THE FOURTH INTERNATIONAL CONFERENCE
ON THE GEOLOGY OF AFRICA
Vol. (2), P-P 1-15 (NOV. 2005) ASSIUT-EGYPT

USING GEOGRAPHIC INFORMATION SYSTEMS AND STATISTICS FOR DEVELOPING A DATABASE MANAGEMENT SYSTEM OF THE FLOOD HAZARD OF RAS GHARIB AREA, EASTERN DESERT, EGYPT

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ABSTRACT

Nowadays, the use of GIS (Geographic Information Systems) is emerging as a powerful tool for the assessment of risk and management of natural hazards. Using these techniques, natural hazard maps can be prepared to delineate flood prone areas. Such maps will help the authorities and planners for rapid assessment of the potential impact of natural hazards to take the appropriate arrangements for reducing the impact of these hazards. Ras Gharib is one of the areas that is affected frequently by flash floods along the Red Sea coast, Egypt. Residential areas, commercial activities, industrial sites, and many essential roads are situated in the area. These vital objectives are especially vulnerable to flooding. Many of these objectives are constructed in unsafe sides due to lake of planning. Currently, the most frequent choice for the local authorities to protect the cities and other objects from flooding is the construction of local drainage control. Therefore, applying modern techniques like GIS and statistical analysis for the assessment of flood hazards is urgent to understand the interaction between different morphometric parameters. This study has four principal objectives: (1) using the GIS and remote sensing techniques in flood hazard assessments, (2) describing the development of the flood hazard zones and constructing vulnerability maps, (3) finding the interrelation between the different morphometric parameters using a statistical approach, and 4) building a GIS database management system for the area. However, there is a need for a broader and comprehensive program for managing floods. Such program will help the planners and decision-makers to take the positive and timely regulations before and after the onset of such crucial crisis.

1. INTRODUCTION

1.1 Background

Natural hazards became a severe threat to many countries all over the world. Many specialists, planners, and authors are looking forward to joining hands attempting to mitigate these hazards. Among these natural hazards, floods are increasingly becoming a major contributor to injuries, deaths, and property damage worldwide and in many places strikes without warning. Alexander (1993) mentioned that the impact of floods is especially serious on the economy and agriculture. With the increase of population and economic activities, governments have begun the development of extensive infrastructures and new urban sites in the nearby desert areas. On the other hand, hazard refers to the probability of a potentially dangerous phenomenon occurring in a given location within a specific period of time (Alexander, 1993). In the light of the limited financial resources in the developing countries, the cost-benefit implications of disaster reduction alternatives must be carefully assessed. The expected damage provides one of the necessary inputs in cost-benefit analyses.

Problems related to flooding and vulnerability of the population have greatly increased in recent decades due to several factors including changes in land-use, urbanization of flood-prone sites, squatter settlements and sub-standard constructions, and increased household density (Munich, 2002; Pelling, 2003). Flood problems are contributing to different factors ranging from topography, geomorphology, drainage, engineering structures, and climate. There are many factors, which have a strong influence on the floods especially in desert; these factors affect each other by different degrees. Saleh (1989) determined these factors which include: rainfall and its characteristics, water loss (evaporation and infiltration), drainage basins, drainage networks, drainage orders, drainage characteristics, and environmental and human processes. Many authors studied the flood hazard in different areas in the country (e.g. El-Shamy 1992a; El-Etr and Ashmawy 1993; Ashmawy 1994).

Traditional methods for flood risk assessment are usually based on hydrological and hydraulic modeling. These models are useful in depicting the spatial and temporal distribution of floods. However, few are well integrated within spatial modeling environments (i.e., GIS) and few are capable of non-expert implementation (Al-Sabhan et al., 2003). Geographic Information Systems are computer-based systems with a high potential to archive, manipulate, analyze and display georeferenced data (Aronoff, 1989). They became a major tool for geological hazard analysis and risk mitigation (Coppock, 1995). Several papers have recently been published concerning the use of GIS tools for the study of geological (Salvi et al., 1999), seismological (Ganas and Papoulia, 2000), volcanological (Kauahikaua et al., 1995; Pareschi et al., 2000; Pareschi, 2002) and landslides data (Carrara et al., 1991; Carrara et al., 1995; Carrara et al., 1999; Jibson et al., 2000; VanWesten et al., 1999). When available, hazard and vulnerability data can easily be represented in a GIS and a great diversity of risk maps can then be produced following the implementation of specific predicting models. The use of GIS tools in such studies has been demonstrated by AGSO (2001) and FEMA (2003).

Many authors used risk as an alternative meaning to hazard. Encarta (99) mentioned that risk is a factor, element, or course involving danger; also, it can be described as the possibility of suffering harm or loss. Risk has become an issue discussed in various fields, in which varied definitions have been given without any discipline claiming authority (Stig, 1996). On the other hand, hazard refers to the probability of a potentially dangerous phenomenon occurring in a given location within a specific period of time (Alexander, 1993). Flooding refers to the inundation of an area by unexpected rise of water by extreme rainfall duration and intensity in which life becomes under risk. In this study, hazard and risk are used to imply the probability of human life and properties within the study area to be affected by high rainfall that generates into flood.

1.2. The Study Area

The area of study is located at the northern part of The Eastern desert covering about 3455 Km^2. It lies between latitudes 27^o 51' 00" to 28^o 23' 00" and longitudes 32^o 17' 00" to 33^o 23' 00" (Figure 1). The area under investigation represents one of the areas that had little studies. This study is concentrating on the assessment of the geomorphological situation using topographic and geological maps as well as satellite images. It is an excellent case for studying the methods, problems and rewards of flood mapping. Topographically, the area is a characterized by a high elevated hills on the west (reach up to 1600 m high) and low land of the coastal strip on the east, . The heart of the urbanized area and some petroleum sites are defined by the mouths of the valleys, flooding into the Red Sea. There is a diverse mixture of housing, commercial, petroleum, and industrial lots along the coast, which illustrates the varied interests of those who have a stake in flood mitigation.

1.3. Research Objectives

Flood hazard mapping is an attempt to identify what areas are in danger under varying flood conditions. The current objectives are directed to create easily-readable and rapidly-accessible charts and maps aiming to help administrators and planners to identify areas of risk and prioritize their mitigation / response efforts. The goal of this paper is to use the GIS techniques in flood hazard assessment, describe the development of the flood hazard zonation and vulnerability maps, implement an interaction relationship between different morphometric parameters using statistical approach, and build a GIS database management system. All these will help to create an accurate series of maps that will serve to further progress in their inventory and risk assessment efforts. Such maps would not only provide detailed lists of threatened structures, forming a concrete basis for the creation of a flood mitigation policy, but would also serve as a valuable educational and public relation tools to garner support.

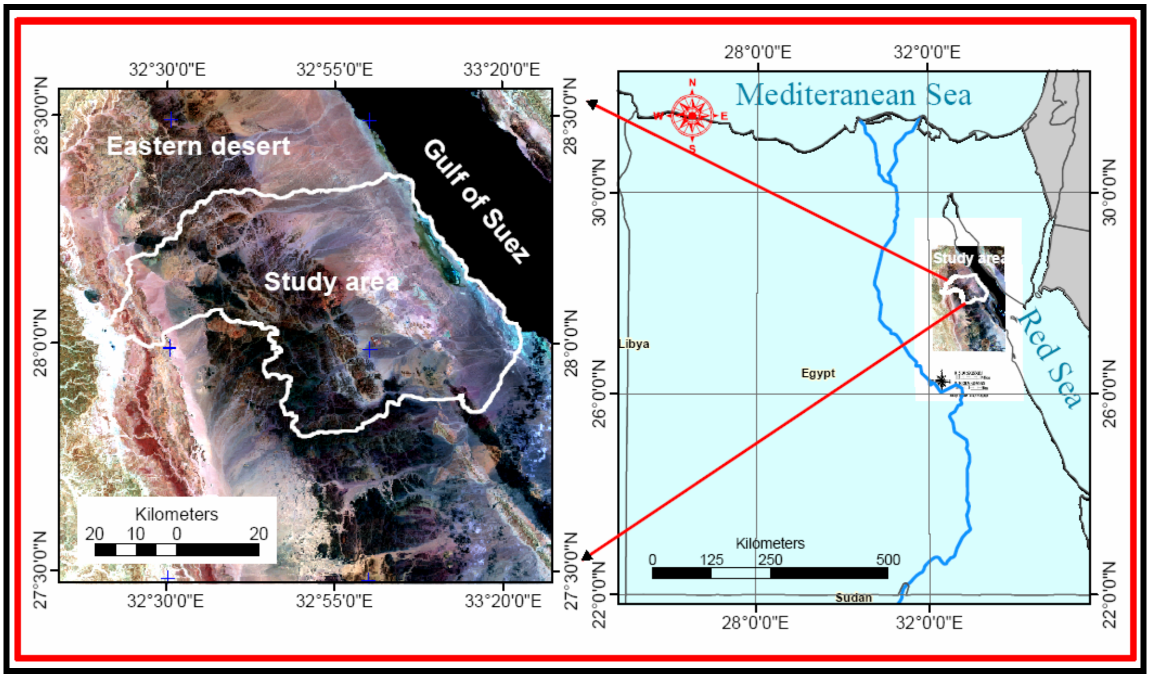

Figure 1: Landsat image shows the location of Ras Gharib.

2. GEOMORPHOLOGY AND GEOLOGIC SETTING

2.1 Geomorphological Features

The morphology of the Ras Gharib area is mainly characterized by two zones 1) the mountainous zone in the west characterized by steep slopes and abrupt changes in slope angles toward east direction, 2) the coastal zone in the east and extends from contour 0 to contour 300 m and characterized by gentle slope toward the east. Figure 2 shows the contour map (A) and elevation map (B) for the study area.

2.2 Geologic Setting

The geology of the study area represents the geology of the northern part of the Eastern Desert. The geologic setting of the area was previously achieved through the geologic maps of Egypt of scale 1:2,000,000 prepared by Egyptian Geological Survey (1981) and 1:500,000 scale prepared by the Egyptian General Petroleum Corporation (Conoco Coral) (1987), as well as maps prepared by other researchers (Figure 3). The area under study consists of a variety of rock units of different ages. The geology of the area has been studied by many authors (e.g. Ball 1952, Abdallah, et al., 1963, Ghanem 1972, and Hassan and Hashad 1990.

3. CLIMATIC SITUATION IN THE STUDY AREA

The area under study lies along the northern part of the Red Sea. It is characterized by arid climate. The location of the area is the main factor controlling its climatic characteristics; the Red Sea hills in the western part of the area increase the amount of the occasional rainfall. The area is generally characterized by high to moderate temperature throughout the year, especially during the summer season. According to the data acquired from the Egyptian Authority for Meteorology (1975 – 2000), the area is surrounded by four meteorological stations which are Hurgada, Suez, San Antinu, and Bair-Owida. Table 1 shows the minimum and maximum temperature, the average temperature recorded during daytime and nighttime, average annual rainfall in mm, maximum rainfall recorded in one day, the evaporation rates mm/day, and the annual relative humidity.

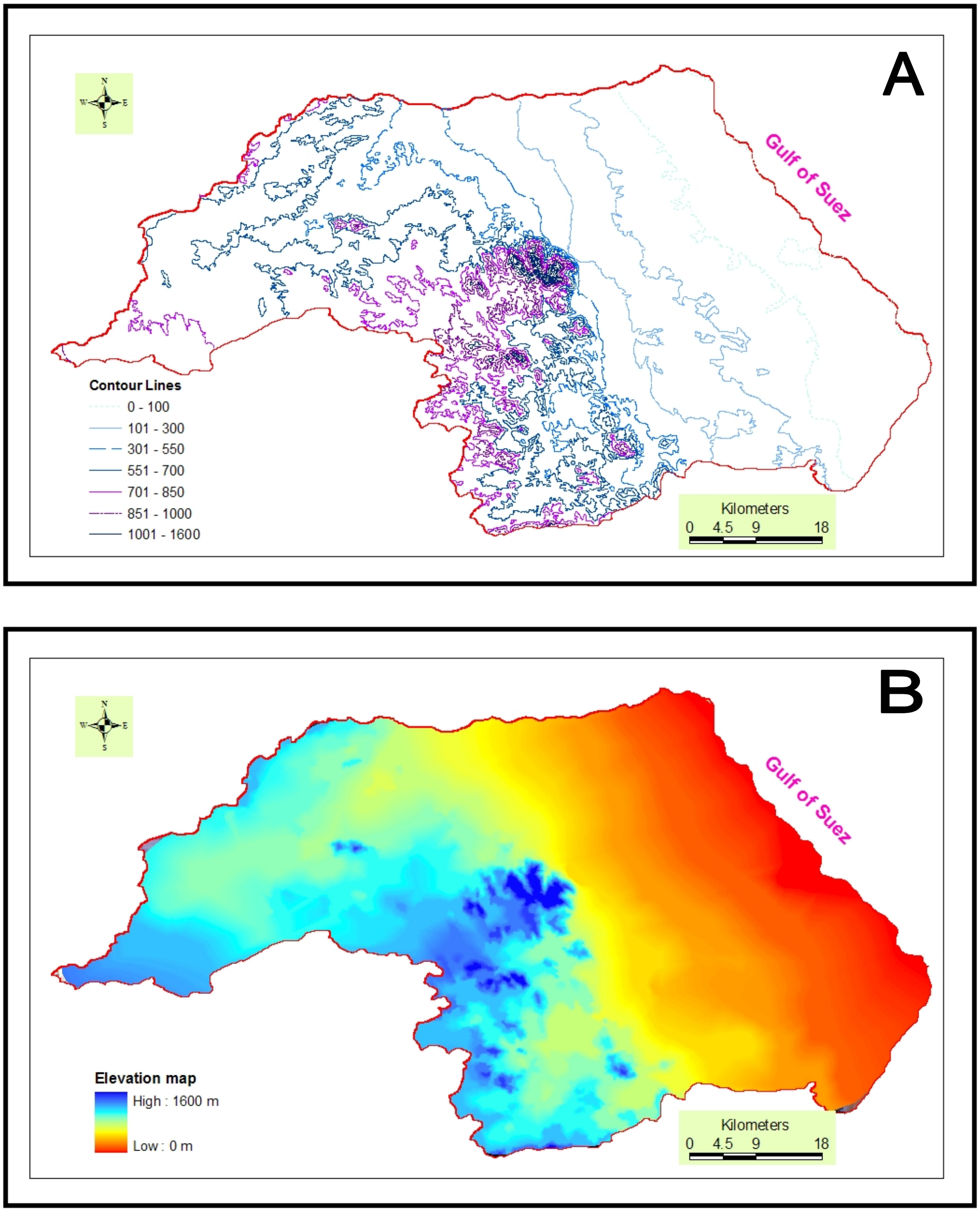

Figure 2: Contour map (A) and Elevation map (B) for the study area created using ArcGIS 8.3.

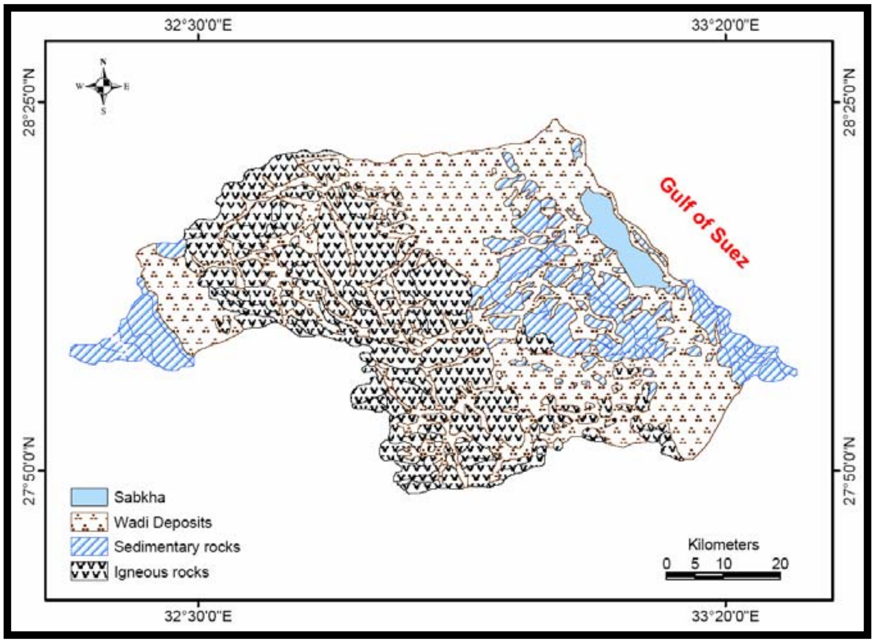

Figure 3: Simplified geological map of the study area digitized using ArcGIS 8.3 (modified after Conoco Coral 1987, scale 1: 500,000).

Table 1: The data collected from the 1975 to 1999 for the four stations surround the study area.

Station	Min. – Max. Temperature in degree	Average temperature in degree night/day	Rain average annually mm	Rain max. in one day mm / day	Evaporation mm / day	Relative Humidity %
Suez	4.1 – 46.1	14.7 – 28.9	0.3 – 6.2	49.6 (1965)	6.7 – 15.4	42 – 56
Hurghada	3.4 – 43	15.7 – 30	0.2 – 1.5	24.7 (1954)	9.8 – 18.8	43- 55
Sant Antinu	(-1.3) – 42.5	13.2 – 29.6	0.2 – 3.1	18.3 (1954)	13.9 – 31.1	31.3 – 51.7
Bair Oweida	(-1.7) – 44.7	10.9 - 28	0.2 – 1.5	3 (1978)	6.2 – 20.2	26 – 64

4.0 DATA ACQUISITION AND METHODOLOGIES

4.1. Data Acquisition

Data used for this study were acquired from two main sources, official and primary. Data from official sources were obtained from published information such as rainfall and human activities within the study area. The data collected from primary sources include different types of maps as geological maps, topographic maps, and satellite images. The methods used to collect other types of information include, field observations, field measurements, and satellite image and topographic map interpretations. To easily incorporate the data into the geographic information system, all maps have been georeferenced using UTM Coordinate system zone 36. Topographic contour maps of scale 1:50,000 with the help of Thematic Mapper satellite image (Landsat mosaic map) with ground resolution 30 m were used. These sheets were scanned and then rectified by using ERDAS IMAGINE 8.5 software followed by vectorization (on screen digitizing). Tracing the drainage line from the topographic maps and verified using TM image has been done to produce drainage network and drainage basin maps (Figure 4). Finally, The morphometric data is sorted in GIS database that will be used to get all possible attribute maps for each of these parameters. ArcGIS 8.3 was used to build up the database for the area and also to finalize hazard and vulnerability maps.

4.2 Drainage Basin Analysis Program (Dbap)

4.2.1. User Input vs. Internal Calculations; DBAP has been designed to be as efficient as required, but has a user interface as simple as possible. The current version uses a Visual Basic user interface with an embedded Microsoft Excel® OLE® object. Figure 5 shows the one page data analysis, which consists of site location information, area data, stream number data, stream length data, rainfall data, and results. The data are either manually entered or dragged from a database table.

4.2.2 Quantitative analysis for the important parameters in flash floods; A): Morphometric data analysis and other parameters that can affect the flash floods including the total amount of main precipitate and the consequent runoff water. To determine the total rain precipitation conservatively, the maximum rate of rainfall was used to represent the worst-case scenario that may affect the area.

The Total rain precipitate =basin area x rate of rain fall
The Total runoff =750 x basin area (rate of rain fall - 8))
The evaporation and peculation = Total precipitation – total runoff

Where 750 and 8 are constants related to the geomorphologic and meteorological factors characterizing the Egyptian Eastern Desert according to EGSMA 1994. These data are very easy to be calculated using the drainage basin analysis program in which we can change the amount of precipitation rate and find out the result for each basin.

4.3. Gis Modeling

The GIS model was employed in the present study to concern the spatial analysis of flood occurrence in the current area. This model has the capability of using all the data to represent an area in which spatial variability of specific parameters can be integrated (Figure 6). The application of a Geographic Information System Model (GISM) to study flood event in its spatial form is therefore appropriate. The model identifies four main stages that could be used for flood hazard zoning and assessment. The first stage involves the generation of various thematic maps of the area, using aerial photographs, satellite images, topographic maps, and field observation and measurements. The second stage involves the incorporation of the thematic data into the Geographic Information System Model (GISM) through digitizing and creating attribute tables of each theme. Thirdly, it involves the use of different functions and overlay operation to get different types of attributed maps (GIS DATABASE SYSTEM). The fourth stage deals with the generation of flood hazard and vulnerability maps for the study area.

5. FLOOD HAZARD SCENARIO ASSESSMENTS AND MAPPING

Based on the information collected during the drainage basin analysis and survey, it was possible to develop hazard map representing the flood hazard in the area.

5.1 Calculating The Hazard Degree

5.1.1 Morphometric analysis of drainage networks and basins; The drainage system of different wadis is a threat to the Ras Gharib area, as well as the roads connecting and crossing the area. The drainage networks of these basins are external, well developed, and highly integrated. These basins originated mainly from the mountainous highland of basement rocks, which are flanked further east by a relatively low-lying sedimentary strip. The area consists of 9 drainage basins; with main wadis flowing through the area from west to east up to the Gulf of Suez coast where there are many developing activities, villages, urban areas, oil construction and tanks, and other industrial sites. The morphometric analysis for drainage basins have been studied by diferent authors (e.g. Strahler 1952, Horton 1945, and Melton 1957).

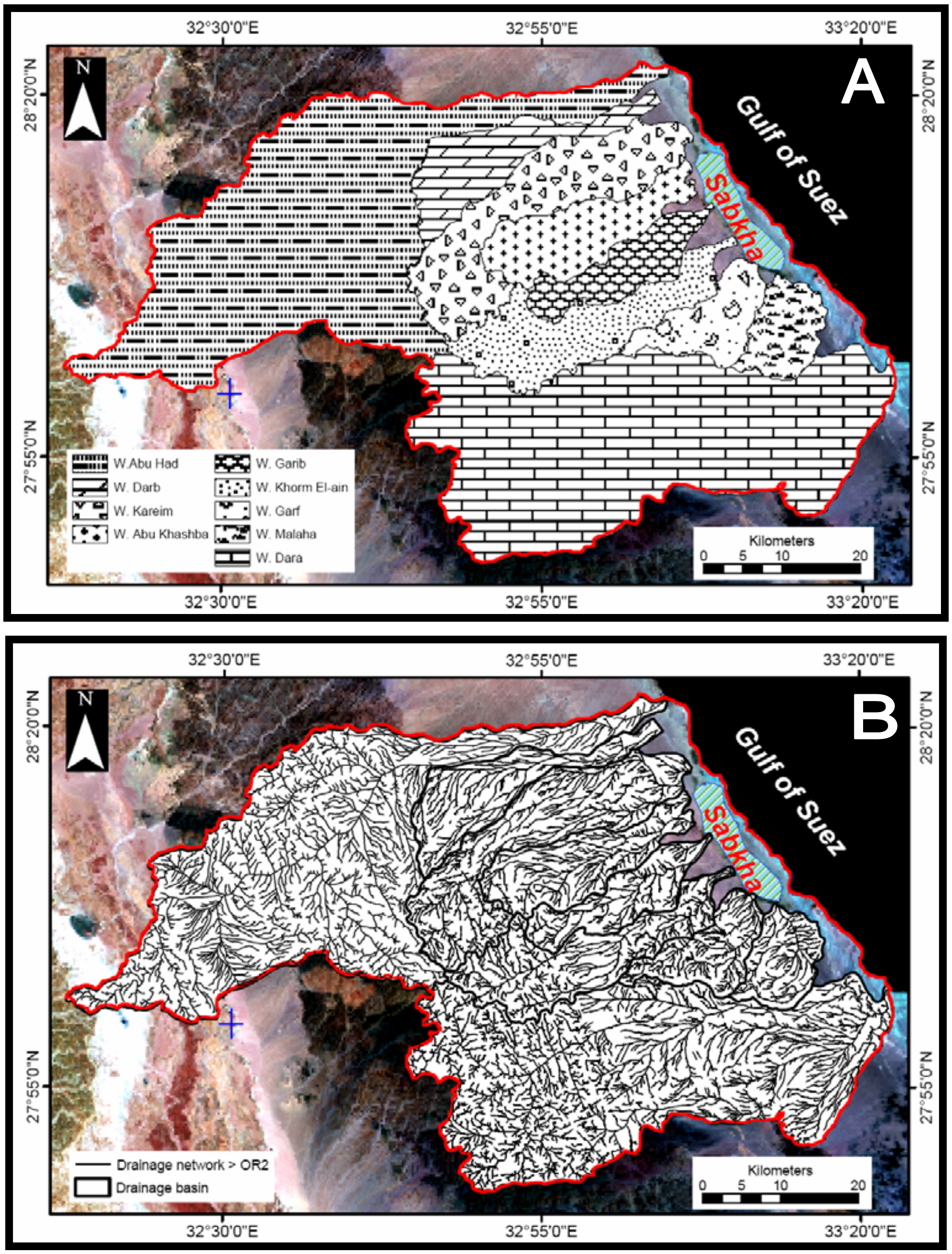

Figure 4: A) Drainage basins for the area and B) Drainage networks for orders above 2.

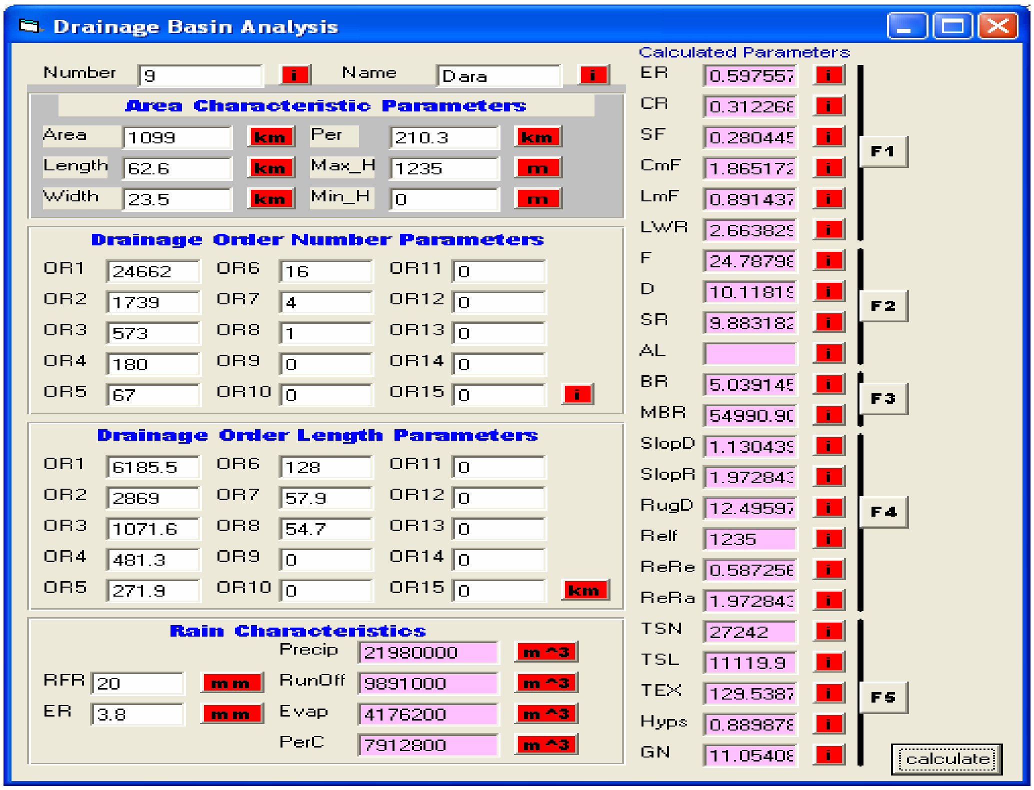

Figure 5: Drainage basin analysis program designed by using visual basic by the authors.

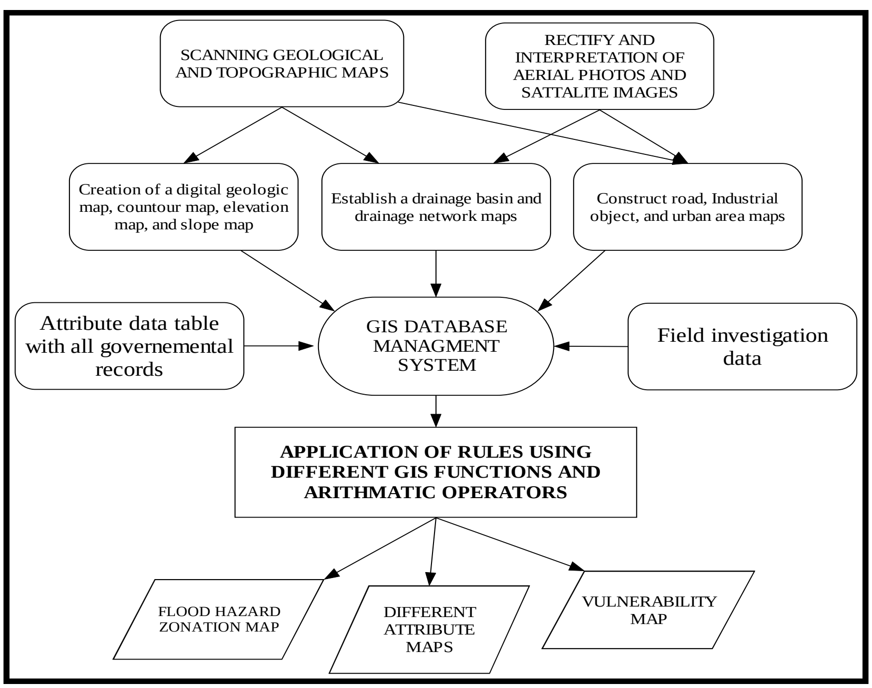

Figure 6: Flow chart for the GIS model used in the current research

Table 3: Risk degree according to the relationship between BR vs. D and BR vs. F (after El Shamy 1992b)

Wadi	BR	D	Risk Degree BR vs. D	F	Risk Degree BR. Vs. F	Final Hazard
Dara	5.04	10.12	M	24.80	M	M
Abu Had	4.27	8.59	H	27.19	H	H
Karim	4.51	5.73	M	29.03	H	H
Khorm el ain	3.82	10.18	H	12.08	H	H
Abu Khashaba	4.14	7.45	H	30.37	H	H
Darb	5.07	9.67	M	21.94	M	M
Gharib	4.49	10.09	M	25.26	M	M
Gorf	4.15	7.94	H	43.04	H	H
Malaha	3.85	7.51	H	33.92	H	H

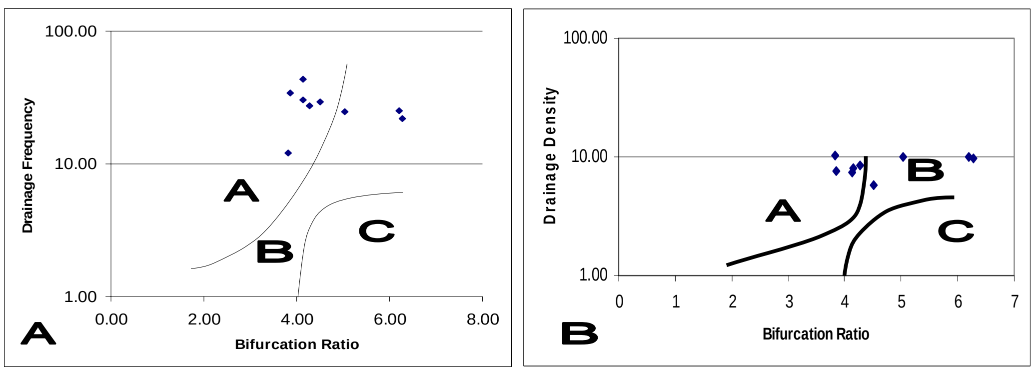

Figure 7: A) Shows the hazard analysis due to Bifurcation ratio vs. drainage frequency and B) Bifurcation ratio vs. drainage density(after El Shamy 1992b).

5.1.1.1 Creation of a flood hazard map for the study area: In order to evaluate the hazard degree of the different basins in the area, some of the geomorphometric parameters of these basins were used. The degree of hazard for each basin was determined using the hazard degree diagrams (Figures 7). The relationship between basin parameters was determined (Table 3). Two different methods were used to determine the hazard degree for each basin in the area (El-Shamy, 1992b). The first approach is the relationship between bifurcation ratio and drainage density and the second represents the relationship between bifurcation ratio and drainage frequency. Both diagrams include three fields A, B, and C; field A represents basins that have high possibility for floods; field B represents basins that have moderate possibility for floods; and field C represents basins that have low possibility for floods. If the same basin has two different fields the more conservative situation will be chosen. The resultant values were added to the GIS attribute table and a GIS drainage basins hazard map is prepared (Figure 8B).

5.1.1.2 Creation of vulnerability maps for the study area: The Office of The United Nations Development Relief Organization (UNDRO) defines the term vulnerability as: “The degree of loss to a given element or set of elements at risk resulting from the occurrence of a natural phenomenon of a given magnitude. It is expressed on a scale from 0 (no damage) to 1 (total damage)”. For example, those areas which **are** more prone to floods are more vulnerable to floods than areas that are away from floods. To make the result more acceptable, a separate domain has been created in which the resultant values were divided into three classes: high, moderate, and low vulnerability areas (Figure 8A). Figure 8B shows part of the Ras Gharib City is located at the mouth of wadi Abu Had, which represent high hazard.

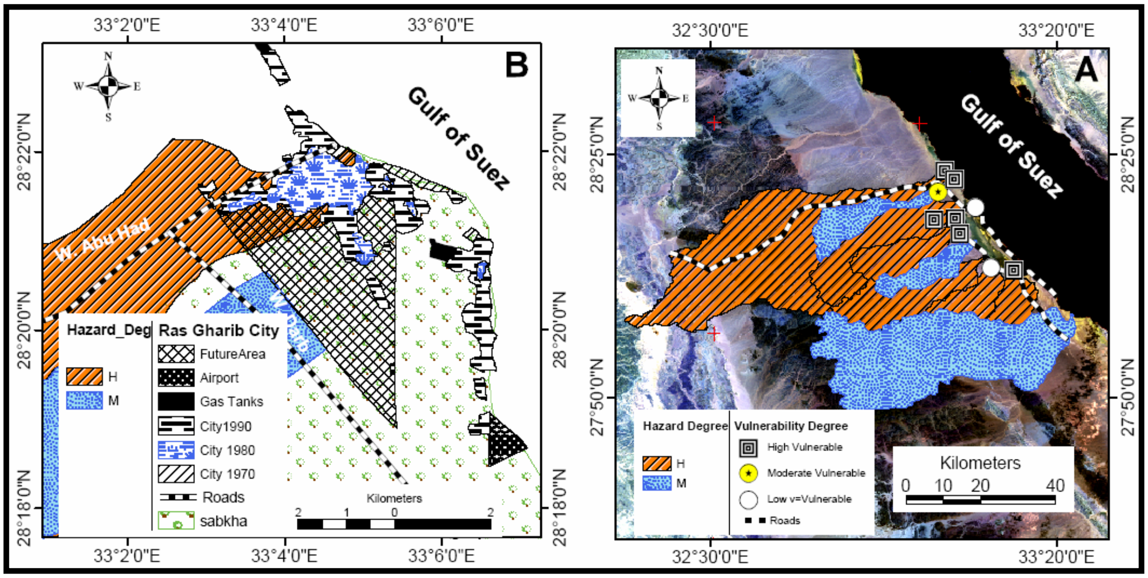

Figure 8: A) Drainage basins hazard map and Vulnerability for Petroleum sites and roads, B) Vulnerability for the Ras Gharib city.

6. STATISTICAL APPROACH FOR MORPHOMETRIC PARAMETERS RELATION

6.1 Factor Analysis

Factor analysis is similar to principal components analysis in that it is a technique for examining the interrelationships among a set of variables (Afifi and Clark, 1998). The factors obtained in a factor analysis are selected mainly to explain the interrelationships among the original variables. The major emphasis is placed on obtaining easily understandable factors that convey the essential information contained in the original set of variables. Factor analysis was used to define the factors that have marked impact on the drainage catchment and to understand the interrelation between the different morphometric parameters. Factor analysis has been established in the present study using SPSS 11.5 software program and factors were rotating using varimax method.

Table 4: Total Variance Explained

Component	**Initial Eigenvalues**			**Rotation Sums of Squared Loadings**		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
Morphometric factor (F1)	10.92	40.45	40.45	8.64	32.02	32.02
Relief Factor (F2)	8.71	32.25	72.70	6.38	23.62	55.63
Shape factor (F3)	2.85	10.54	83.24	5.71	21.15	76.78
Drainage network factor (F4)	2.44	9.02	92.26	3.69	13.68	90.46
Basin bifurcation factor (F5)	1.18	4.38	96.65	1.67	6.19	96.65

Extraction Method: Principal Component Analysis.

From the analysis five factors were recognized as follow:

1. F1 (Morphometric Factor) including basin area 0.966, basin length 0.885, basin width 0.869, basin perimeter 0.916, total order numbers 0.966, total order length 0.948, texture 0.832, hypsometric integral 0.882, geometric number 0.859, and modified bifurcation ratio 0.632;
2. F2 (Relief Factor) including relief ratio 0.945, rough degree 0.790, relative relief 0.933, slope degree 0.944, slope ratio 0.944, and relief 0.944;
3. F3 (Shape Factor) including elongation ratio -0.937, circulation ratio 0.-878, shape factor -0.922, compaction index 0.850, leminescate factor 0.941, and length/width ratio 0.561;
4. F4 (Drainage Network Factor) including frequency –0.718, density 0.913, average drainage elongation 0.870, and stream retain –0.885; and
5. F5 (Drainage Bifurcation Factor) including modified bifurcation ratio 0. 539, and bifurcation ratio 0.882.

7. BUILDING A GIS DATABASE MANAGEMENT SYSTEM

Generally, the traditional map data have been recorded in the form of lines and symbols on paper, and descriptive data or attributes have been restored in a written form on file cards and various documents. These traditional data documentations are organized in various systems of filing cabinets and drawers, and each data repository may be regarded as a "library" or "bank" from which different users may retrieve information (Bernhardsen, 1992). A data bank may either be available to a wide range of users or restricted to only a few authorized users. For a GIS purposes, a file is regarded as a single collection of information that can be stored in a particular way by a Database Management System (DBMS), and accessed through it. Effective data management can also support facilitate decision making in resource management. The logical organized structure for the data management system is clearly important. The primary goal of a data management system is to provide the best quality data possible within a reasonable budget and providing consistent and acceptable documentation, and supporting the feedback of summary information to investigators for scrutiny.

7.1 Loading Data Into The Geodatabase Schema

The scheme that includes all the data representing the different parameters for each basin is prepared. To complete this task different techniques were used as digitizing data and add attribute table using Drainage Basin Analysis Program, and finally written tables. Other data as urban areas, roads, geological maps, contour map, and landsat images are loaded to the GIS, but before adding these data to GIS database it was urgent to check the coordinate system and datum for each one to make sure that all layers have the same coordinates. Once the data and associated classification were recorded, this information was entered into the geographic information system.

7.2 Attribute Table Parameters Acquired From Gis And Dbap

The attributed data includes 1) drainage basin area map parameters (area, length, width, perimeter); 2) drainage network maps (drainage orders number and Drainage orders length); 3) morphometric parameters coming from excel spread sheet; 4) urban areas, petroleum sites, and any development resolved areas; 5) geologic, contour, and elevation maps with all the information associated to them; 6) road names and lengths; and 7) hazard degree units. In addition, the database has been expanded to include, digital photos, summary information from geologic and engineering reports, and maintenance records.

7.3 User Interface

7.3.1 Data Integration: To develop and refine the working site model, data from various sources need to be integrated. GIS provides tools for integrating these data. The user can shade the map based on desired attributes. The application also generates the corresponding legend enabling users to read the thematic of various datasets used for analysis. Also, the user can click on the map and retrieve information from the database for all map layers. Documents can be associated with features. At the same time a color photo for that site can also be automatically queried using a "hot-link" button in ArcGIS. A specific way that the GIS database can be utilized is by identifying which basins have high hazard and also the area that is highly vulnerable to these floods.

7.3.2 Data visualization and analysis: Using GIS to visualize and analyze site data can expedite this process, as illustrated in Figure 9. Figure 9 shows how the user can view both the basin area for each catchment with the drainage network and some histogram relationships between different parameters. The user can select the layer to be used for navigation.

7.3.3 Data presentation: Another benefit of using GIS is data presentation. Layouts can be created for use in reports, papers, posters, and presentations in varying page sizes and formats. Labels, symbols, scale bars, north arrows, and text can be added to maps to provide clarity and improve information transfer. The figures used in this paper were created in the GIS program and exported in a graphic format (Figure 10).

8. REMEDIATION EFFECTS

Because of the hazardous flood that repeated according to the mentioned meteorological data, the authors are suggesting a set of proposed barriers located in the upstream of each basin and another set of dams in the down slopes. The highly damaging effect of the flash flood is mostly caused by its load capacity that contains big boulders. The barriers will obstruct and prevent the boulders to move down by the gravity action. The dams will help also in saving the runoff water. The saved runoff water can be used in developing the study area.

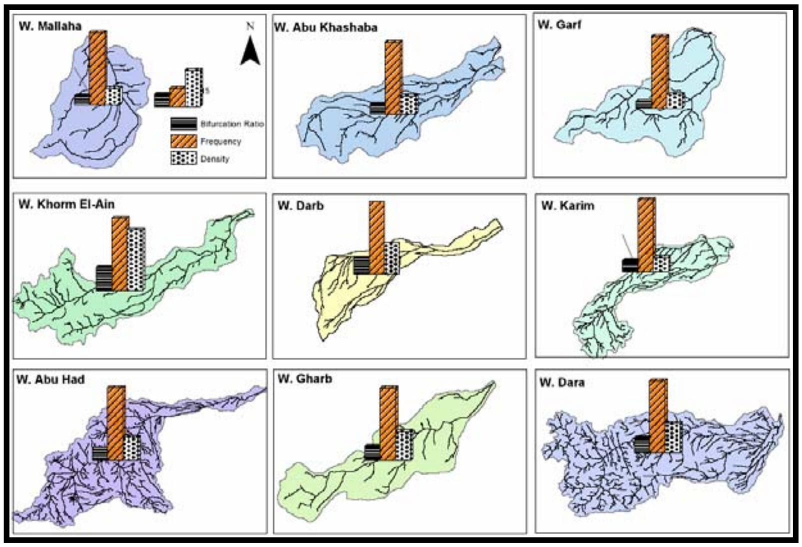

Figure 9: Visualize of data stored in the database using GIS.

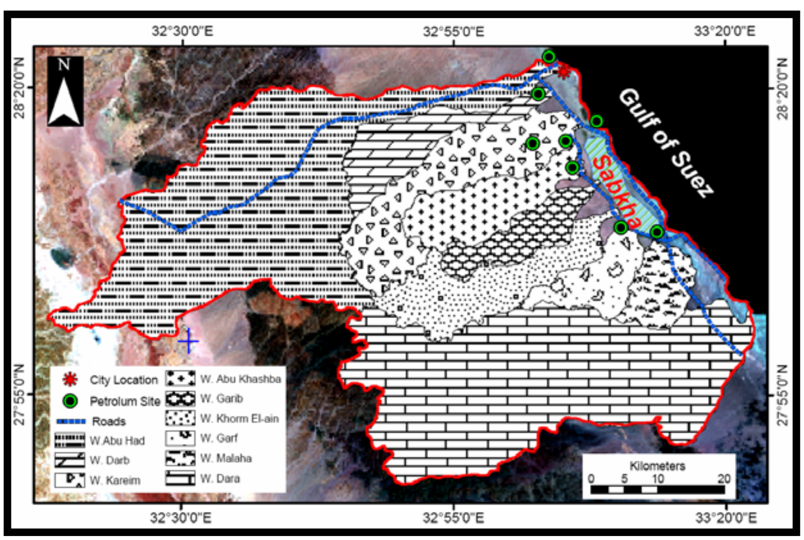

Figure 10: Final GIS map visualizes the data for the study area.

9. CONCLUSION

Creating detailed flood hazard and vulnerability maps serve three primary purposes for Ras Gharib area. First, it is a "proof-of-concept" regarding the effectiveness of GIS mapping. Second, it provides a good database management system that will help in disaster mitigation and forming response plan for protecting the vital objectives. Finally, the maps are visible evidence regarding hazards and vulnerability. The result shows that there are 6 basins having a high possibility flood hazard: Abu Had, Karim, Khorm el ain, Abu Khasaba, Gorf, and Mallaha. On the other hand, 3 basins are moderately flood hazard, including Dara, Darb, and Gharib. In addition, there are some petroleum sites, some road parts, and part of Ras Gharib city are located in the high possible flood hazard and they are accounted as a highly vulnerable sites.

The Statistical approach, using the Factor analysis method, has been applied for the morphometric parameters to understand their interrelationship. The major emphasis of the factor analysis approach is to obtain understandable factors conveying essential information about the morphometric parameters. Five factors have been extracted using such statistical technique: Morphometric, Relief, Shape, Drainage Network, and Drainage Bifurcation Factors.

Finally, the possibilities of using GIS for flood hazard mapping are considered as endless as the tasks accomplished for the critical projects. From that study it is clear that 1) database management system for any area using GIS technique will save time and give a good view for the decision makers. 2) the GIS database inventory application was developed as the integrating platform for a variety of information on each basin along the studied area. 3) the developing of drainage basin analysis program is a vital part in the drainage basin analysis to save time and wasteful expenditure.

10. ANTICIPATED BENEFITS

The benefits of this research will be powerful for all people who work in geomorphology, watershed analysis, and flood hazard as well as planners and decision makers in which the drainage basin analysis program has been introduced, use of GIS in hazard analysis, database management system for strong and retrieving different data, and statistical interaction between different parameters have been explained. The decision makers will be able to prioritize, schedule, and do the appropriate maintenance to reduce the hazard in the highly vulnerable areas due to flash floods.

ACKNOWLEDGMENTS

The authors are very thankful to Dr. Adly Omar for his generous help. We are thankful to officials of Ras Gharib city who provided different kinds of valuable information about the area.

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