

# Using Geographic Information Systems (GIS) in Soil Classification and Analysis in Gaza City, Palestine

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## Abstract

Geographic Information System (GIS) can integrate and relate any data with a spatial component regardless of the source of data. It's easy to store, retrieve, manage and analyze geotechnical data. In this study Geotechnical field was chosen because Gaza Strip governorates lack studies in this field. Given that there is a large quantity of data in hard copy format which is difficult to handle without the implementation of GIS. Thus Gaza City has been selected as a case study.

This research aims to investigate the development of a Geographic Information System (GIS) to better collect, manage, analyze and visualize soils data which obtained from boreholes test results collected from 92 boreholes covering about 70% of Gaza City. The methodology applied is divided into several stages including data compilation and editing, preparing data for analysis, archiving, analyzing and presentation.

This research presents the results of soil logs (2D or 3D logs) and their engineering properties for any specific location that may be chosen. Models, sections, profiles and fences can also be obtained. In addition to Maps as bearing capacity, water content, type of foundation, excavation depth and lithology planer map at any depth can be created through employing GIS technology.

Finally, the research provides engineers with the necessary geotechnical information for designing construction in the different projects as buildings, towers and roads.

**Keywords:** archiving, analyzing, boreholes, GIS, Gaza City, soil data

## 1. Introduction

### 1.1 Preliminary

“A Geographic Information System (GIS) is a collection of computerized maps and databases that are linked together for the purpose of storing, retrieving, managing and analyzing information.” (ESRI, 2003).

Geotechnical Engineering currently maintains a large database of boreholes plans and corresponding test boreholes logs. These plans and logs are in hard copy format and are stored in boxes, file cabinets, and plan drawers. Locating specific boreholes plans and test boreholes logs can be a very time consuming process that also relies on the memory of the personnel who are responsible for maintaining the database. Sometimes it is very difficult and expensive to identify soil properties that will be used in civil engineering applications.

This research presents the results of a successful study to investigate the development of a Geographic Information System (GIS) of soil data which obtained from test boreholes results.

### 1.2 Research Problem

The current system that is used for storing, archiving and retrieving data in soil laboratories in Gaza Strip in Palestine is not efficient and it is time consuming; also data can be lost or missed.

This study will provide an electronic archive that contains all needed information about Gaza City boreholes and linked with its location on a map.

### 1.3 Objectives

The overall objectives of this research are to accomplish the following:

- a) Documentation and archiving soil investigation reports.
- b) Getting soil logs (2D or 3D) logs and their engineering properties for any specific location.
- c) Preparing Cross sections, profiles and fences.
- d) Creating maps (map of bearing capacity, map of water content and lithology...)

#### 1.4 Review of Literature

Player (2006) introduces GIS and applications of the technology to identify potential geological hazards; plan and track field work; create maps and figures; and improve communication. Fayer et al. (1995) carried out a study to estimate the recharge using GIS. It was used to identify all possible combinations of soil type and vegetation. Procedures to assess erosion in a catchment in Northwest Iran were evaluated using GIS and Remote Sensing (Meijerink et al., 1996). Rahman et al. (1997) evaluated an alternative methodology for producing soil maps through a process of model construction and projection into a map base using Geographical Information Systems. Soil Salinization risk at regional level was assessed using geographical information system by Bui et al. (1995).

Williams (2002) conducted a successful pilot study to investigate the development of a GIS to better manage and disseminate soils information, as developed from test boreholes results. That makes it easier to obtain information regarding soil types at a specific project location.

According to ESRI (2012), Customized GIS applications for habitat mapping, natural landslide searching, air pollutant monitoring was developed to facilitate engineering work.

Expert systems have been developed for many of geotechnical applications such as site investigation planning, soil classification parameter assessment, choice of type of foundation, and many others, Youssef, and Elkhoully, (2000). Some of these systems aimed to develop inference of the deposition patterns for subsurface layers by means of interpreting the field and laboratory data such as Rehak et al. (1985), Lok (1987) and Adams et al. (1989) which provided two dimensional subsurface profiles. Also a knowledge based system developed by Olephant et al. (1996) provided two dimensional interpretations of the ground conditions. An integrated GIS and knowledge based Geostatistical system is developed by Adams and Bosscher (1995) enables to view and retrieve the subsurface data. The system can provide inference of soil formation and properties at any location within the area of data.

#### 1.5 Study Area

##### 1.5.1 Geography of the Gaza Strip



Figure 1. Gaza location

Gaza Strip is located in the Middle East along coastal area of the Mediterranean Sea (at 31° 25' N, 34° 20' E). It has an area of 365 km<sup>2</sup>, a length of 40 km and a width ranging between 6 and 21 km as shown in Figure 1. Gaza city is located in Gaza Strip at latitude (31.3 degree) North, and longitude (34.18 degree) East, with an area of 45 km<sup>2</sup> approximately, and a population of 483.869 inhabitants until 2007. The primary economic activities in Gaza are small-scale industries, agriculture and labor. However, the economy has been devastated by the blockade and recurring conflicts. Gaza has a very young population with roughly 75% being under the age of 25, and today the city has one of the highest population densities in the world, there are 1.5 million Palestinians living in the Strip. (Gaza Municipality website, 2012).

## 2. Proposed Methodology

The methodology of this research is divided into several stages which illustrated as follows:

### 2.1 Data Compilation and Editing

Compiling geographic information is the most costly and time consuming part of developing a GIS. The geographic information that is created is a valuable but time sensitive asset, so care and precision must be taken in its collection and maintenance.

The process of compiling and editing data in ArcGIS can be divided into two categories of operations: collecting data and integrating data. Data collection involves entering new data into GIS, while data integration involves transforming data and maintaining its integrity.

There are many sources of data:

- Material and Soil Laboratory of Islamic University in Gaza.
- (Soil investigation reports that containing soil attributes data.)
- 92 boreholes covering about 70% of Gaza City and containing the necessary engineering properties of different layers.
- Municipality of Gaza.
- (Drawing files (.dwg) that contain boundaries, areas and elevation of Gaza governorate layers).
- Ministry of Transportation.
- (Shape files (.shp) that contains main streets of Gaza Strip).
- Google satellite image with 4800 dpi and 400 feet high.

### 2.2 Preparing Data for Analysis

In this stage Georeferencing process has been made for satellite images and coordinates system has been chosen, and database has been created and the process are explained as shown as below:

#### 2.2.1 Georeferenced Image

Georeferencing process has been made in the satellite images that have obtained from Google earth to have a map with coordinates according to GCS\_Palestine\_1923 coordinates system.

#### 2.2.2 Create Project Database

Creating database is a critical part of the project. The completeness and accuracy of the data used, determines the accuracy of results.

Tables which are needed have been filled using Access program. One of table contains general information of soil such as (real location, date of test, water level... etc), and the second one contains the properties of each layer such as (liquid limit, water content... etc). Then tables have been connected with relational model that is suitable for this data type. Using primary key (lab number column) one-to-many relation have been used.

#### 2.2.3 Data Connection with Software

##### 2.2.3.1 Connecting Data with ArcGIS Desktop

Connecting to ArcGIS 9.x Desktop software which includes connecting attribute, spatial data for boreholes and all data related to soil properties in preparation for its analysis.

Beyond showing data as points on a map, ArcGIS Desktop gives the power to manage and integrate data, perform advanced analysis, model and automate operational processes, and display results on professional-quality maps.

### 2.2.3.2 Connecting GIS Data with Other Software

For further analysis, data has also been linked to Rockworks 2006 due to its competent in soil.

#### RockWorks GIS Link

The new RockWorks GIS Link allows generating RockWorks Cross-sections, Profiles and Fence Diagrams using ArcMap and RockWorks. Lithology Sections and Fence Diagrams can be interpolated or based on Hole-to-Hole Straight Lines sections.

### 2.3 Result and Discussion (Archiving, Analyzing and Present Data)

Data have been analyzed. Maps, logs and sections have obtained.

For details of our proposed methodology, please see Figure 2.

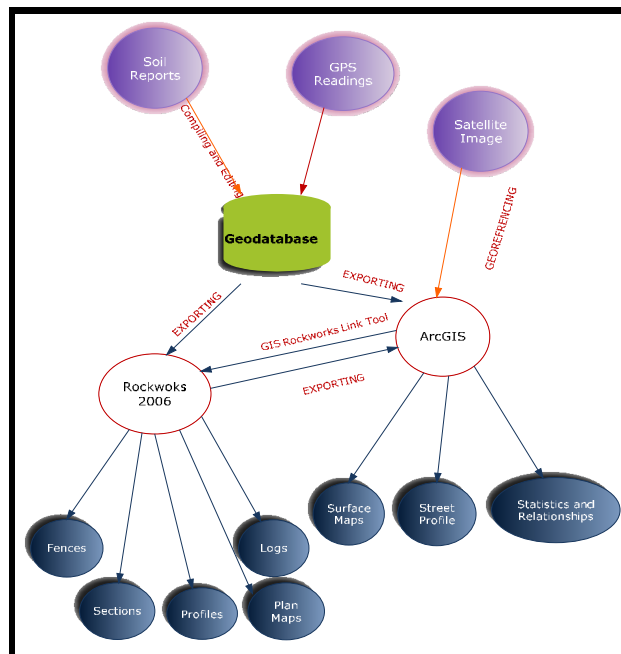


Figure 2. Methodology chart

### 3. Results and Discussion

Based on analyzing, present data and our observations the methodology accomplishes the following four outcomes:

- Surface Maps
- Street profiles
- Statistics and Relationships
- Visualize subsurface Data with Rockworks

The details of the result as shown as below:

### 3.1 Surface Maps

#### A-Bearing capacity analysis

This type of analysis gives engineers the initial prediction to design foundation safety. As is shown in Figure 3 bearing capacity ranges between 100 to 250 KN/m<sup>2</sup>.

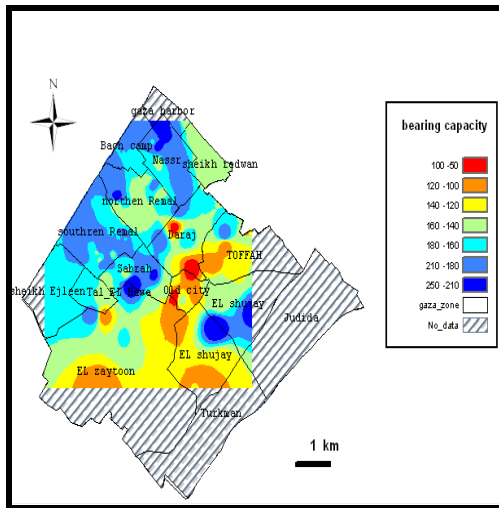


Figure 3. Bearing capacity analysis

#### B- Max gravel analysis

Max gravel means the max percent of gravel in different layers of specific borehole which has a depth of approximately 15 meter. The gravel is better and safer for construct economic foundation. The Max Gravel percentage is shown in Figure 4.

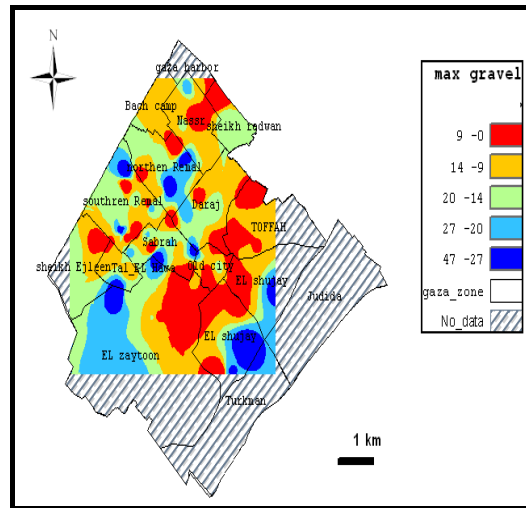


Figure 4. Max gravel analysis

#### C- Max fines (Silt and Clay) analysis

Max fines analysis is important because the danger of constructing over this type of soil. Silt and clay can store water among their voids, besides after the water escapes, the construction footings will be affected from soil settlement. The Max fines percentage is shown in Figure 5.

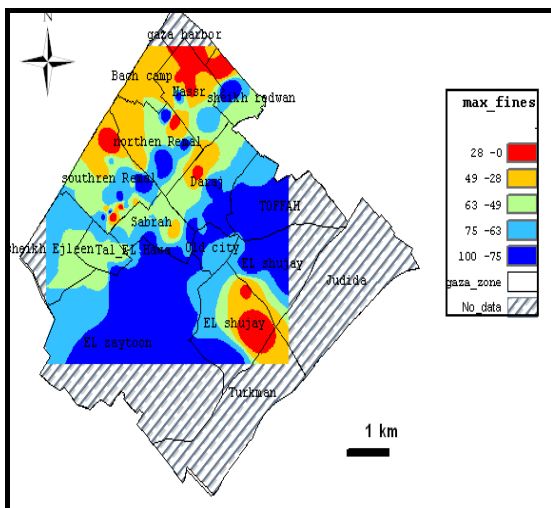


Figure 5. Max fines (Silt and Clay) analysis

#### D- Max Water content analysis

Each layer has different percent of water; the higher percent represents the worst options for construction. Water content also gives prediction about the type of soil, higher percent of water mainly occurs in clay and silt soil. The Max water content percentage is shown in Figure 6.

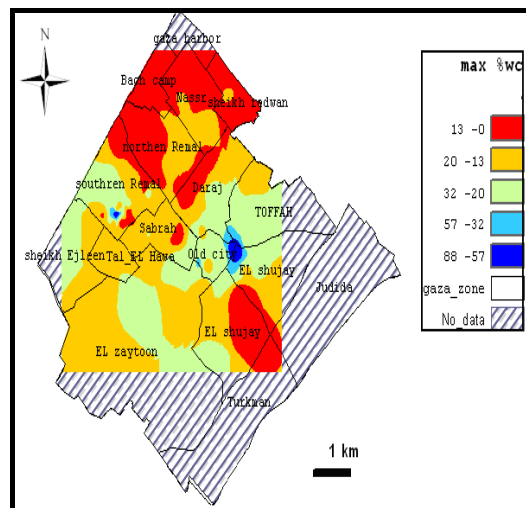


Figure 6. Max Water content analysis

E- Max liquid limit analysis

Liquid limit test made for fines only (the particles that pass sieve No.200), The Max liquid limit percentage shown in Figure 7.

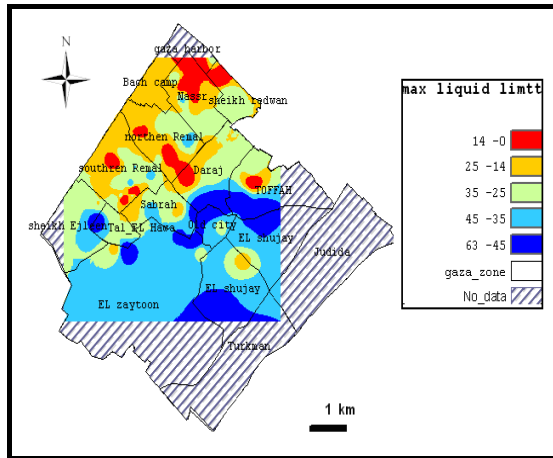


Figure 7. Max liquid limit analysis

F- Max Plastic limits analysis

When the percent of water between the void of silt or clay increases, the fines will be more plastics. The Max Plastic limits percentage shown in Figure 8.

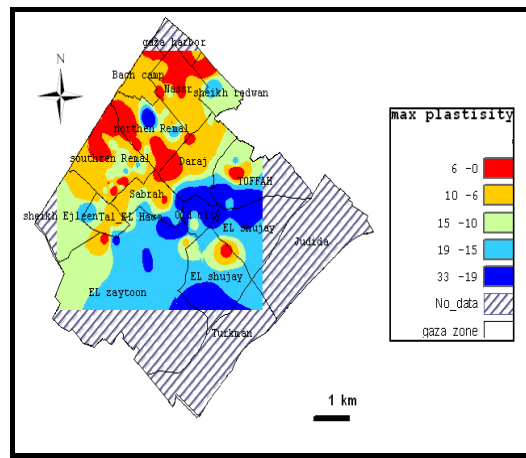


Figure 8. Max Plastic limits analysis

G- Minimum dry density analysis

Minimum dry density gives initial prediction for the characteristic of soil. The Minimum dry density shown in Figure 9.

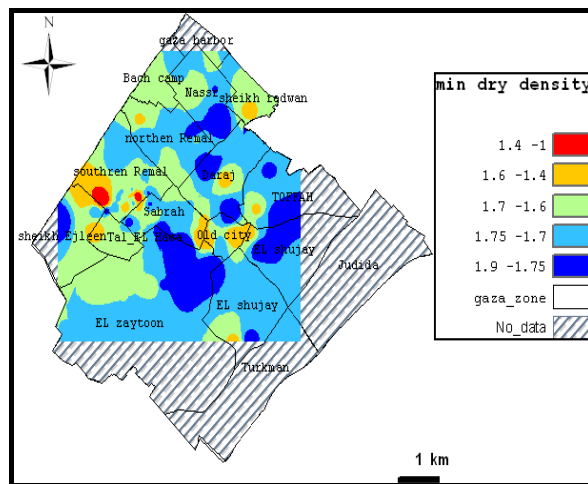


Figure 9. Minimum dry density analysis

H- Classification analysis

This classification gives more details for soil types. The type of soil helps engineers taking decision regarding the foundation type selection. The Soil Classification is shown in Figure 10.

I-3D Elevation Analysis

This map shows the elevations for the surface of Gaza City, which gives more sense as where the highest place and the flow of water in winter.

From Figure 11 it can be noticed that Montar region in east of Gaza is the highest region in Gaza city





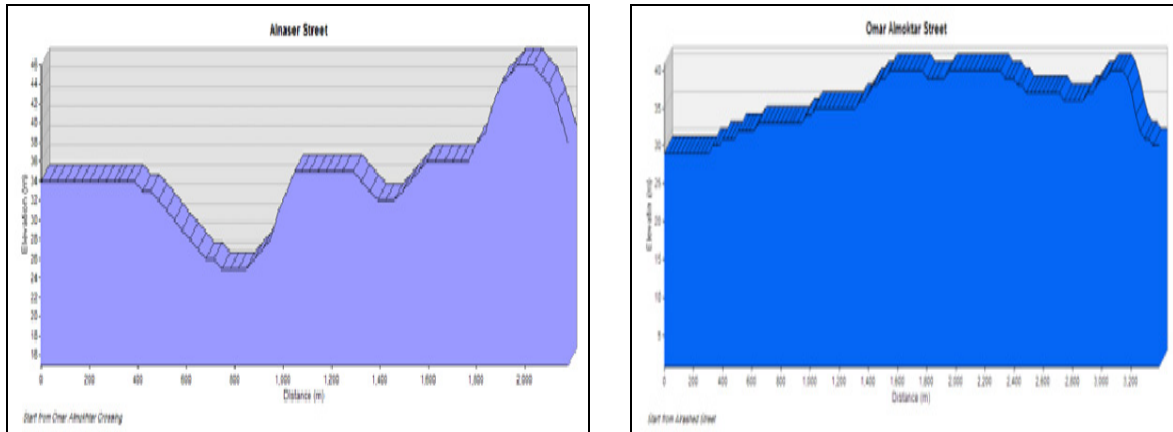


Figure 13. More streets profiles

### 3.3 Statistics and Relationships

Statistics and relationship are considered to be one type of the output analysis by using GIS for easy understanding and making decision also the relations and statistics relevant to determining the soil type and characteristics of basic knowledge.

A-Classification according to date of drill locations in Gaza

B-Statistic for the number boreholes test in Gaza zone

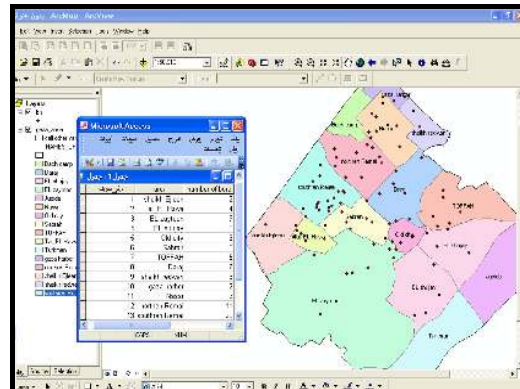
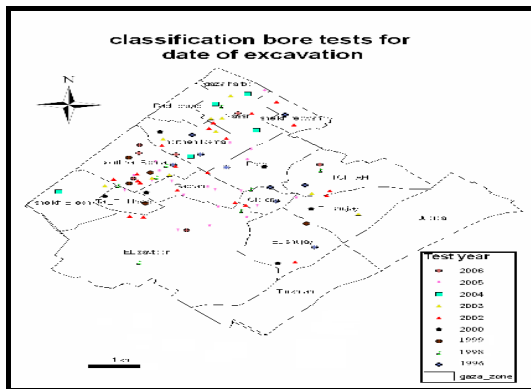


Figure 14. Distribution of boreholes in Gaza City suburban

C-Classification according to foundation types in Gaza

There are different types of footing as will be shown in Figure 15:

Piles are used clearly in El Zaytoon, El Shujaya and Toffah (This system used in clay soil).

Isolated is used clearly in Tal El Hawa, SheikhEjleen, Remal, Nassr and other places (This system used sand soil.)

Mat is used in heavy construction like towers.



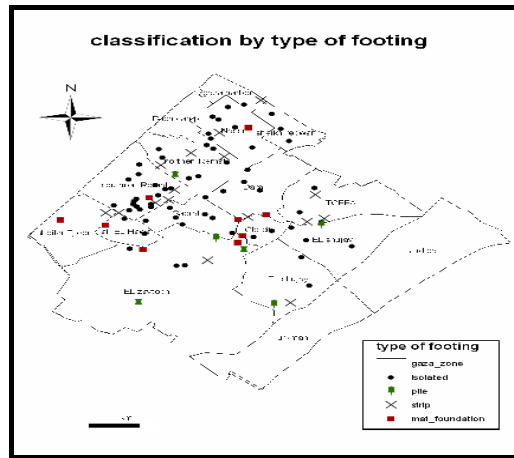


Figure 15. Different types of footing

3.4 Visualize Subsurface Data with Rockworks

RockWorks is integrated software package for geological data management, analysis, and visualization. RockWorks specializes in visualization of subsurface data as logs, cross sections, fence diagrams, solid models, and maps in both 2D and dynamic 3D windows.

The borehole data manager is used for easy entry of borehole data. From this data can create point, contour, plan-view, and lithology/stratigraphy surface (geology) maps; logs; cross sections; and profiles. In addition there's an assortment of 3D diagrams: logs, surfaces, fence diagrams, and solid models.

A- Log Profile

A log profile is one in which the logs of individual borehole are "projected" onto a single profile line cut.

In log profiles, the distance between logs is determined by their perpendicular projection onto the profile line.

Log profiles can be divided in 2D logs and 3D logs as shown in Figure 16 and Figure17.

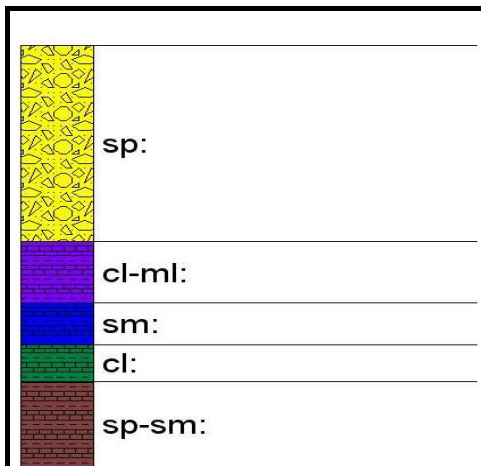


Figure 16. 2D log profile



Figure 17. 3D log profile



### D-Lithology Profile

Using Rockworks makes it possible to interpolate a solid model or read an existing model representing lithology and create a 2-dimensional (flat) vertical profile, between any two points in Gaza city (study area). The profile layers are color-coded based on soil type.

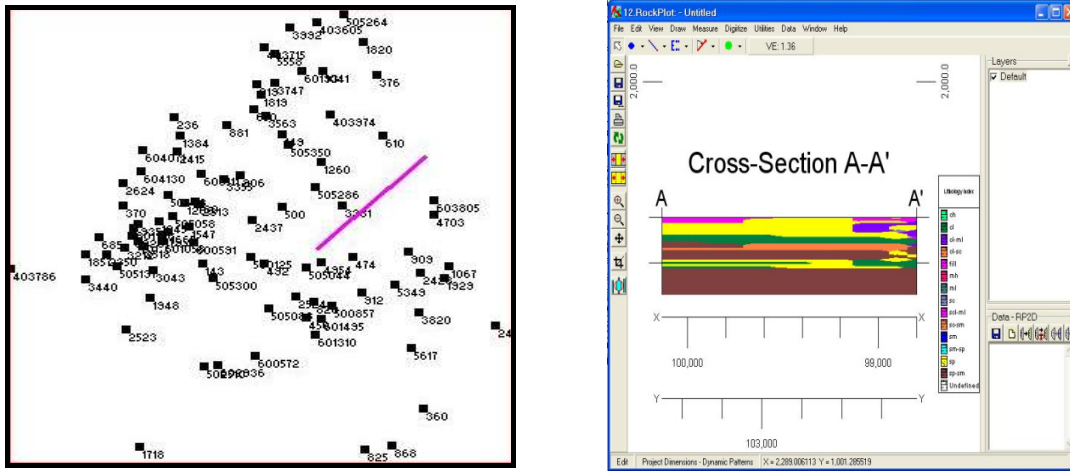


Figure 20. Soil profile in Gaza City

### E-Lithology Section

This tool is used to interpolate a solid model or read an existing model representing lithology and create a 2-dimensional, vertical, multi-paneled section of lithology. The section panel endpoints can be drawn anywhere in Gaza city (study area). The section's layers are color-coded based on soil type.

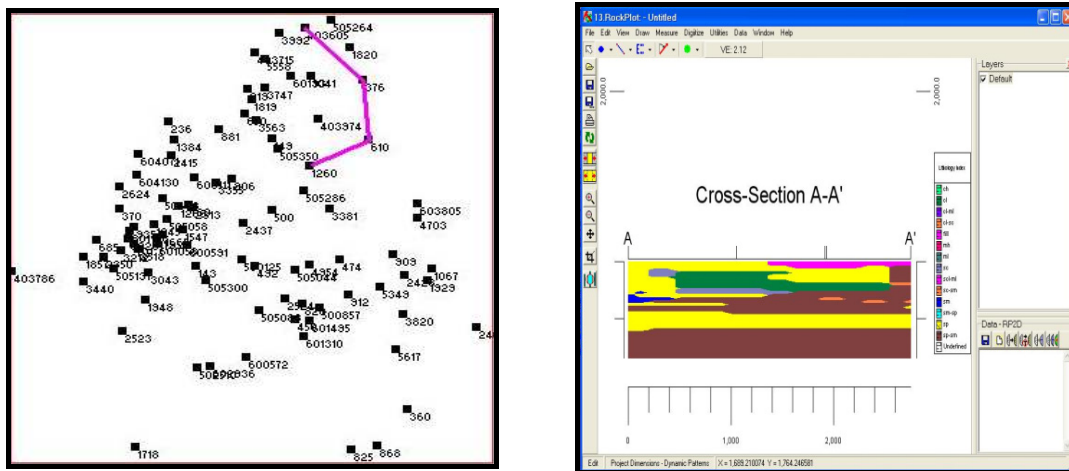


Figure 21. Soil section in Gaza City

### F-Lithology Surface Map

This tool is used to interpolate a solid model or read an existing one representing lithology and to create a 2-dimensional map representing the lithology where it intersects a designated surface, typically the surface topography. In other words, it creates a geological map based on borehole lithology data. This is stored as a RockWorks grid model (GRD), and the map is displayed in the RockPlot2D window as shown on the Figure 22.



- By using GIS, the users can produce the maps of soil classifications, obtain engineering information regarding soil type, an initial indication of soil properties and create soil profile for any location.
- ArcGIS was used as an analysis tools to get maps as (bearing capacity, water content, ...etc) and Street profiles and statistical relationship.
- Rockworks was used to input and manage boreholes which linked with ArcGIS to get 2D logs, 3D logs, fences, sections, profiles and maps for any location in Gaza City.
- Flexible GIS models that manipulate compile and process spatial data above or below earth's surface have provided a powerful tool in geotechnical engineering.

### 5. Recommendations and Future Works

Based on our research outcomes, we recommend the following essential issues for future implementations:

- Establish database containing all geotechnical data from all soil laboratories in Gaza Strip.
- Use GPS in locating borehole investigation test.
- Carry out more uniformly distributed boreholes to cover the borderline zones in order to get more accurate maps.
- Use Rockworks software in soil labs instead of the currently implemented traditional methods and software.
- Expand this study to cover all areas of Gaza Strip.
- Make more studies about soil to solve several problems in this field.
- Apply GIS technology in all ministries, Institutions, and companies which deal with a huge quantity of data.

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