The Egyptian Journal of Remote Sensing and Space Sciences (2011) **14**, 15–28

National Authority for Remote Sensing and Space Sciences

The Egyptian Journal of Remote Sensing and Space Sciences

www.elsevier.com/locate/ejrs
www.sciencedirect.com

Hazards mitigation and natural resources evaluation around Sohag – Safaga highway, Eastern Desert, Egypt

Salwa F. Elbeih [a,*], Abdel Aziz B. Belal [b], El-Sayed A. Zaghloul [a]

[a] *Engineering Applications and Water Division, National Authority for Remote Sensing and Space Sciences, P.O. Box 1564, Alf Maskan, Cairo, Egypt*
[b] *Agricultural Applications, Soil and Marine Science Division, National Authority for Remote Sensing and Space Sciences, P.O. Box 1564, Alf Maskan, Cairo, Egypt*

Received 30 December 2010; accepted 5 January 2011
Available online 22 February 2011

KEYWORDS

Sohag – Safaga highway;
Natural resources;
Flooding hazards;
Soils;
Construction materials;
Mineral resources

Abstract The Egyptian government is showing a great interest on the lateral population extension in the deserts. Accordingly, a number of roads were constructed. Sohag – Safaga new highway in the Eastern Desert that connects the Nile Valley with the Red Sea is an example of such roads. A number of developmental extensions have been proposed aligning roads including agricultural, urban, industrial, touristic, and commercial projects. These extensions need different studies concerning their sustainability to protect them from any hazard that may act on them and to make use of the available natural resources that are required for development. These natural resources include engineering construction materials, soil for agriculture, surface and subsurface water resources, and mineral wealth. The study area is characterized by different geomorphological units: mountains belts, sandstone and limestone plateaux, wadi terraces, wadi bottoms, alluvial fans, out wash plains, sand sheets, sand dunes, and hilly areas. The water resources in the study area include groundwater obtained from a number of existing water wells and surface water that can be utilized by retaining water from flashflooding.

This research mainly depends on using recent satellite images of Misrsat-1, Landsat TM5, and ASTER with the aid of Geographic Information Systems (GIS). Different soil types that were

* Corresponding author. Fax: +002 02 26225800.
E-mail addresses: saelbeih@narss.sci.eg (S.F. Elbeih), belalaz@yahoo.com (Abdel Aziz B. Belal), eazaghloul@narss.sci.eg (E.-S.A. Zaghloul).

Peer review under responsibility of National Authority for Remote Sensing and Space Sciences.
doi:10.1016/j.ejrs.2011.01.001

Production and hosting by Elsevier

delineated are mostly suitable for agricultural landuse. The suitability of this agriculture depends on the availability and quality of the irrigation water.

1. Introduction

Under the intensive increasing rates of population in the Nile Valley and Delta, establishing of new communities in the desert fringe areas is required. Aligned with the governmental interest for developing the Upper Egypt governorates, roads are considered to be one of the most important ways to conduct various developmental projects in these territories. However, the selection of the new paths for these roads should consider many criteria. The most important one should be the connection between the Nile Valley and the Red Sea. The objectives of this study are: utilization of the various natural resources along the new road required for agricultural, mineral wealth, urban development and lateral spreading up of population through establishing new communities along the road. Sohag – Safaga new highway is one of the lateral roads that connect the River Nile with the Red Sea. After the completion of the construction road, 178 thousand feddans (1 feddan = 4200 m^2) on both sides of the road will be available for both agricultural and industrial investments. However, through the site selection of this road, limited attention has been paid to the various natural resources that are available and are potentially suitable for various landuses.

The availability of suitable construction materials within economic hauling distances is crucial for planning most engineering projects. Granular materials are the most common construction materials where they can be found as naturally occurring unconsolidated deposits or suitable consolidated deposits can be crushed to obtain the required materials. The following are types of unconsolidated deposits: (1) Alluvial deposits: terraces, valley fill, fans, basin; coastal plains – beach ridges, deltas and mountain outwash. (2) Aeolian deposits. (3) Gravity deposits: talus. (4) Man-made deposits: mine tailings. The following are types of consolidated rocks used in engineering construction: (1) sedimentary rocks: limestone, dolomite, sandstone, and conglomerate; (2) igneous rocks: intrusive – granite, syenite, monzonite, diorite, gabbro, basalt, dolerite; (3) metamorphic rocks: gneiss, schist, and quartzite. Remote sensing imagery proved to be of a great value in performing inventories for construction materials. Materials successfully mapped from various imagery span the range from boulders and quarry rock, sand and gravel of varying quality to bituminous-filler and clay-binder materials (Rib, 1975).

Soils are a complex three-dimensional system, at the interface of living organisms and inorganic matter, with solid, liquid and gaseous phases. This complexity has an influence on reflectance characteristics of terrain and represents an additional difficulty for the use of satellite data in soil survey and mapping. In fact, unlike as in land form and land cover interpretation, the interpreter cannot identify soils on satellite images. Usually, in satellite images, the interpreter can only infer information about soils from other evidences such as land form, land cover (Abdel-Hady et al., 1991). Although conventional soil maps are essentially static products, when structured in GIS they can provide useful information for analysis or interpretation aiming to soil prediction. This is true for soil polygons as well as for the field sample collection points, whose data have higher confidence. So, we should not stop with traditional surveys, but improve methodologies attempting to optimize data collection procedures and to make results more consistent and easily available (Weber et al., 2008).

This research focused on the evaluation of the required natural resources for the already proposed development projects on both sides of the road, including urban, agriculture, industry, tourism, and commerce. Analysis of satellite images and Digital Elevation Models (DEM) were performed for the study area for delineating the different land use classes and the different soil units for agriculture using Arc GIS 9.2 and Erdas Imagine 9.1 softwares.

2. Site description

2.1. Location map

The study area occupies a large district between the Nile Valley and the Red Sea. It passes across four governorates (Fig. 1). Three of them are along the Nile valley from the north to the south: Assyut, Sohag, and Qena governorates and the fourth is a large sector of the Red Sea Governorate. It begins from Sohag governorate and extends toward the Red Sea in the east where it joins Qena – Safaga road. The first stage of this project is a single lane roadway with a length of 415 km that was finalized in January 2010. The second stage is a double lane roadway and it is expected to be completed by the end of 2012. At the same time of constructing this road, Sohag international airport was opened in May 2010 and it is expected that a new building for Assyut airport will be opened very soon.

2.2. Population and landuse

The Egyptian Government, delegated by the National Center for Planning Governmental Land Uses, had proposed various development projects around the road including agricultural, residential, industrial, touristic, and commercial projects (Fig. 1). Table 1 shows some social, geographic and sectoral indicators of the four governorates that cover the study area (IDSC, 2009). As water is considered one of the main requirements for any development project, all drainage basins that flow into the road have been considered as a part of the study area that is about 35,000 km^2 (Fig. 1).

2.3. Climatic conditions

The meteorological data in the study area are obtained from five meteorological stations: Sohag, Qena, Assyut, Assyut Airport and Hurghada. The area is located in the central part of the Eastern Desert and it lies within the barren desert range that is distinguished by hot summer and cold winter with an obvious change in the temperature range. Generally,

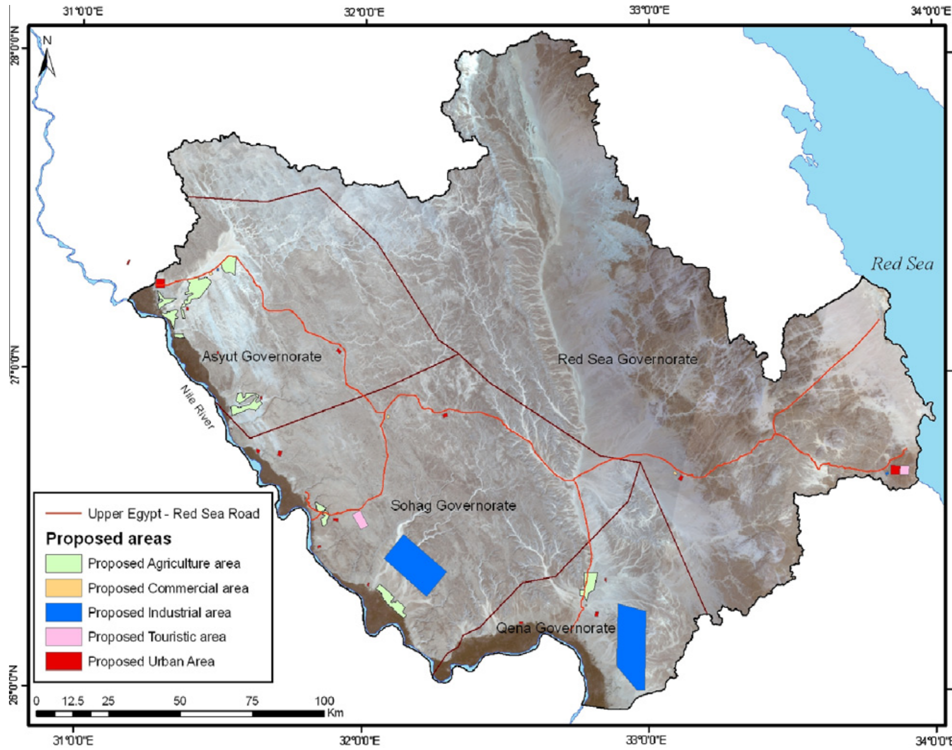


Figure 1 Location map of the study area overlaid over a Landsat TM satellite image showing the roadway alignment and the proposed development areas.

Table 1 The main social, geographic and sectoral indicators of the four governorates (after IDSC (2009)).

Governorate	Total population (million persons) in 2007	Total cultivated land in 2007 (thousand feddan)	Cultivated area (% of total) in 2007	No. of industrial establishments in 2007
Sohag	3.83	316.2	12.1	315
Qena	3.06	322.4	12.5	165
Assyut	3.52	353.0	5.7	569
Red Sea	0.29	0.6	0.002	49

it is distinguished by the scarcity of rain and relatively high moisture content. The area is affected by northern winds especially in summer and the mean wind direction is north to northwest directions. The average seasonal wind velocity ranges between 2.3 and 6.3 km/h. In November 1994, the area received about 25 mm/day where floods struck the Red Sea and the Nile Valley provinces and caused serious damage (EMA, 2000) and in January 2010, floods struck the Western side of the study area. Considering the western part of the study area (the southern part of Sohag Governorate) it belongs to the arid belt of Egypt where it is characterized by long and hot summer and warm winter with almost no rainfall. The average maximum recorded temperature is 36.5 °C in June while the minimum is 15.5 °C recorded in January. At Wadi El Assiuti, seasonal temperature varies from 5 °C in winter to 45 °C in summer. The relative humidity ranges between 50% and 60% in winter while the minimum is 33–35% recorded in summer. The rainfall over the study area is very limited and variable (Diab et al., 2002; Abu El Ella and Abdel Mogeeth, 1993).

2.4. Geological setting

As far as the study area covers a tract from the Red Sea region in the east to Sohag in the west, the study area can be geologically classified into the following three regions:

2.4.1. The Nile Valley region

The geological setting of the Nile Valley region can be described from older to younger units as follows:

2.4.1.1. Thebes formation (Lower Eocene). It consists of about 200 m of thick-bedded limestone with chert bands and flint concretions with marl at the base and it is highly fossiliferous.

2.4.1.2. Issawia formation (Pliocene). It forms the high terraces at the base of the scarp face at the Nile Valley and the lower part of Wadi Qena Basin (Said, 1981). It consists of about 70 m of brown marls and clay, limestone, diatomitic limestone, conglomerate and limestone capped with thick red breccias which is used as commercial marble (Brocatelle).

2.4.1.3. Qena – Dandara formation. It consists of about 30 m of fluviatile sand and silt intercalations of the ancient Nile deposits. It is covered by a thick gravel sheet that represents the ancient terraces from the Pre-Nile sediments (Said, 1981).

2.4.1.4. Debira – Arkin formation. It is made up of modern Nile silt with marl and lenses from gravel and sheet wash. It forms the cultivated land and the newly reclaimed areas.

2.4.1.5. Quaternary deposits

- *Alluvial Fan-glomerates:* It consists of about 10 m of thick limestone, flint and dolomitic limestone gravels and boulders. At the lower part of Wadi Qena, it contains materials from the Pre-Cambrian Basement rock fragments.
- *Wadi Deposits:* It is made up of reworked materials from the different rock units. It forms the floor of the wadis.

2.4.2. Wadi Qena region

The following is a brief description of each rock unit from older to younger:

2.4.2.1. Lower clastic unit (Nubian Sandstone). It is made up of a thick section of snow white, varicolored, cross bedded, sandstone with shale and clay interbeds and kaolinitic clay at the lower parts. The age ranges from Paleozoic to the Lower Cretaceous ages. It is found in the form of hills or dissected ridges at the foot slopes of the main scarp.

2.4.2.2. Lower carbonate unit. This marine rock is well represented all over the area and can be easily identified lithologically and paleontologically from the underlying sandstone and the overlying thick carbonate unit. This unit covers highly dissected parallel scarps due to intensive faulting systems in the area. This unit attains a maximum thickness of about 200 m. It consists of limestone, dolomite, dolomitic limestone, chalky limestone, phosphatic layer. It is highly fossiliferous with different assemblage fossils from Cenomanian to Maastrichtian ages.

2.4.2.3. Esna formation. The Landenian – Lower Eocene is exposed at the southern cliffs of El-Galala El-Qibliya Plateau by Esna Formation that assumes an average thickness of 20 m of shale and marl.

2.4.2.4. Upper carbonate unit. The Lower – Middle Eocene crops out at the western cliffs of Wadi Qena and forms the Plateau surface. It mainly consists of about 300 m of chalky limestone at the lower part and grayish white sandy limestone with flint concretions and chert bands, thick-bedded siliceous limestone intercalated with marly limestone and gritty sandstone, highly fossiliferous.

2.4.3. The Eastern desert (Red Sea region)

2.4.3.1. Pre-Cambrian basement rocks. The basement rock crops out in the Eastern Desert high mountains forming the highest summits of the area. They mainly consist of old metamorphic rocks, metavolcanics, intruded by pink (orthose and biotite) or gray plagioclase granites and old granites. These granites are cut by numerous doleritic dykes. It is composed of more basic plutonic rocks, Diorite.

2.4.3.2. Sedimentary rocks. The sedimentary succession in the study area is started by the Pre-Cretaceous sediments which is represented by Nubian beds.

2.4.3.3. Miocene. The Miocene sequence of the Red Sea is commonly subdivided into Lower Miocene which is referred to as the Gharandal Group and Middle Miocene referred to as the Ras Malab or Evaporite Group. Both groups are important: the lower containing the richest source rocks in combination with excellent reservoirs deposited under most favorable structural conditions; the upper group providing the most efficient seal for both Miocene and pre-Miocene reservoirs.

2.4.3.4. Pliocene sediments. The Pliocene section consists of rounded gravels with rolled fragments of *Ostrea* sp. beds and oolitic limestones are reported in the South Zeit range (Sadek, 1959).

2.4.3.5. Quaternary and recent sediments

- Horizontal Pleistocene reefal limestone associated with wave cut terraces with beach gravels coalescing alluvial fan deposits.
- Sand sheet accumulation.
- Bushes, Shrubs and Phytogenic mound along the course of the wadis.
- Sabkha and salt marches.

Fig. 2 shows a generalized geologic map for the different units covering the study area.

2.5. Faulting

The area is structurally controlled by the major western marginal fault. The faulting systems are in different trends: NW–SE, NE–SW with minor E–W trend. They are not continuous with a partial overlap. In addition, most of these faults are considered to be of Post Miocene and Pliocene ages. The main fault trends are as follows:

- N 65 W trend that is related to the Gulf of Suez. The faults are of normal, gravity and longitudinal type. The downthrown is toward the north and the northeast.
- N 25–35 W trend that is the Gulf of Suez trend (Pelusic trend). Most of these faults are normal, gravity, strike and longitudinal types.
- N 15–25 E trend that is a minor trend related to the Gulf of Aqaba system.
- The faults that have a N 30 W extend for about 8 km length and the spring of St. Paul Monastery is situated at the intersection of the two faulting systems: N 30 W and N 65 W trend.

2.6. Geotechnical soil properties

The geotechnical soil properties for the plateau surrounding Sohag from the east were investigated (El-Tahlawi et al., 1994). The plateau is located between latitudes 26°23′N and 26°38′N and longitudes 31°45′ and 31°56′E (about 400 km^2). The plateau is composed of Lower Eocene carbonate rocks (mainly limestone of 200–250 m thick). The lower

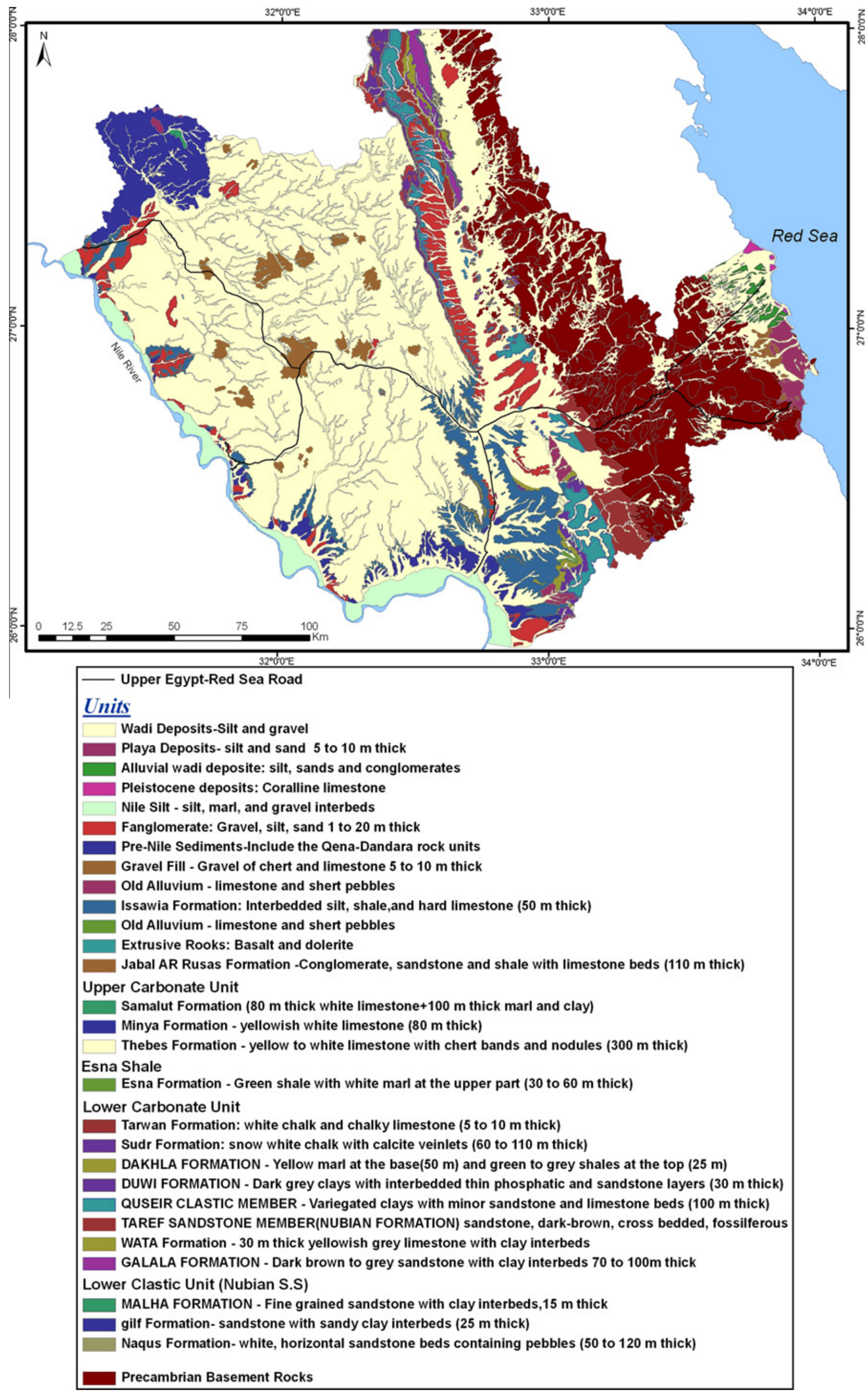


Figure 2 The different geologic units covering the study area obtained from the geologic map of Egypt 1:250,000 (EMRA).

Eocene limestone was investigated through column sections at Wadi Bir Al-Ain North Awlad El-Sheikh village. The geotechnical investigation included the determination of physical and mechanical properties of a different limestone forming the sedimentary sequence of the two main formations found in the study area: Thebes Formation (Top) and Drunka Formation (Bottom). The geotechnical properties of the Lower Drunka Formation, 98 m in depth, are summarized in Table 2.

3. Materials and methods

3.1. Data sources

3.1.1. Satellite data

Four Landsat TM satellite images (August 2005) are mosaiced to cover the study area and used for delineating the drainage network of the main wadis. ASTER images were used for producing a Digital Elevation Model (DEM) generated with a

Table 2 Geotechnical soil properties East Sohag area (El-Tahlawi et al., 1994).

Property	No. of samples	Min.	Max.	Average
w_c (%)	17	0.01	0.871	0.098
γ_b (g/cm^3)	111	1.89	2.74	2.395
C (kg/cm^2)	142	50	3313	468
G_s	51	2.415	2.67	2.556
n_t (%)	51	2.386	24.229	11.923
n_e (%)		0.967	21.854	10.518

W_c: water content; γ_b: bulk density; C: compressive strength; G_s: specific gravity; n_t and n_e: total and effective porosity.

30 m spatial resolution used to generate a slope map of the study area. Nine Misrsat-1 satellite images (acquired in January 2010 after the flashflood hazards that took place in this area) were geometrically corrected and mosaiced and four subsets were produced for the four governorates where the road passes through.

3.1.2. Maps

For studying the different natural resources of the study area a number of maps were used:

- Six topographic maps issued in 1986 with a scale of 1:250,000.
- Four geologic maps with a scale of 1:250,000 (EMRA, 1983, 1992 and 2005).
- Six hydrogeological maps of RIGW with a scale of 1:100,000 1990 and 1992 were used for describing the groundwater aquifers of the eastern side of the study area.
- A reconnaissance soil map of FAO (1966) (1:200,000) for the study area was used.

3.1.3. Other data sources

Available water wells in the study area, mainly concentrated in the Nile Valley with some scattered wells in Wadi Qena region, are used for evaluating the available groundwater resources around the road.

3.2. Soil for agriculture

The remotely sensed data and soil maps were geometrically rectified to the projection of Universal Transverse Mercator (UTM) coordinate system optimally enhanced and histogram matched to be comparable during the visual interpretation through AgrcGIS software. The root mean square error (RMSE) for the rectified image was less than 0.4 pixel. The DEM data and the slope class map of the study area are shown in Figs. 3 and 4, respectively. After eliminating the speckle effects by smooth filtering, a vector map of the slope classes was produced by screen digitizing. The produced vector format slope class map was overlaid to color composite Landsat image of the studied area to delineate soil boundaries and other land features by visual interpretation. A 3D perspective view map and a hill shade relief map were generated using the DEM where the 3D presentation of the landscape is required to detect soil and landform relationships. Thus, a color hill shade relief map with slope classes was produced by overlying the final maps. Soil properties for mapping units were determined based on the physical and chemical analyses according to (Abdel-Samei, 1991).

3.3. Groundwater and surface water availability

Sources of water to the ground-water flow system in the Eastern Desert are most probably due to meteorological sources

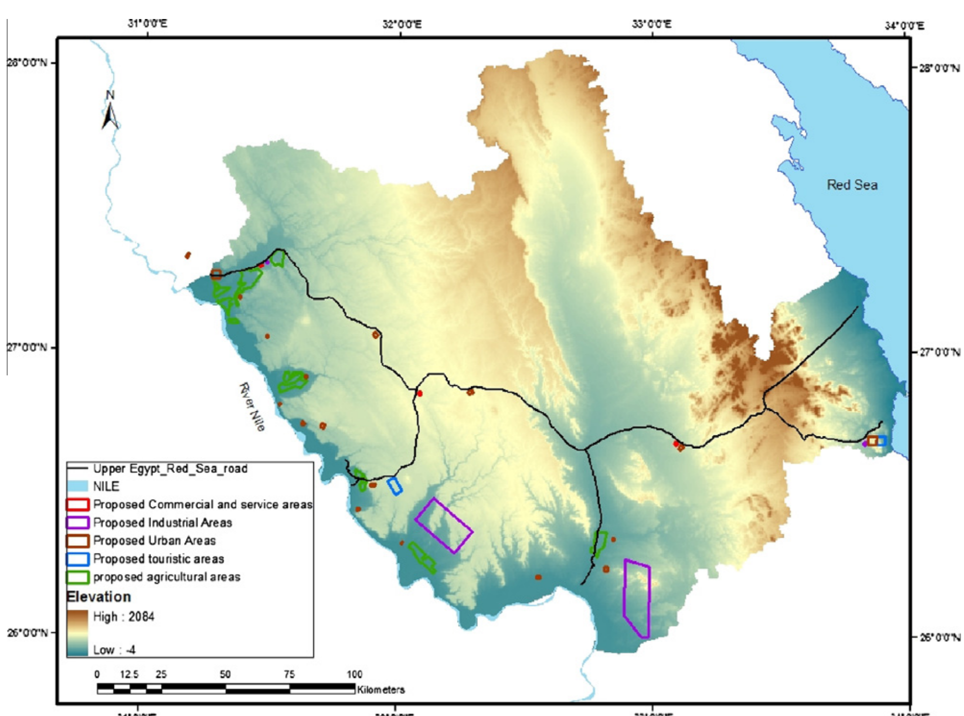


Figure 3 A map showing the elevation of the study area with the proposed development areas.

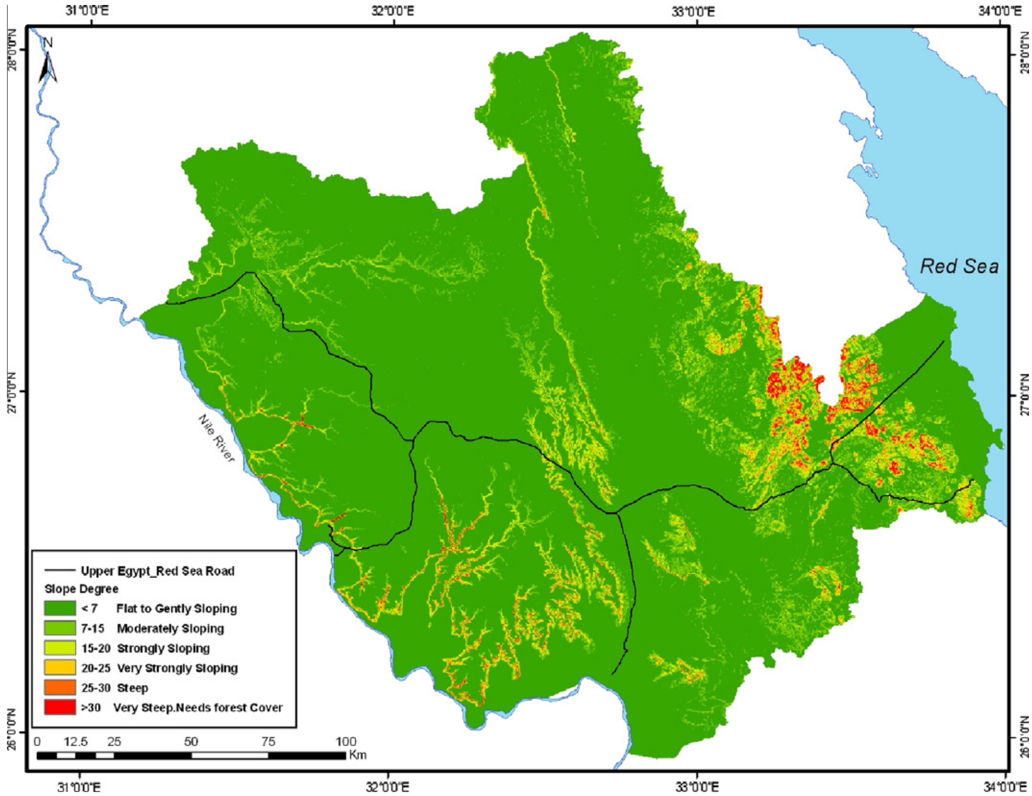


Figure 4 Slope classification map for the study area.

and natural recharge because of the predevelopment conditions of the study area. Natural discharge could be in the form of: infiltration of mountain-front runoff, infiltration of precipitation on bedrock outcrops (or upper valley) and infiltration of precipitation on valley floors (Cairo University, 2004). The water wells that were found in the study area were constructed mainly to serve for the development projects that now exist or are in operation. The different groundwater aquifer systems that cover the study area were investigated through different researches. The western section (near the River Nile) was investigated in detail by the Research Institute of Groundwater (RIGW, 1990 and 1992). The different aquifers and lithological formations that cover the western section of the study area are: highly productive aquifer; highly to moderately productive aquifer; moderately to low productive aquifer; low productive aquifer and non-aquiferous, consisting of clay or shale (Fig. 5). The hydrogeological aspects of the western section of the study area were investigated where the water bearing sediments are mainly composed of gravels, sands and clay of Qena Formation (Abd El-Bassier, 1997).

A water table contour map was compiled according to Abdel Baki (1996) and Aggour (1997) as shown in Fig. 5. The water wells used in constructing the contour map are those which have available water levels data.

The main drainage network was produced using the hydrology module on Arc GIS using the DEM produced from ASTER data (Fig. 6). Sixteen water points were investigated in the following wadis: Wadi Umm Kebash, Wadi Umm Enab, Wadi Fateira, Wadi El Baroud, Wadi Safaga and Wadi Abu Marawat (Abdel Baki, 1996). The groundwater conditions of each of these wells are as follows:

- *Wadi Umm Kebash Basin:* springs are used for drinking, limited yield (0.5 m^3/day), salinity 1100–4400 mg/l (a wide variation due to recharge conditions). A hand dug well (Abu Gariya wells) on the main channel of Wadi Umm Kebash, water depth about 20 m from ground surface.
- *Wadi Umm Enab Basin:* Two springs: discharge less than 1 m^3/day, salinity: 300–330 mg/l. The water freshness is due to direct recharge from local rainfall.
- *Wadi Fateira Basin:* Water obtained from three wells of a maximum depth of 20 m. Water depth range from 16.6 to 19.5 m, TDS 480 to 800 mg/l.
- *El-Basha well:* TDS = 480 mg/l used to irrigate a small garden (about 2 feddans) $Q = 5\ m^3$/day.
- *Wadi El Baroud Basin:* Two drilled wells, to supply Safaga City with fresh water for domestic purposes. Water depth = 16 m, TDS = 2500 mg/l.
- *Wadi Safaga Basin:* Found in two water bearing formations: Duwi Formation and the fractured metavolcanics. Duwi Formation: water found at 190 masl, TDS = 3300–9600 mg/l. Metavolcanic water bearing rocks: depth = 5.4 m, TDS = 15,300 mg/l.
- *Wadi Abu Marawat:* Depth is 33–36 m, TDS: 6800–6900 mg/l.

Water samples were collected from some wells in the study area (Fig. 7) and their chemical analysis is shown in Table 3 (Aggour, 1997).

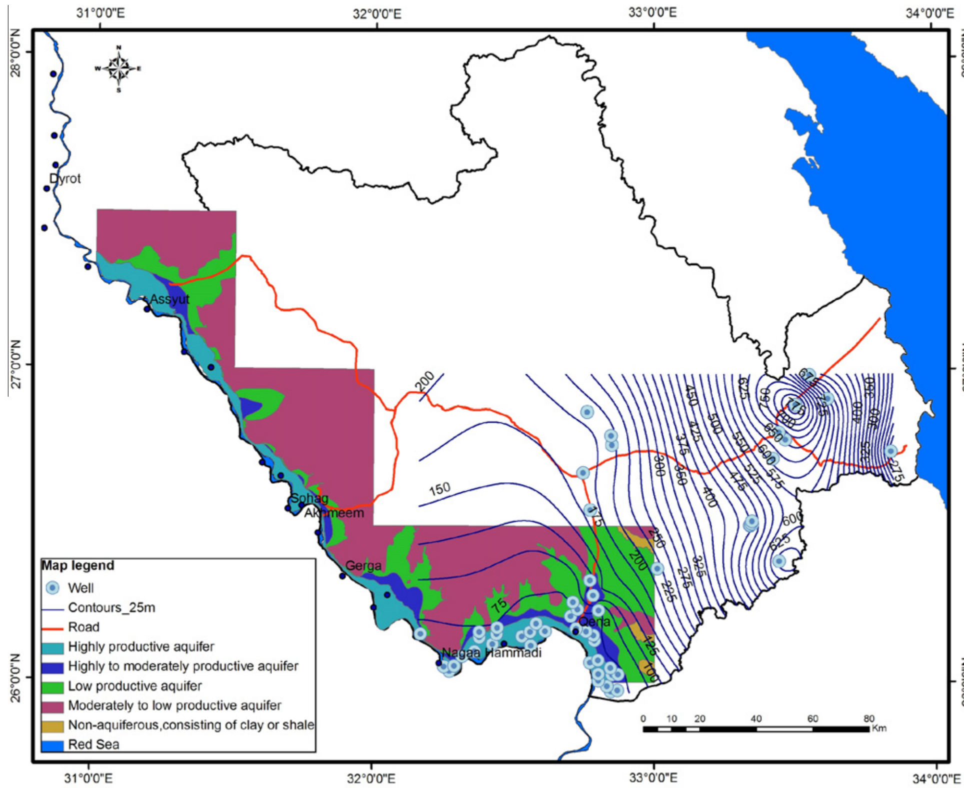


Figure 5 The different hydrogeological units in the western section of the study area (modified after RIGW (1990 and 1992), Abdel Baki (1996) and Aggour (1997)).

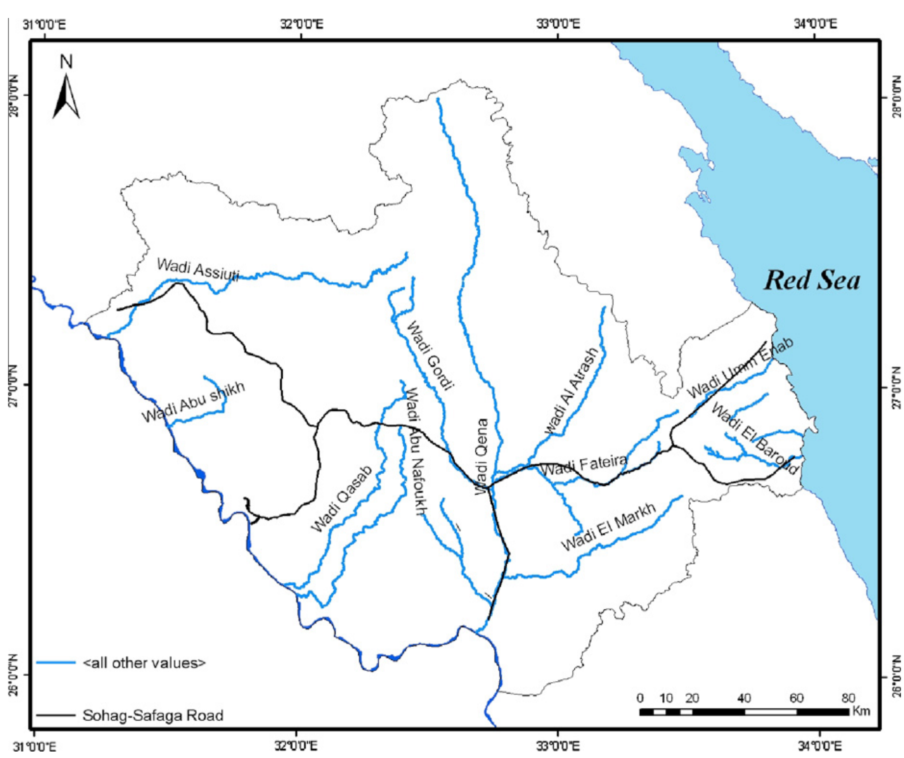


Figure 6 The main wadis in the study area produced from the DEM.

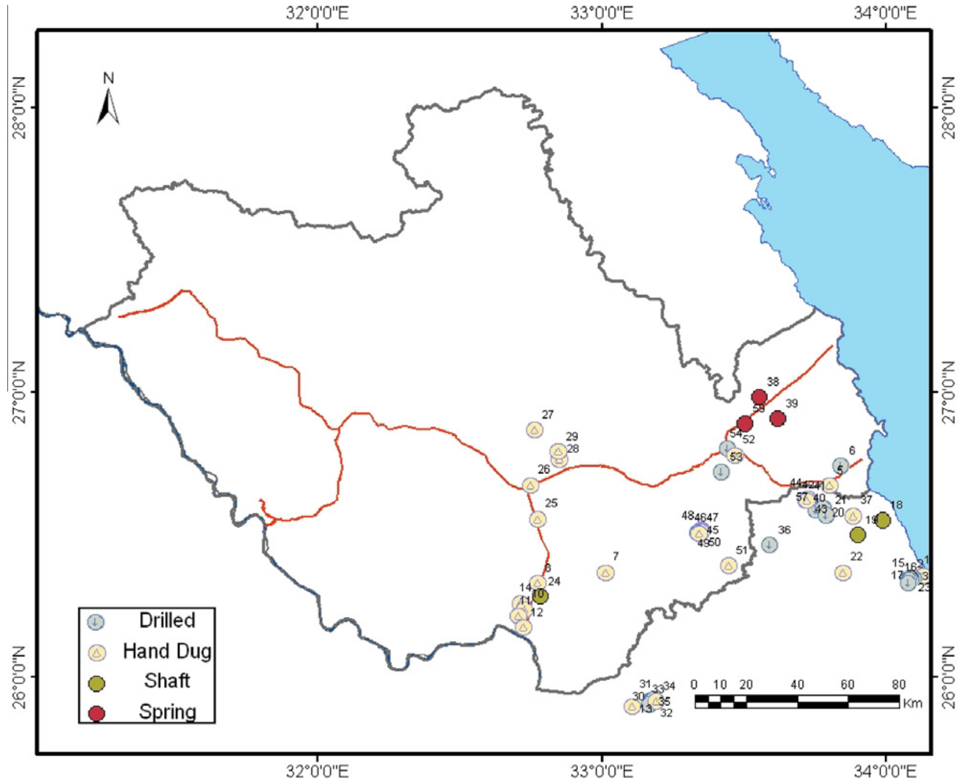


Figure 7 Location map of water points, Qena – Safaga district (modified after Aggour (1997)).

4. Results and discussion

4.1. Ornamental and building stones materials around the road

Granite, dolomite, limestone, phosphate, gypsum and building stone materials (cement materials) can be exploited and quarried from the exposed different rock units. White sand for glass industry in Wadi Qena, Kaolinitic clay for ceramic can be also exploited. Commercial marble (limestone – red breccias Brocatelle at the top of Issawia Formation) and others can be used. Diatomite was found in Issawia Formation in Wadi Qena. Dolomite and diatomite in East Soahg (East Akhmim and Issawia) could be used for bridge foundations and lining canals.

4.2. Oil potentiality

In the Gulf of Suez, oil mostly occurs in sands of Miocene, Cretaceous and Carboniferous ages. Commercial oil is also present in Miocene, Eocene and Upper Cretaceous fissured and fractured reefal and shelf limestone. Fracture and fissure porosity encountered in the limestone reservoirs is due to the intense structuring that affected the Red Sea area.

4.3. Groundwater resources

The groundwater resources in the study area are mainly concentrated in the western side of the study area (Nile Valley region). Other wells scattered in Wadi Qena are characterized by high water salinity that reaches about 10,000 mg/l in some wells (Table 2). It was observed from Fig. 5 that water levels change from about 75 masl in the vicinity of the Nile Valley and reaches to about 700 masl at the connection of the road to Safaga and Hurghada then decreased to about 275 in the Red Sea Coast.

4.4. Suitability for different development projects

Image classification on the stacked images took place using the automated supervised classification method. For each image, the main classes obtained are: agriculture, urban, desert, water, and valleys. For each class, a number of signatures were used; 50 for desert, 64 for valleys, 1 for agriculture, 1 for water and 2 for urban. For Assyut governorate, the main classes are the wadi deposits (35%), followed by agriculture that occupies about 13% of the study area. The urban areas are mainly concentrated around the Nile Valley and are beginning to spread inside Wadi El-Assiuti. For Sohag area, wadis occupy only 6% of the study area and agriculture only 2.2%. Concerning Qena governorate, wadis occupy about 50% of the study area while agriculture only occupies 1.6%.

The different lithological units were obtained for the subset area of the study area giving more attention to the proposed areas for the development demand aligning the roads.

4.4.1. Assyut zone

Agricultural, urban, industrial and commercial areas are proposed development activities (Fig. 1). In Wadi El-Assiuti, agricultural areas are the main developmental activity. The elevations in the agricultural areas were estimated from the DEM range from 28 to 220 masl. For the urban areas, the elevations vary between 28 and 321 masl (Fig. 3). The industrial

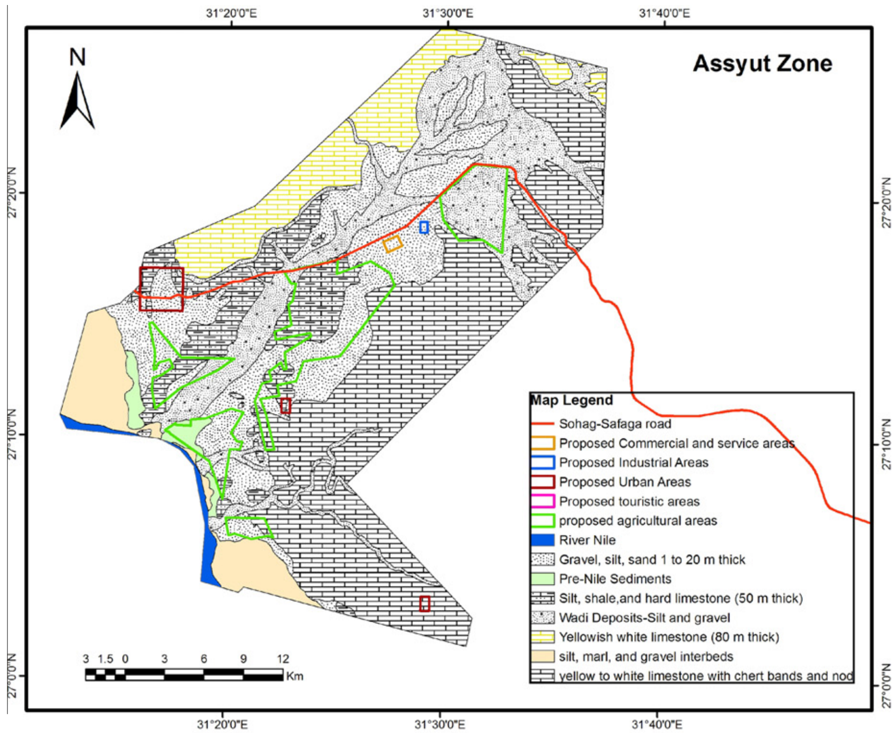
Table 3 Data of some water points in the study area (modified after Aggour (1997)).

Num.	Type	Depth to water (m)	Salinity (mg/l)	Water level (masl)	Total depth (m)
38	Spring	Spring	1152.19	518.00	
39	Spring	Spring	1069.14	600.00	
59	Spring	Spring	382.27	820.00	
6	Drilled	19.57	2827.90	180.43	
54	Drilled	17.07	556.21	670.93	18.32
52	Hand dug	24.25	667.29	679.75	24.65
53	Drilled	16.82	413.26	633.18	17.12
51	Hand dug	19	371.00	633.00	23.00
7	Hand dug	15.41	19707.30	238.96	15.41
25	Hand dug	Flowing	1812.59	184.00	548.00
26	Hand dug	12	1615.78	188.00	646.50
28	Hand dug	43	1470.00	217.00	628.00
29	Hand dug	43	1470.00	217.00	622.00
27	Hand dug	28	1894.08	211.00	443.00
8	Hand dug	2.3	7227.37	116.45	3.28
24	Shaft	Flowing	1610.66	145.40	655.00
14	Hand dug	10.62	3120.72	75.38	10.81
10	Hand dug	8	4298.43	74.00	32.00
11	Hand dug	2.85	381.87	73.15	4.59
12	Hand dug	0.86	249.87	72.90	2.44
18	Shaft	Shaft	11693.40	28.00	
19	Shaft	Shaft	9313.89	−11.00	
37	Hand dug	W. fall	10,967.90	119.00	
57	Drilled	5.1	14424.20	264.90	5.40
20	Drilled	Shaft	6986.90	192.00	
21	Drilled	Shaft	2675.76	192.00	
36	Drilled	13.3	2068.00	516.70	13.50
5	Hand dug	9	5040.49	264.00	10.60
22	Hand dug	14	11368.20	216.00	17.60
13	Hand dug	2.48	4824.30	122.38	3.28
1	Hand dug	9	13524.20	0.50	10.00
3	Drilled	17.08	1649.00	13.63	36.00
17	Drilled	8.87	1810.00	33.63	55.00
15	Shaft	0	4813.31		
2	Drilled	8.7	4404.00	38.63	14.50
23	Drilled	26.29	2102.00	32.52	156.00
16	Drilled	62	4020.00	40.04	111.00
30	Drilled	Flowing	2227.08	140.80	592.00
32	Drilled	Flowing	2437.71	132.70	461.00
31	Drilled	Flowing	2151.30	141.80	432.00
35	Drilled	Flowing	2157.52	134.70	400.00
33	Drilled	Flowing	2305.30	134.20	421.00
34	Hand dug	Flowing	2101.50	134.30	390.00
44	Hand dug	2.64	1079.06	624.34	3.11
43	Hand dug	1.75	337.07	623.86	
42	Hand dug	2.65	561.81	615.94	4.81
40	Hand dug	0.89	475.16	617.11	4.13
41	Hand dug	1.9	525.02	616.14	4.15
49	Hand dug	15.58	450.72	482.97	17.55
48	Hand dug	17.4	536.01	475.13	19.48
50	Hand dug	18.8	2006.50	475.91	19.48
46	Drilled	16.55	536.18	469.52	27.82
45	Drilled	15.62	551.20	468.13	23.28
47	Hand dug	16.11	523.29	469.02	16.11

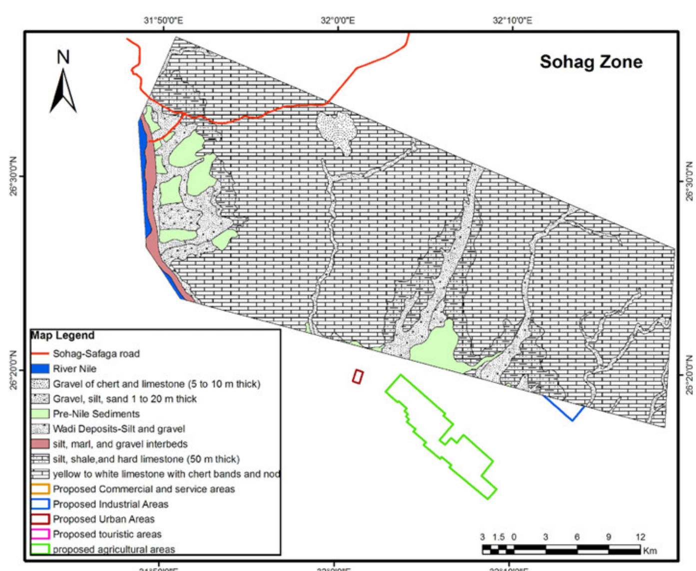
and commercial areas are located in the elevations of 134–220 masl. The proposed site for urban development is located at the northwestern side of the Assyut section which is partly located on layered gravel, silt and sand (1–20 m thick) and partly layers of silt, shale, and hard limestone (50 m thick). From the geotechnical point of view, both areas will be suitable as shallow foundation rocks for new urban communities and will not require deep foundations (piles). The same is for the proposed industrial site in the eastern side of the roadway (Fig. 8a).

4.4.2. Sohag zone

A large industrial area is proposed in Sohag governorate that has elevations ranging between 28 and 424 masl (Fig. 3). Most of this large area is lying over limestone with chert bands and nodules (300 m thick) and is dissected by three main drainage



(a)



(b)

Figure 8 The different rock formations and proposed development areas around the roadway path in each governorate. (a) Assyut zone. (b) Sohag zone. (c) Qena zone. (d) Red Sea zone.

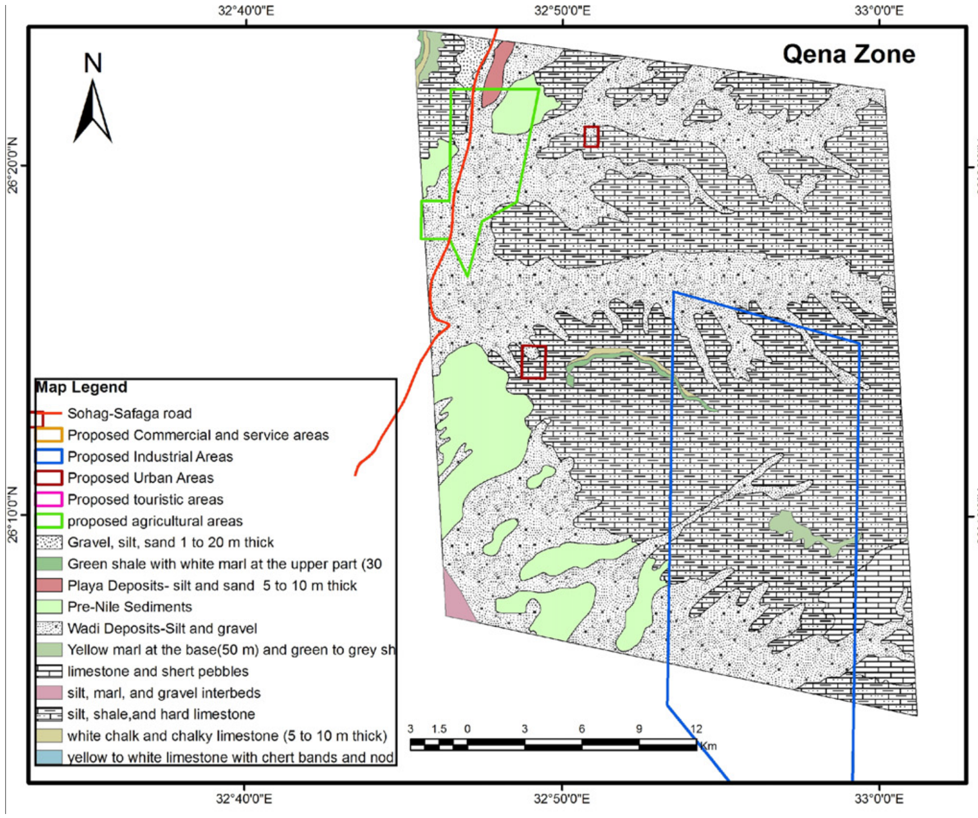
lines that represent the flashflooding hazard (Fig. 8b). Concerning the urban areas, the same lithological formation is found out of the flashflooding hazard path. These limestone beds are considered a good foundation base.

4.4.3. Qena zone

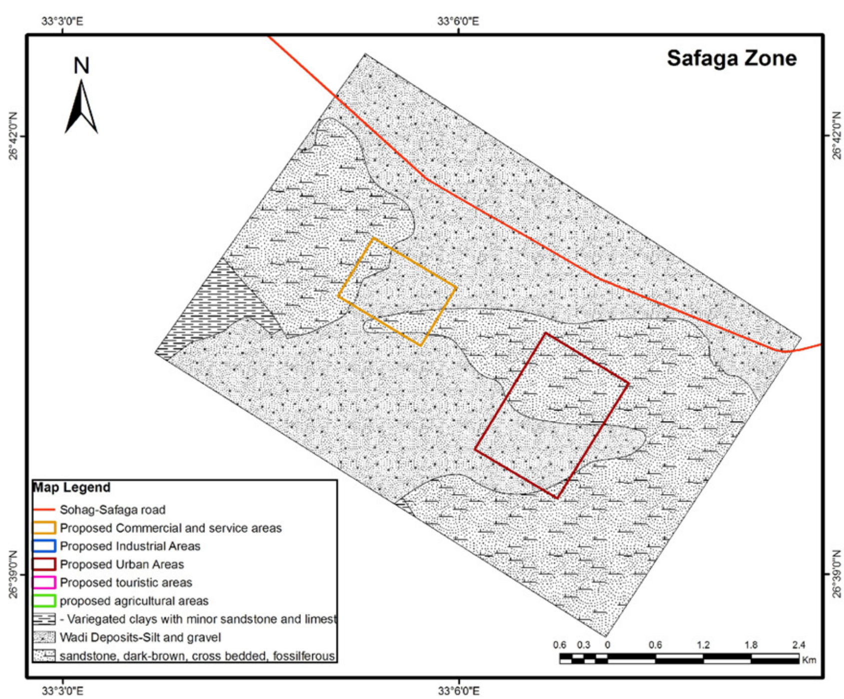
The main proposed developmental agricultural project in Qena governorate is a large semi triangular land with an area of about 33 km^2. This area is mainly located within elevations ranging between 220 and 790 m (Fig. 3) that is a wide variation of elevation. This large area is mostly lying over silt, shale and hard limestone (Fig. 8c).

4.4.4. Red Sea zone

The main proposed developmental projects in the Red Sea governorate are urban and commercial projects. They are relatively small areas lying on the southern side of the road. This



(c)



(d)

Fig. 8 (*continued*)

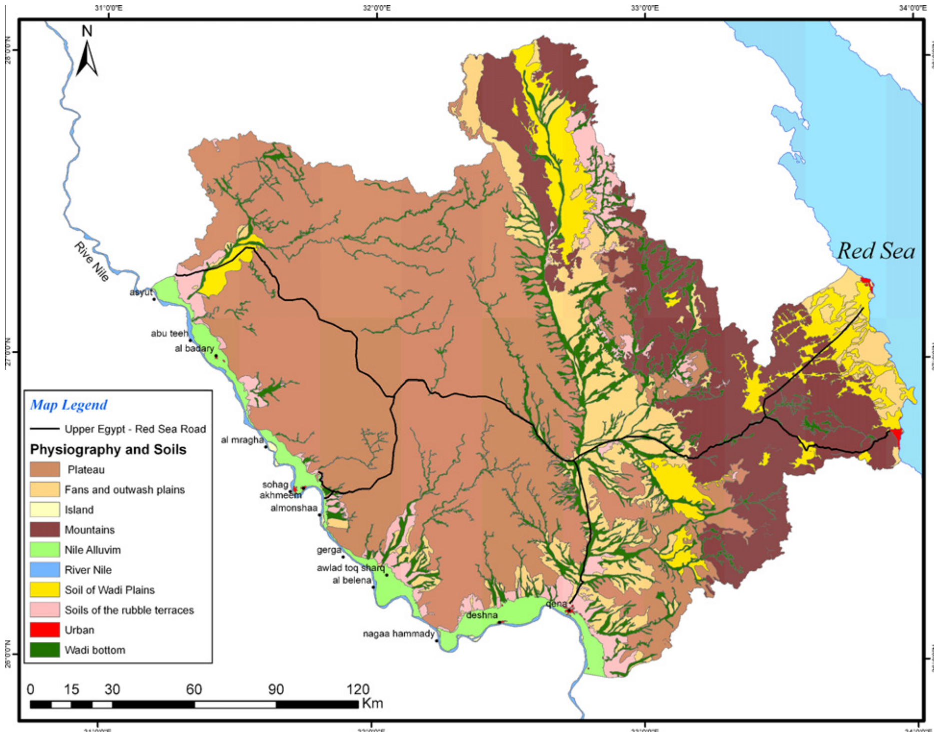


Figure 9 Physiographic and soil map of the study area.

large area is mostly lying over sandstone and wadi deposits (silt and gravel) (Fig. 8d).

4.5. Soil for agriculture

Fig. 9 shows the physiographic and soil map for the study area which is characterized by the following soil units:

- The mountains belt.
- The sandstone and limestone plateau.
- Terraces.
- Wadi bottoms and wadi plains.
- Alluvial fans and out wash plains (Piedmonts).

4.5.1. Terraces

Theses terraces are remnants of the alluvial plains. They were left out with gravels, sand or coarse detrition materials brought down from the slopes of the highland. Subsequent uplift of land in relation to the level of the sea has resulted in the number of terraces which are distinguished according to their relative age. Soil texture is sands, sandy loams, loamy sands and clay loams. Gravel contents were detected in the surface layers and some subsurface layers are gravel. Soils are very deep. Depending on the soil chemical characteristics, these soils are neutral (pH 7.1) and slightly alkaline (pH 7.5). The total soluble salts indicate that the soil is non-saline to extremely saline, ECe values range from 0.8 to 49 dS/m. The contents of organic matter are traces (0.26%). Cation exchange capacity ranges between 7.30 and 26.35 cmol/kg soil.

4.5.2. Fans and outwash plains (Piedmonts)

These are accumulations of debris at the foot of the escarpments. They are brought down from the plateau by steep tributary streams descending through ravines, so that the detrital material spreads out in the shape of fans. These deposits cover narrow areas in between highlands. They are described as outwash plains. Alluvial fans are the dominant class of groundwater reservoirs in many locations in the study area. Soil textures are sandy loams, loamy sands, loams and clay loams. Gravel contents are detected in surface and subsurface layers. Soil depth is very deep. Soil pH values range from 7.1 to 7.8 (neutral to slightly alkaline). Total soluble salts indicate that the soils are extremely saline, ECe values range from 34 to 500 dS/m. The high soil salinity is a function of factors including parent material, aridity, topography and soil texture. The low-lying lands receive more run-off water from neighboring high lands. Soluble salts carried from the surface downward by rain water. Soil depths are deep to moderately deep having high contents of coarse matrix and migration of soluble salts to the surface by capillary rise occurs in dry season. The organic matter content is very low being the climatic condition is arid. CEC ranges between 6.8 and 13 cmol/kg soil.

4.5.3. Wadi bottoms and wadi plains

Wadis could be differentiated into wadi bottoms and wadi plains. Soil of wadi bottoms represent the lower parts of the natural drainage pathways showing one or more stream beds. Soil wadi plains are areas without streams beds which are occasionally flooded by run-off water from adjacent elevated areas. Such plains have no free external drainage and the deposition of finer material is still lacking place. The particle size distribution shows the alternative pattern of sedimentation and soil textures are sands, sandy loams, loamy sands and loams. The soils are neutral to moderately alkaline (pH values range from 7.1 and 8.2). Soil salinity is expressed as electrical conductivity (ECe) which range from 0.5 and 70 dS/m. These soils are non-saline to extremely saline. The organic matter contents fluctuate between 0.01% and 0.19%, while the CEC contents range from 1.96 to 25 cmol/kg soil.

4.5.4. Hilly areas

These hills are located in both the eastern and western sides of the wadis. They have soils of very steep slopes and many rock outcrops with very shallow soils having very gravelly or stony surfaces. They are widely differing with regard to their morphology, texture and mineralogy, which depend on the genesis of parent materials and the sedimentation processes forming these soils.

4.6. Hazards mitigation

Flashflood hazards are considered one of the most important hazards for this vital road. Thus, a number of pipes (culverts) are constructed below the road to drain the water below the road without destroying it. These culverts protected the road from the flashfloods that occurred in January 2010. This collected water can be used in recharging the groundwater aquifer using either surface recharge by basins or deep recharge by wells.

5. Conclusions

This research is a part of a research project that took place at NARSS (NARSS, 2010). In this research, the different natural resources available in the vicinity of the Sohag – Safaga highway were investigated. These resources include: soils for agriculture, water, building materials, ornamental stones. The different proposed developmental sites were investigated for their suitability for the proposed function. In this research, only topographic, geologic, hydrogeologic, soil maps were used in addition to satellite remote sensing data. In order to produce a detailed map, further investigations are required using soil sampling using spectro radiometer and traditional geotechnical laboratory analysis. Detailed geotechnical investigations are required for studying the soil properties for the developmental areas and their suitability for the different proposed developmental projects.

The proposed methodology was adequate to identify some types of soils for agriculture using remote sensing, GIS, and showed the importance of relief in the study area. In order to produce a detailed soil map using this methodology, additional fieldwork is necessary. Soils are function of five formation factors: parent rock, relief, vegetation, climate and time. In this study, the relief factor was only considered. For large areas with lesser scales, other soil formation factors may be included in the analysis, with the purpose of obtaining satisfactory results.

Acknowledgments

Deep thanks are dedicated to the National Authority for Remote Sensing and Space Sciences (NARSS) for all the funding and facilities provided for this research that is part of a research project that is going on at NARSS since 2009 until now (NARSS, 2010). The authors would also like to thank Mr. Tarek Ismail Idris, the GIS specialist at NARSS for his efforts in producing the output maps.

References

Abd El-Bassier, M.A., 1997. Hydrogeological and hydrogeochemical studies of the Quaternary aquifer in Qena Governorate, Egypt. M.Sc. Thesis, Assyut University.

Abdel Baki, A.A., 1996. Groundwater supplies in Safaga area, Red Sea Coast A.R.E.. El Minia Bull. 9 (Part 1).

Abdel-Hady, A.M., Rognon, P., Escadafal, R., Pouget, M., 1991. Contribution of Landsat data (MSS) to soil survey: application to the soil of south-western Sinai (Egypt). Int. Remote Sens. J. 12 (5), 1053–1061.

Abdel-Samei, M.K.A., 1991. Soil studies related to origin and formation of some wadis in Eastern Desert, A.R.E. M.Sc., Fac. of Agric., Moshtoher Zagazig University.

Abu El Ella, E.M., Abdel Mogeeth, S.M., 1993. Hydrogeological aspects of the groundwater aquifers in Wadi El-Assiuti, East Assyut, Egypt. Bull. Fac. Sci. Assyt Univ. 22 (1-F), 55–71.

Aggour, T.A., 1997. Impact of geomorphological and geological setting on groundwater in Qena-Safaga district – Central Eastern Desert – Egypt. Ph.D. Thesis, Ain Shams University.

Cairo University, Irrigation and Hydraulics Department, 2004. Developing renewable ground water resources in arid lands: the Eastern Desert of Egypt.

Diab, M.Sh., El-Shayeb, M.H., Abdel Moneim, A.A., Said, M.M., Zaki, S.R., 2002. Evaluation of water resources and land suitability for development in the southern part of Sohag, Upper Egypt. Ann. Geol. Surv. Egypt XXV, 487–512.

El-Tahlawi, M.R., Mansour, H.H., Abdel Rahman, A.M., 1994. Geotechnical assessment of the Lower Eocene limestones, East of Sohag, Upper Egypt. In: Proceedings of the Fourth Mining, Petrol and Metallurgy Conf., Fac. of Eng. Assyut Univ., February 5–7, Mining Eng., vol. 1, pp. 48–56.

Egyptian Meteorological Authority (EMA), 2000. Climatic database.

Egyptian Mineral Resources Authority (EMRA), 1983, 1992 and 2005. Geological map of Egypt scale 1:250,000 (Gebel El-Urf: 1983; Hurgada: 2005; Wadi Qena: 1983; Quseir: 1992).

FAO, 1966. High Dam Soil Survey. Ministry of Agriculture, Egypt.

NARSS, 2010. Establishing an integrated engineering system for supporting the development projects around Sohag – Safaga highway – Eastern Desert. An Internal Research Project, Final Report.

Rib, H.T., 1975. Engineering: regional inventories, corridor surveys, and site investigations. In: Bowden, L.W. (Ed.), Manual of Remote Sensing. Interpretation and Applications, vol. 2. American Society of Photogrammetry, Falls Church, Virginia.

Research Institute of Groundwater (RIGW), 1990 and 1992. Hydrogeological map of Egypt, sheets of Assyut, Gerga, Sohag, Tahta, Qena and Naga Hamadi scale 1:100,000.

Sadek, H., 1959. The Miocene in the Gulf of Suez region Egypt. Geol. Surv. Egypt 9, 1–18.

Said, R., 1981. The geological evaluation of the River Nile. Springer-Verlag, New York/Heidelberg/Berlin, 151pp..

The Egyptian Cabinet, Information and Decision Support Center (IDSC), 2009. Egypt's Description by Information Years of Development, eighth ed.

Weber, E., Hasenack, H., Flores, C.A., Potter, R.O., Fasolo, P.J., 2008. Digital Soil Mapping with Limited Data. Springer Science + Business Media B.V. (Book Chapter No. 9).