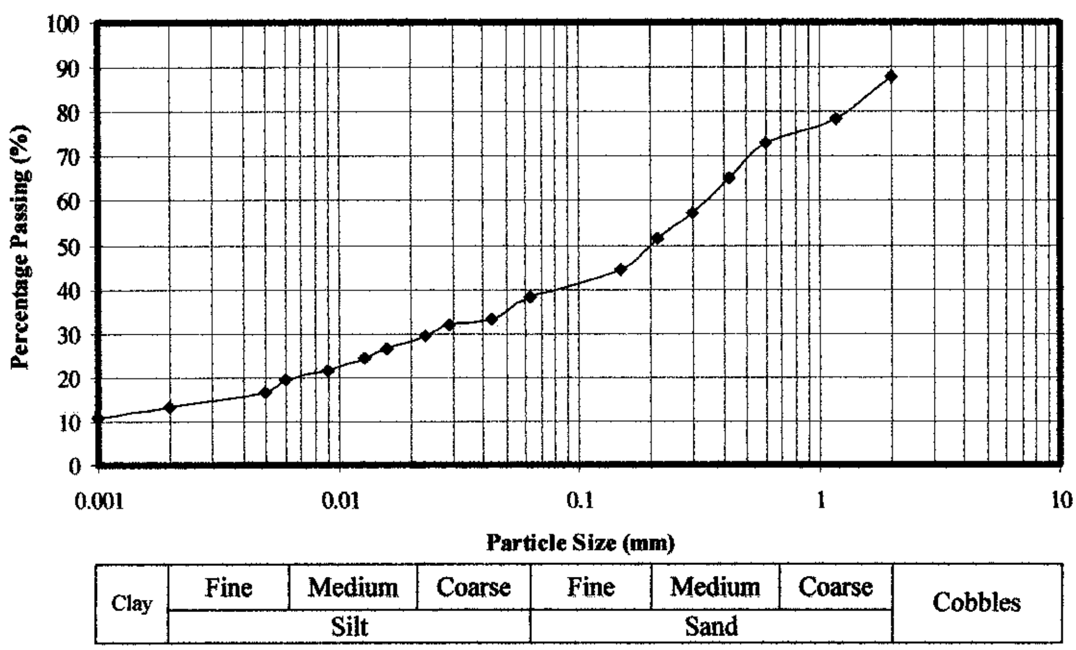


Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

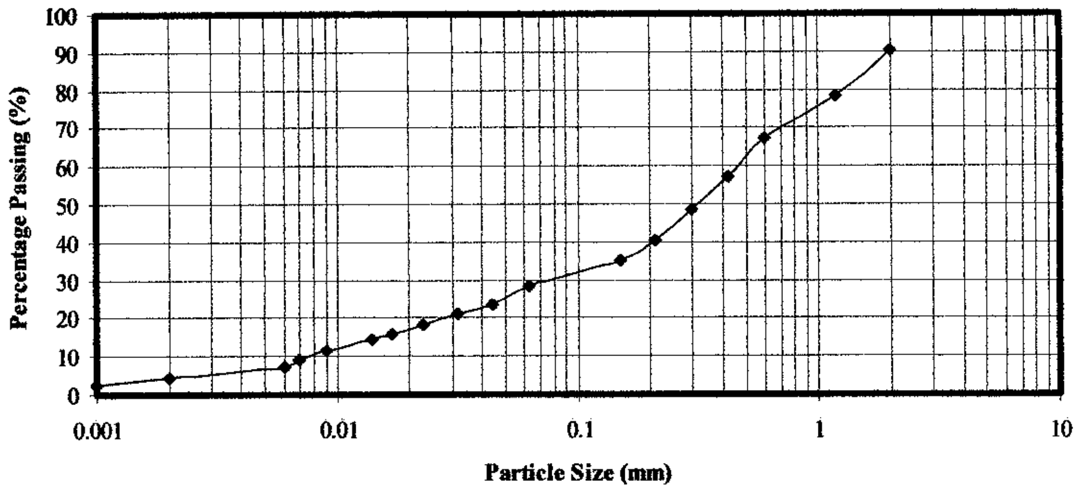
Sampling Location: 14E



Sampling Location: 10E

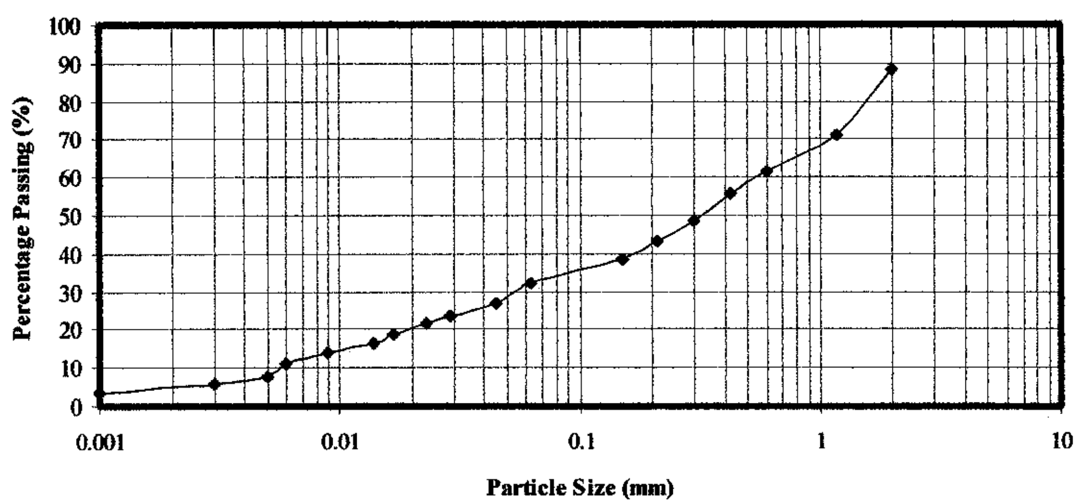


Sampling Location: 20F



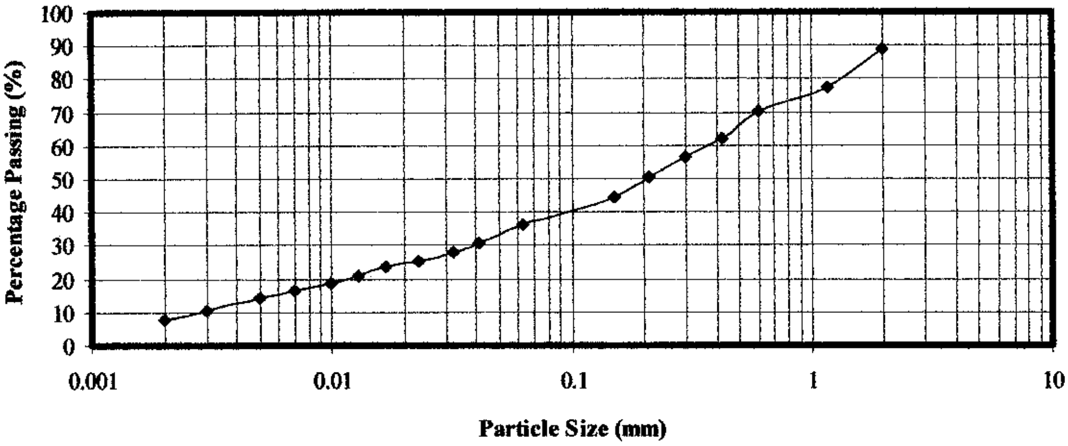
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 16F



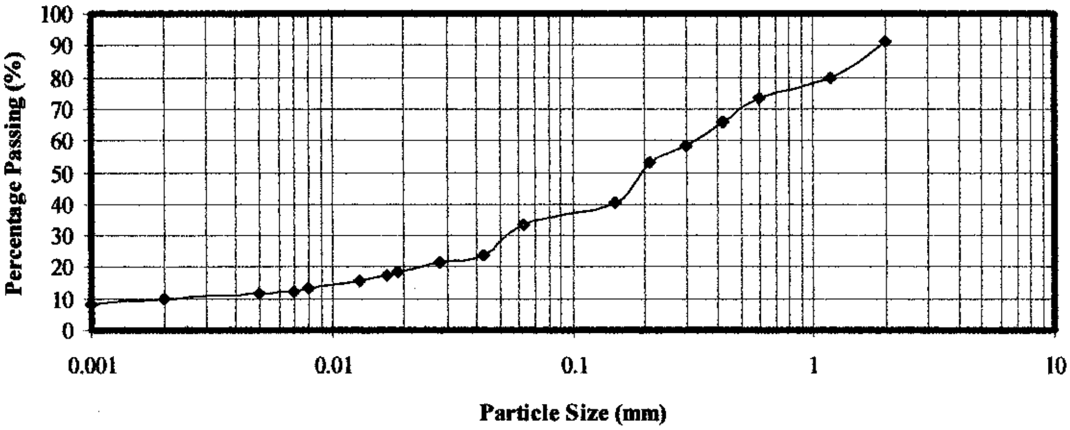
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 19F



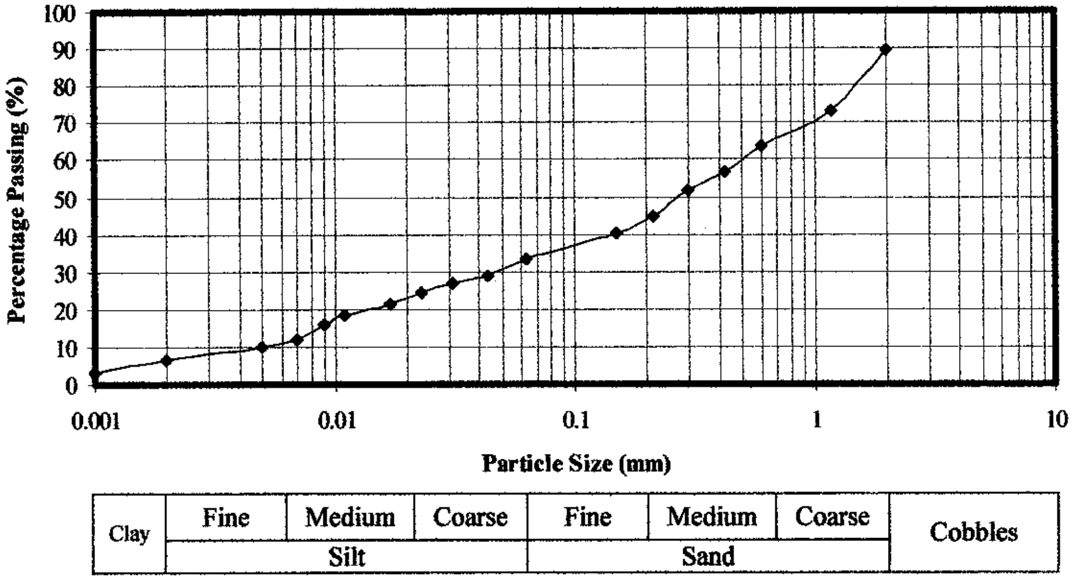
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 13F

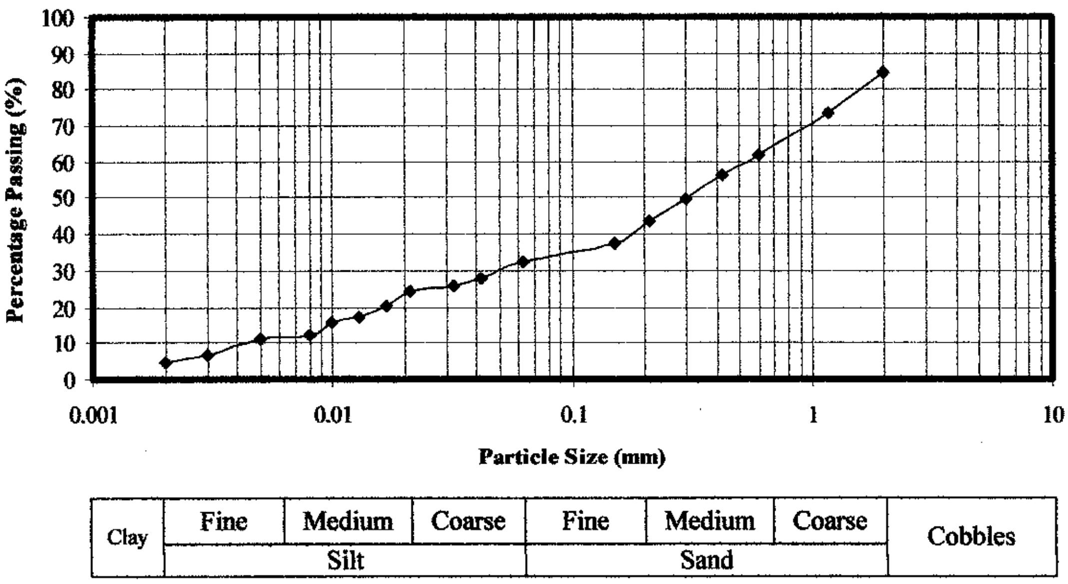


Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

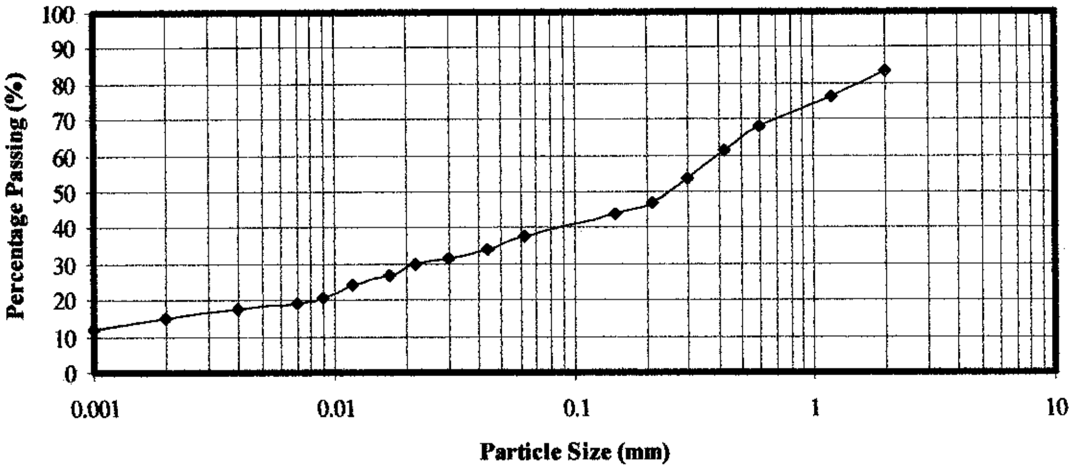
Sampling Location: 20G



Sampling Location: 10F

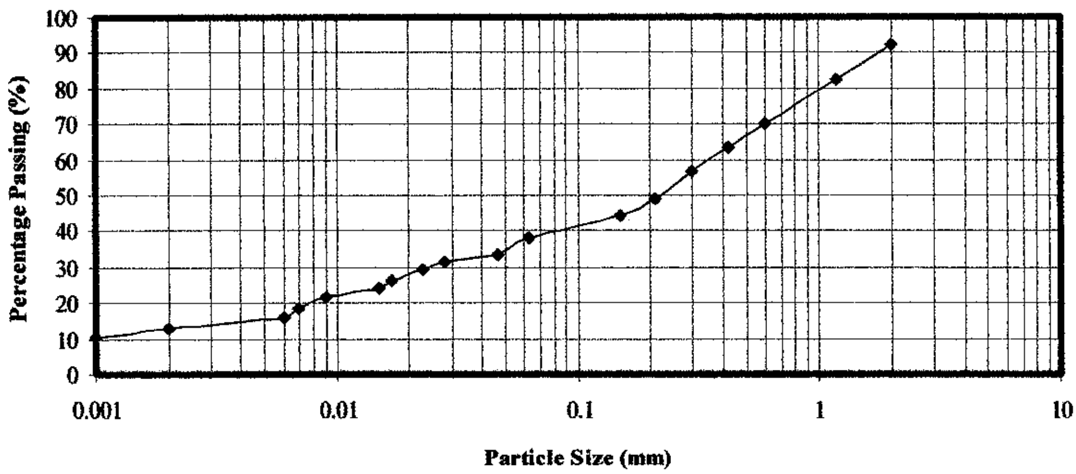


Sampling Location: 16G



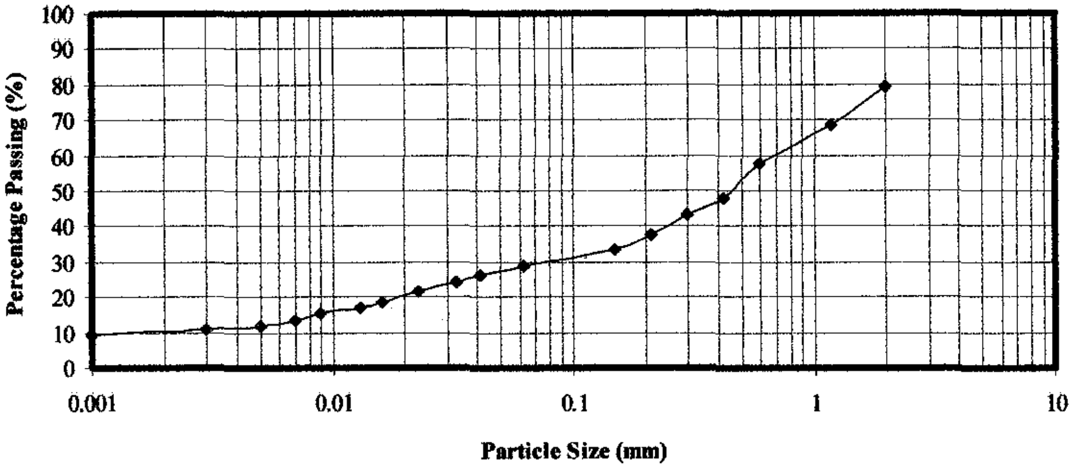
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 14G



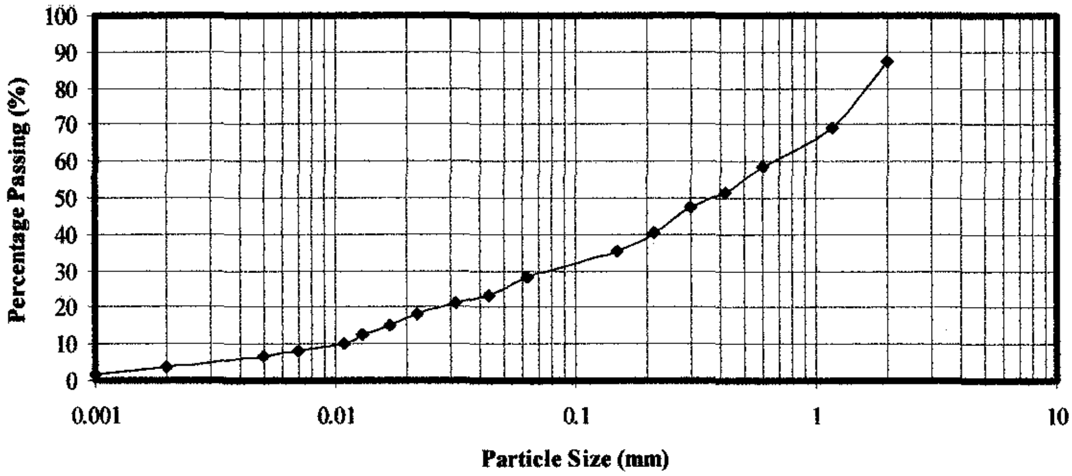
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 15G



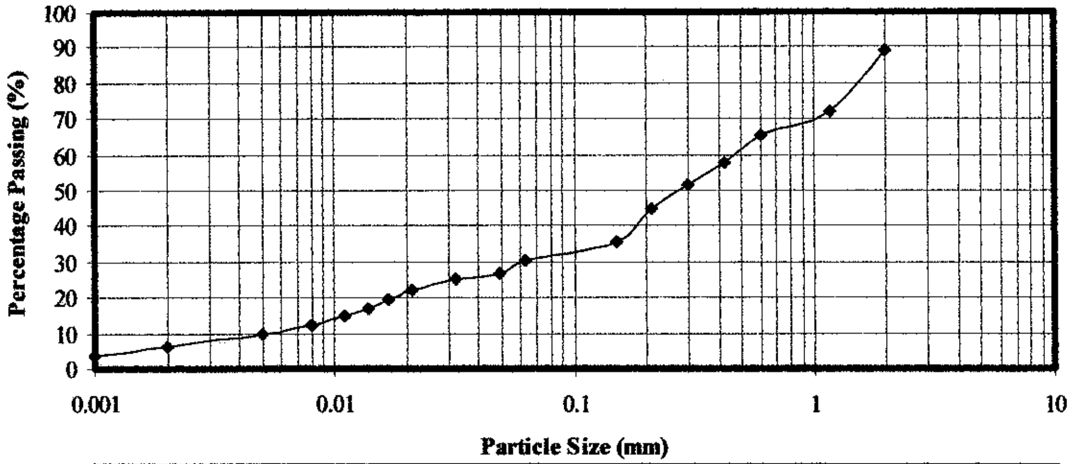
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 13H



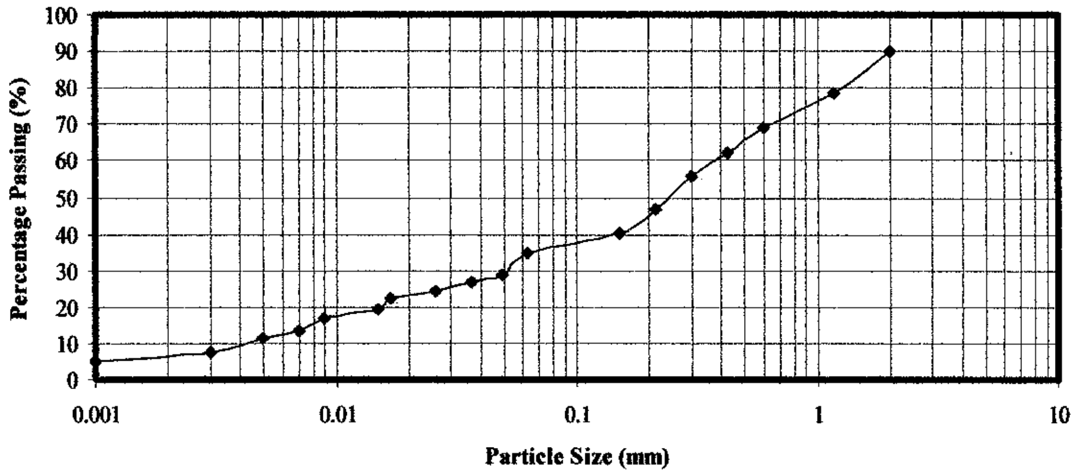
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 12H



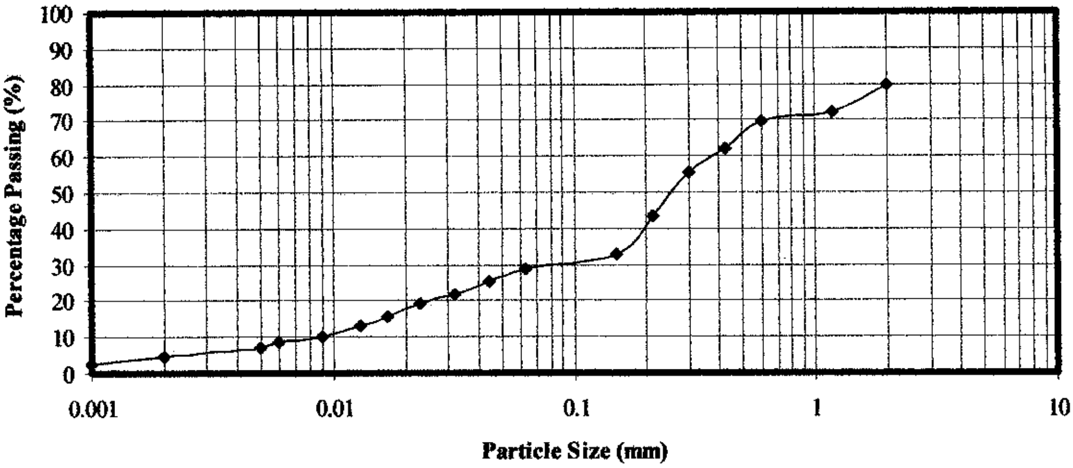
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 12I



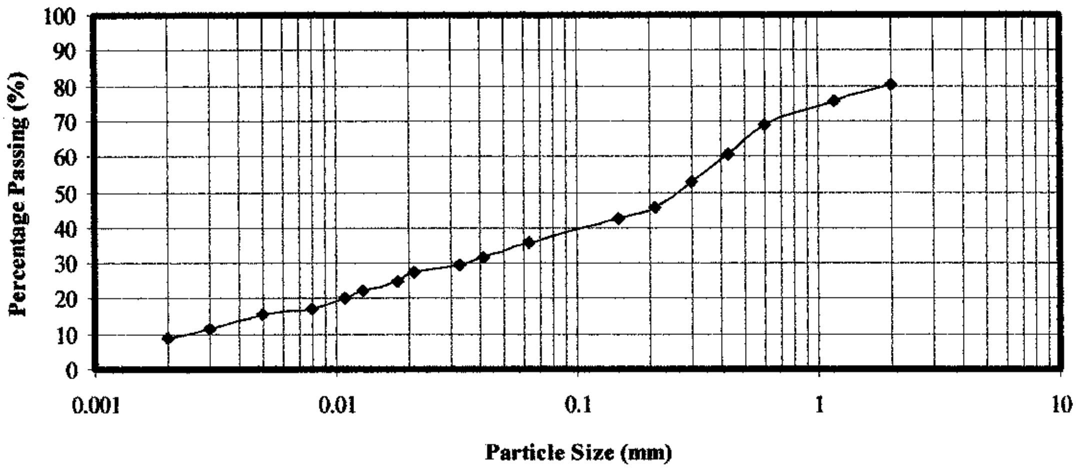
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 13J



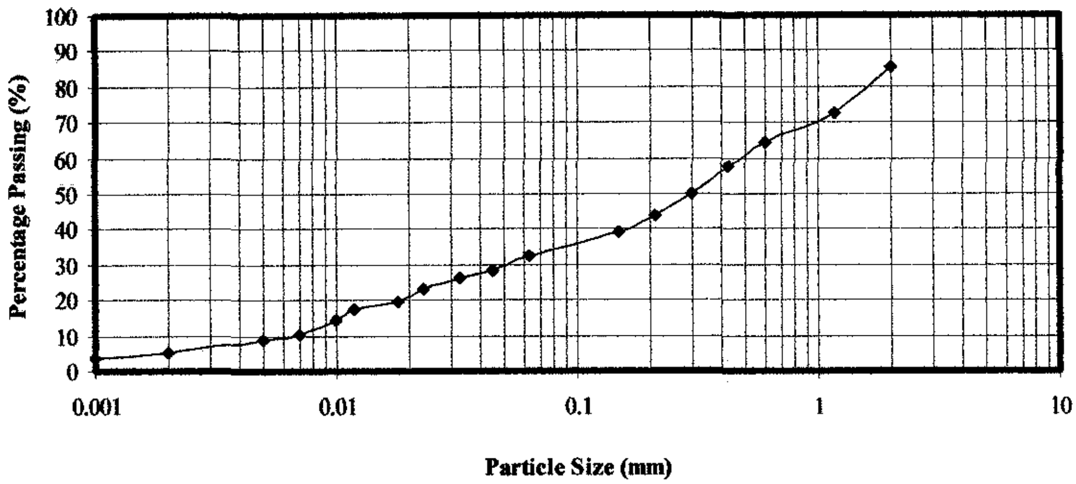
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 11I



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 12J



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
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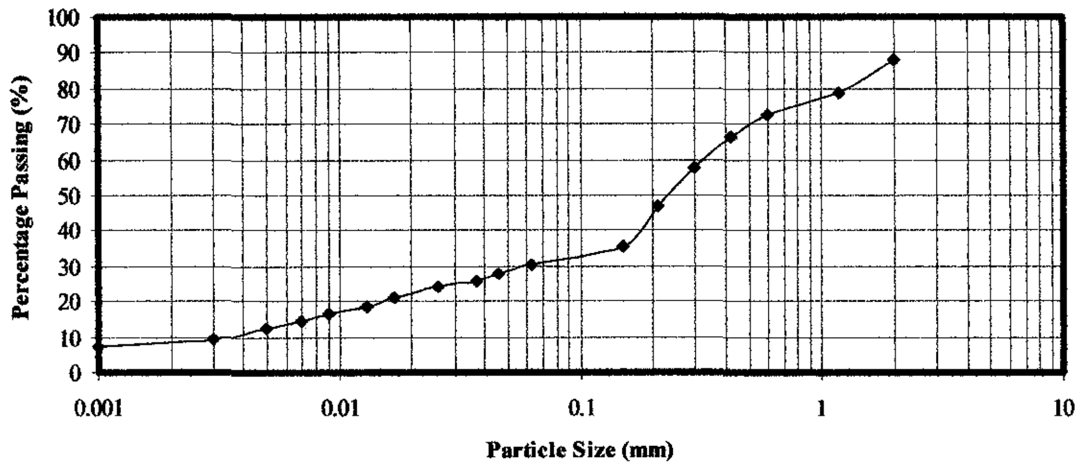
Sampling Location: 11J



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
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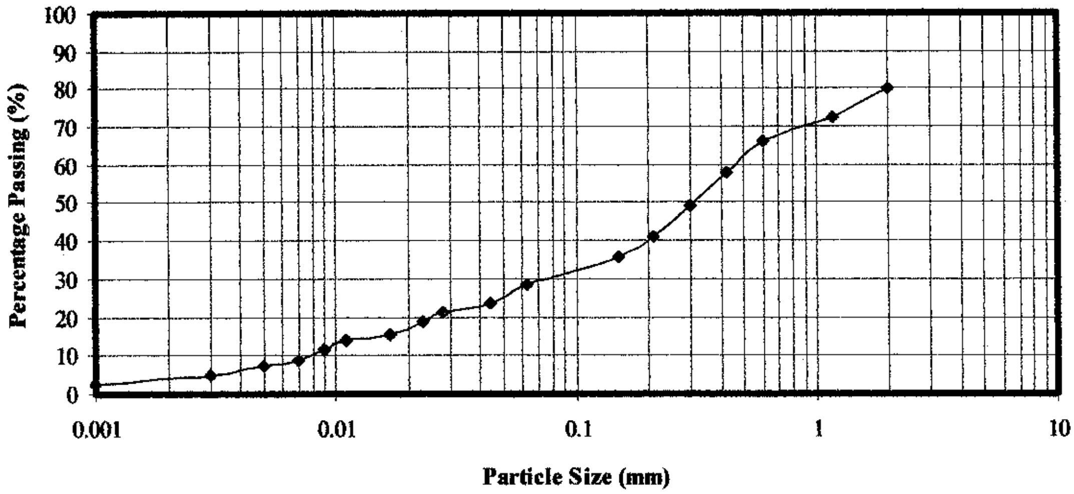
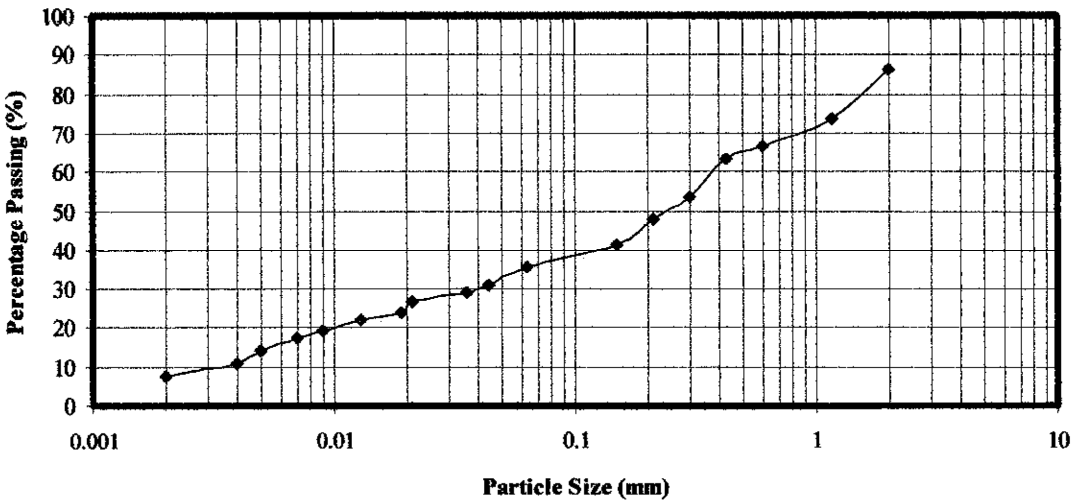
Sampling Location: 11E



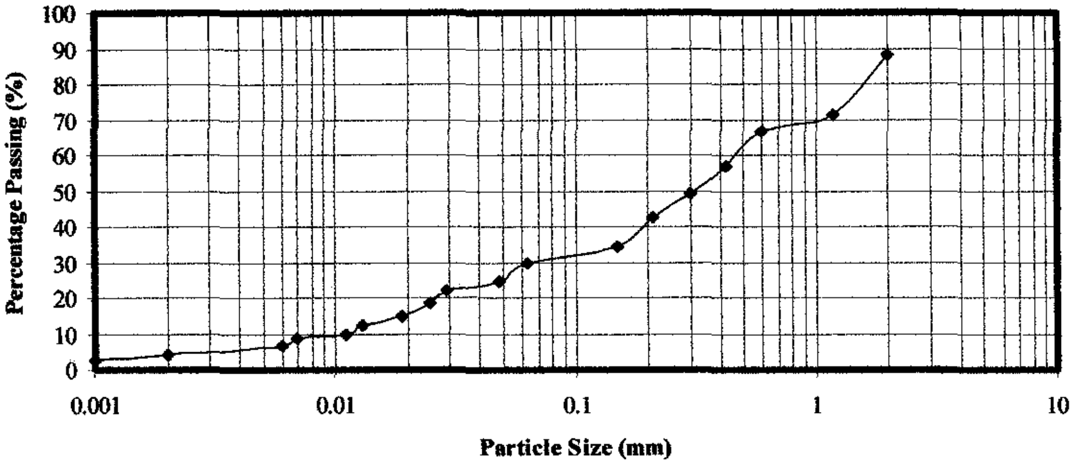
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 11F



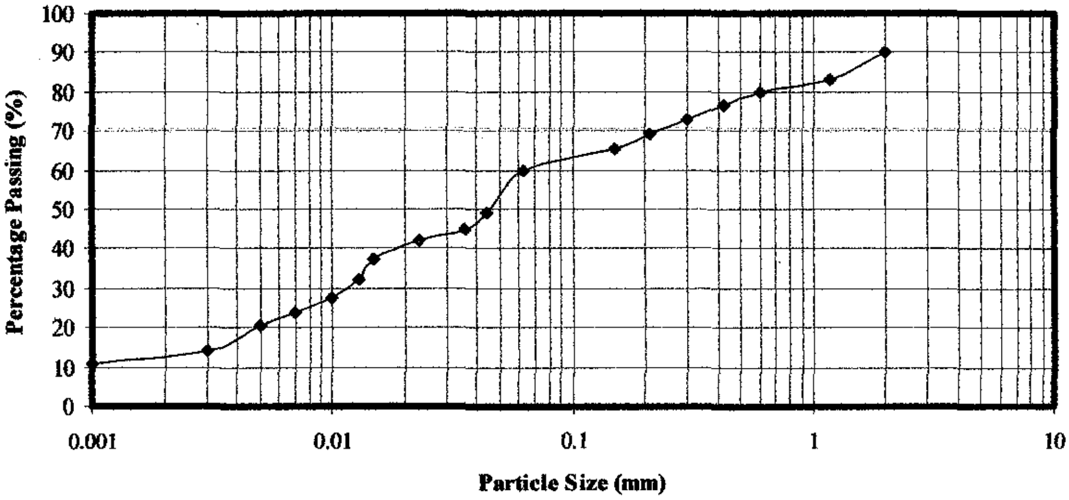
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 10G



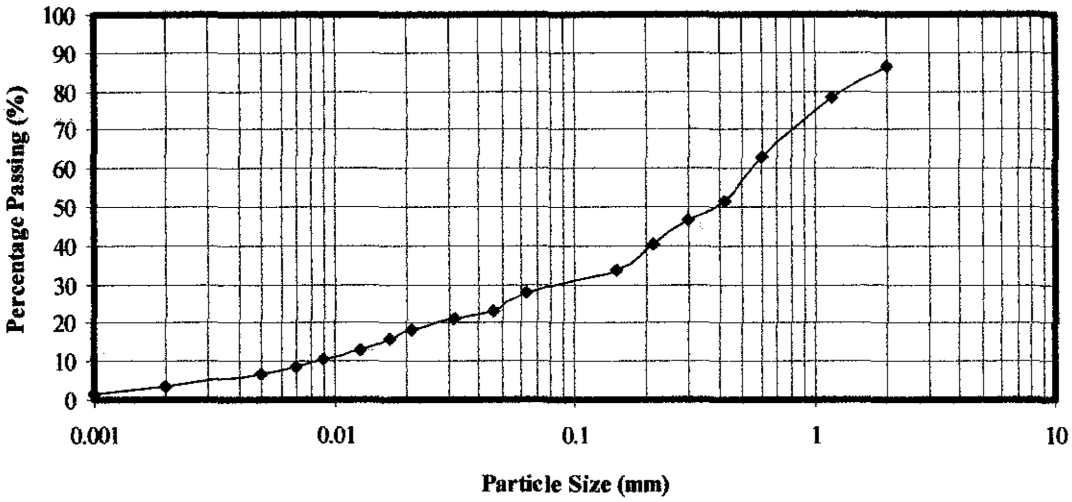
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 9G



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 9H



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<tr><td colspan="3">Silt</td><td colspan="3">Sand</td></tr>
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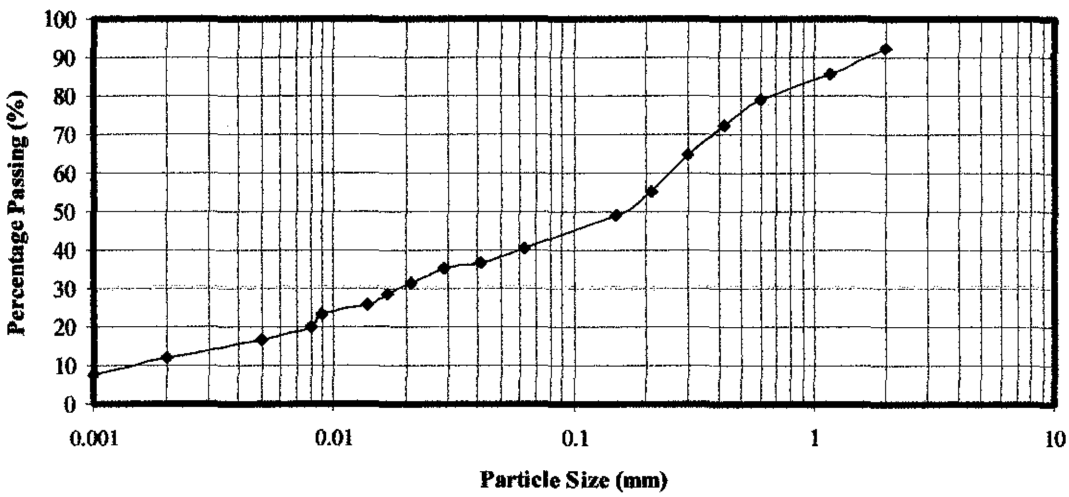
Sampling Location: 13I



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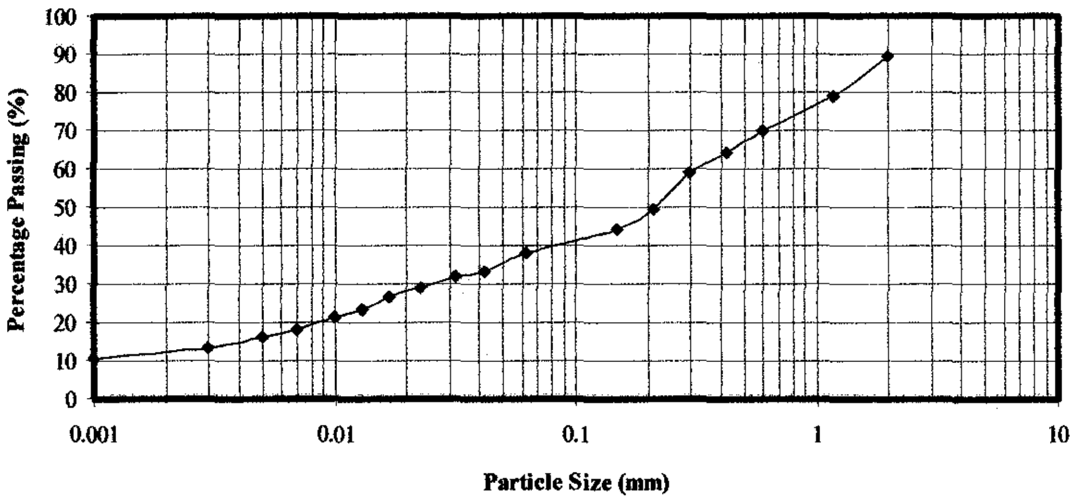
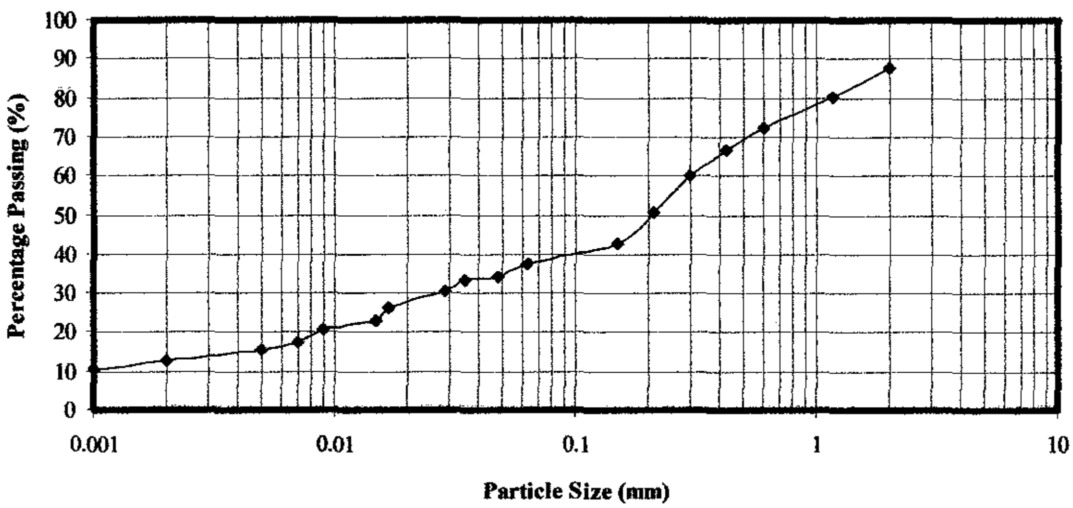
<tr><td colspan="3">Silt</td><td colspan="3">Sand</td></tr>
</table>

Sampling Location: 9I



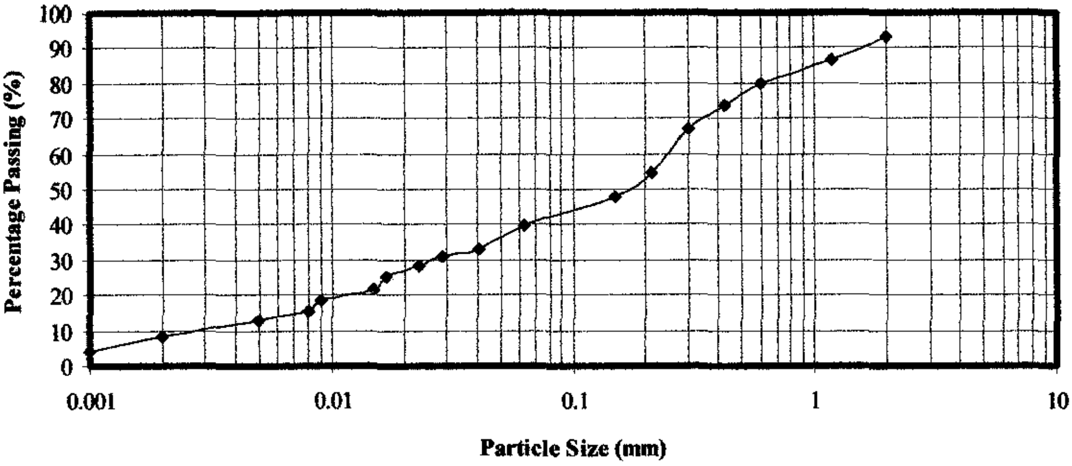
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 10J



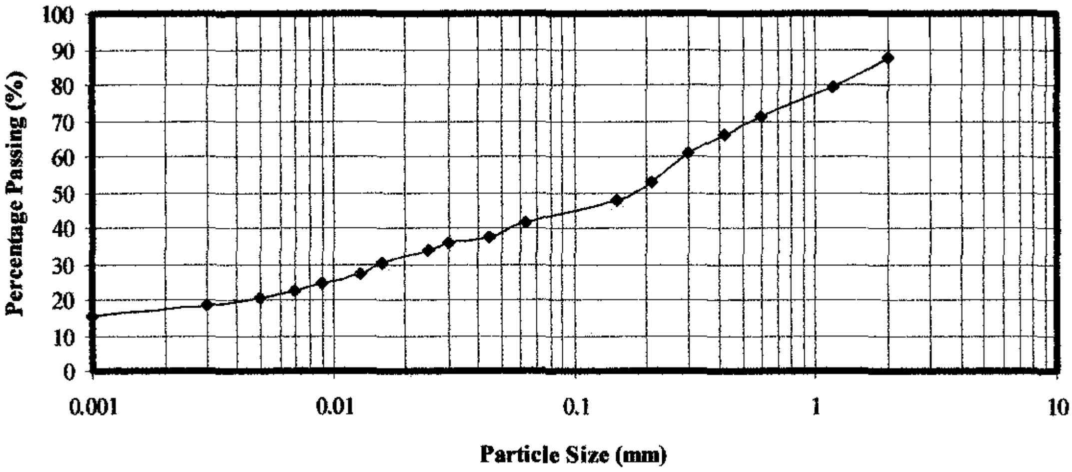
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 22E



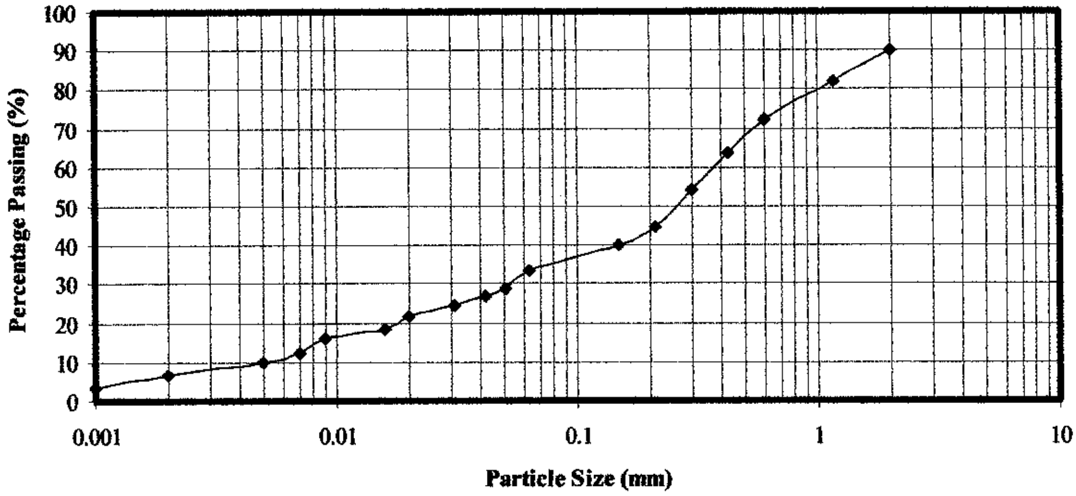
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 21E



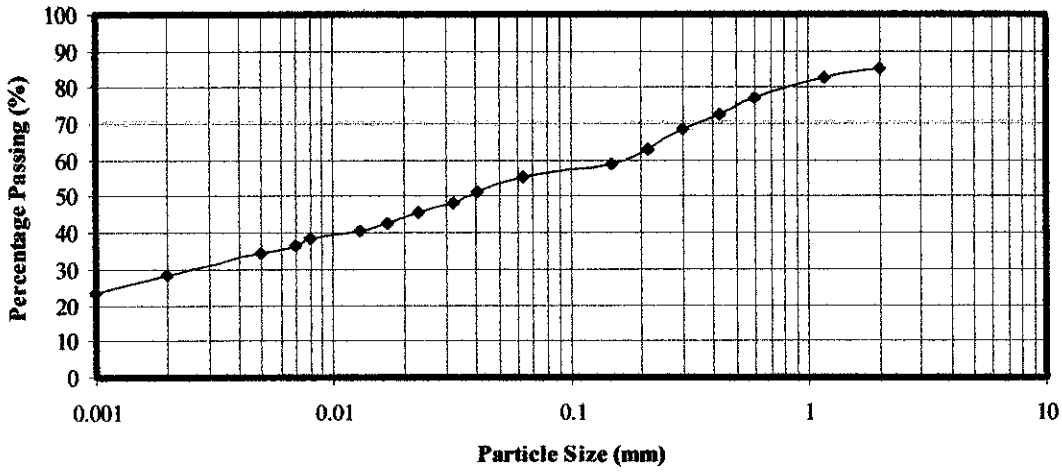
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 17E



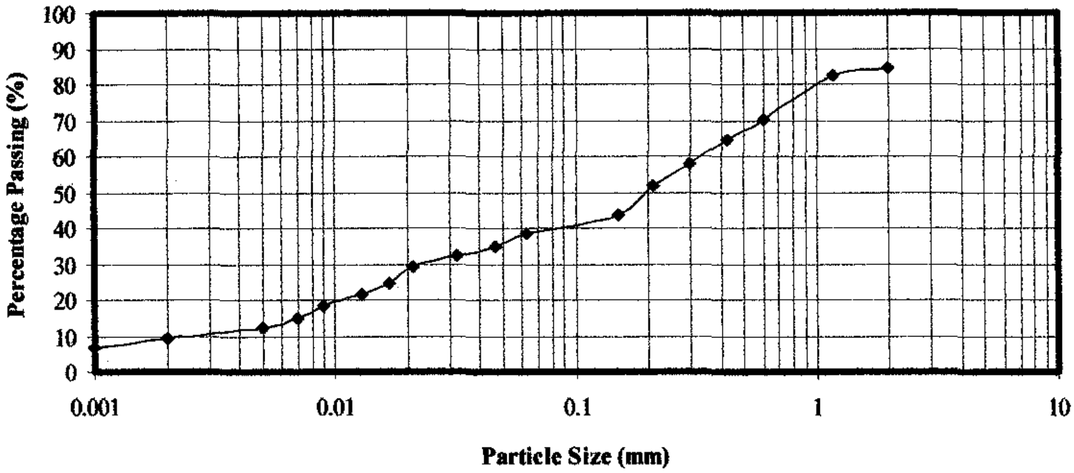
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 22G



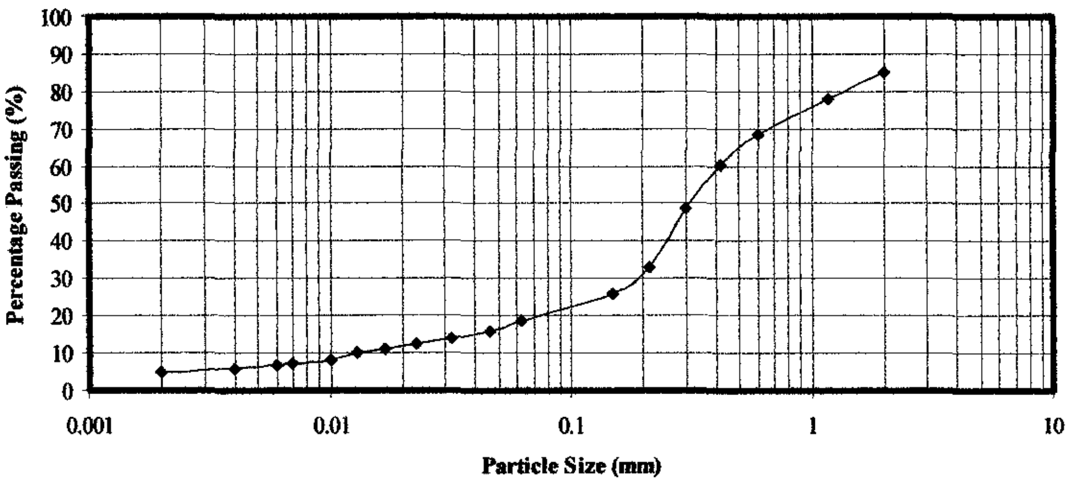
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 19G



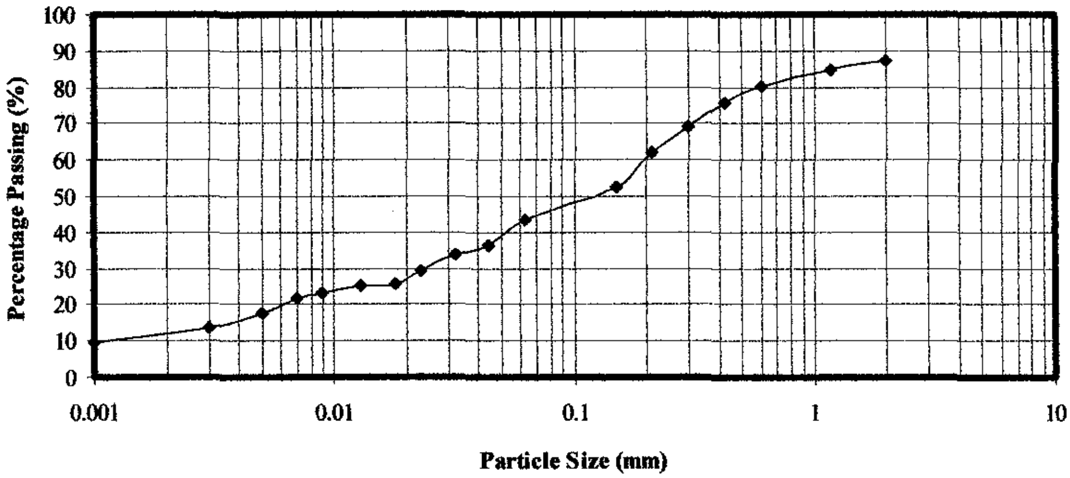
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 22H



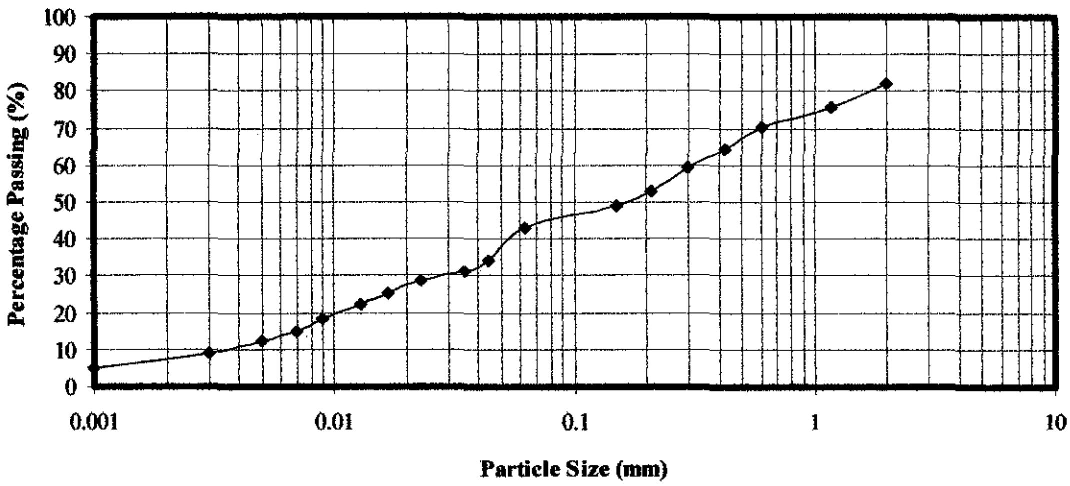
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 21H



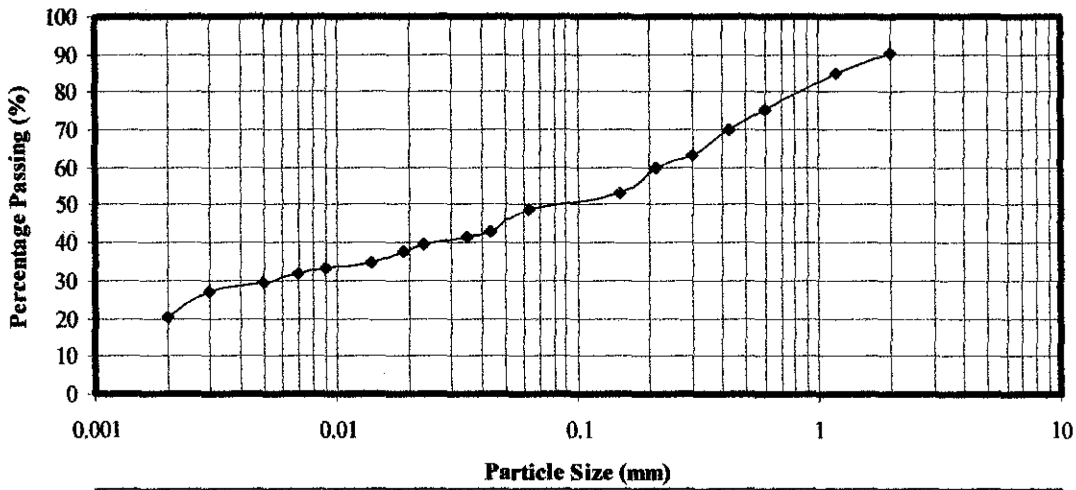
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 20H



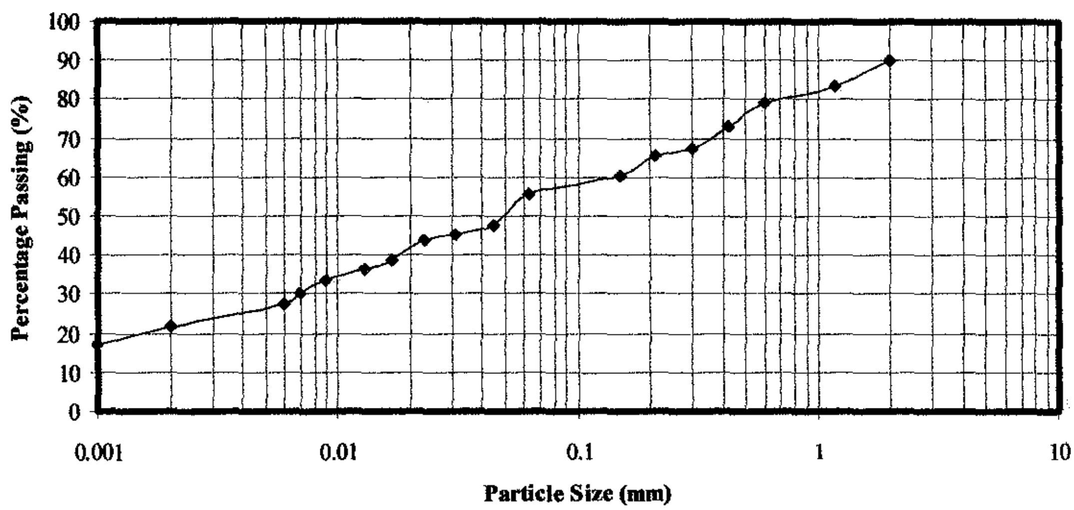
Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 18H



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			

Sampling Location: 19H



Clay	Fine	Medium	Coarse	Fine	Medium	Coarse	Cobbles
	Silt			Sand			