Preliminary Investigation For Choosing The Best Location Of The Dams Using High-Resolution Satellite Imagery And GIS Modelling

A.M. Abdel-Wahab, M.A. Rashwan

Abstract: Many countries, which are located near mountainous areas, are exposed to the risks of floods, which cause many losses of lives and properties. Jeddah province had been subjected to a number of floods, the most serious was during the last ten years. This flood was what happened in November 2009, which caused great losses in lives, properties, and public utilities. In addition, it was repeated again in January 2011 with many damaged too. This research as preliminary investigation studies, aims to find a solution to the quick selecting of dam's location to avoid the impact of damage floods. The spatial analyst (tools in ArcGIS) and GeoEye satellite imagery were used with the DEM derived from LiDAR data to obtain the quick solution for selected of a suitable location of the dams. Three dams are selected to overcome this issue of torrential flooding in the chosen study area east of Jeddah (Wadi QAWS), which is one of the areas affected by floods in the periods mentioned before. In this context, there are recommendations for a necessity of supporting the selected locations with other required studies, such as collecting geological, geotechnical, and geophysical data to complete this work. The obtained results indicate that a careful selection of the dam's location based on the accuracy of the DEM with spatial analysis of GIS saves time and cost for all other studies such as geological, geotechnical, geophysical, and field surveys, focusing on specific areas and not spending effort and time in useless locations.

Key words: Flood, Satellite Imagery, LiDAR, GIS, Spatial analyst

1. INTRODUCTION

The studying of hydrological and environmental risks in several wadies in western KSA, specially Jeddah region, for the purpose of reduction and prediction concerning risks through the remote sensing images and GIS techniques utilization for finding a solution for this issue [1], [2]. In this research work, the study will concentrate on Wadi QAWS area that is distinguished by different geological and climatological features [3]. In general, the eastern Red Sea coast is characterized by unconsolidated landforms, rapid population growth, and urbanization in major cities in KSA, such as Jeddah, and numerous villages scattered around [4]. This area contains important man-made structures, including desalination plants, oil refineries and factories, in addition to major highways. The main objectives of this research work are to select the locations of the dams by estimating rainfall and flood prediction through different return periods, and to delineate, map different risk phenomena, and get a solution by choosing the optimum location of the dams by using Remote Sensing (R.S) and (GIS) techniques with an accurate DEM [5],[6]. Jeddah governorate is located within an independent water basin with an area of 1760 km2, in the western region between latitudes 21° 15' N and 22° 00' N, and between longitudes 39° 00' E and 39° 30' E. From the north of this basin is the outlet of Wadi ASFAN, to the south by Wadi Fatima, while it is bordered to the east by mountain ridges and the west by the Red Sea [7]. The elevation ranges from zero on the seacoast and reaches 500 m in the mountains hill's east of the basin. The main water basin of Jeddah Governorate is divided into three main sections, as shown in figure (1a and b), which are:

1) The northern sub-basin, with an area of 675 km2 and water flowing into it to Wadi Al-KARAA (SHARM OBHUR).
2) The middle sub-basin, covering 650 km2 and flowing water into it at the Qasr AL SALAM Lake.
3) The southern sub-basin, covering an area of 435 km2 and flooding water into the ALARBEYN Lake.

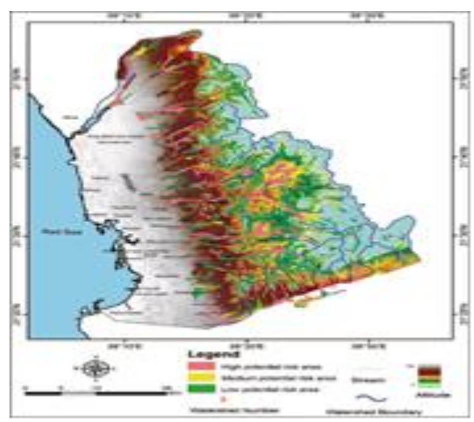

Fig. 1a: *Water Drainage Basins and their relationship with the Jeddah city Location [8].*

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Fig. 1b: *Jeddah sub-basins of Jeddah. [9].*

2 STUDY AREA

Wadi QAWS is located within the southern sub-basin, which empties into the forty lake and it has an area of 63.7 km2. The current part to be studied is located to the east of the stalagmites Figure (2). The water basin of Wadi QAWS was exposed to a rainstorm on 11/25/2009 corresponding to 12/12/1430 AH, which led to the eruption of torrential damages that extended to humans, animals, public, and private properties [10]. In addition, there is a major damage to some infrastructures and features which are illustrated in figure (3 and 4) [8], [11].

Fig. 2: *The location of the study area (Wadi QAWS Basin until the beginning of the SWAAID zone).*

Fig. 3*: Showing the destruction District in Jeddah near from Wadi QAWS area [12].*

The Wadi QAWS is distinguished by having three different areas, as shown in Figure (5), which are the collection area, the

Fig. 4: The destruction that occurred as a result of the flood in private and public properties and infrastructure [12].

straits area, and destruction area. Where there are high areas that were affected by large amounts of rain, and after the collection operations, the flood was moved, creating some destruction in many regions, then the flood was passed through the straits area, where the width of the valley ranges from 100 to 150 meters. So, the narrow area of the waterway, and the curving in some areas caused an increasing in the gathering of flood. Also, it increases the speed of water due to inclination. After leaving the straits region, the amount of torrents is very huge, which resulted in massive destruction and heavy losses in the area facing the torrents, which was called the area of severe destruction and included THE QUWAIZAH district, FARAJ AL-MASAAD neighborhood, the highway, and KING ABDULAZIZ University as illustrated before in figures # and 4) [4].

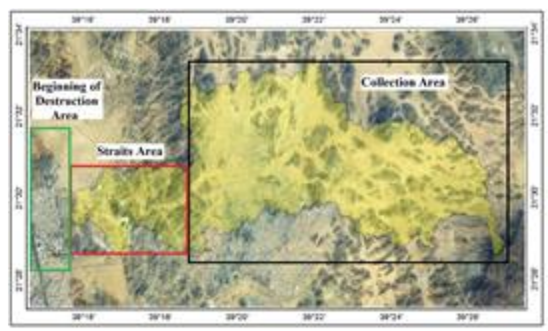

Fig. 5*: Illustrate the main three area of Wadi QAWS*

3 THE USED DATA

This research aims to find the solutions to reduce flood disasters which comes to the Wadi QAWS region by choosing the most appropriate places to construct a number of dams and drainage canals. By using the DEM from Lidar data and using the Spatial Analyst Tools in ArcGIS the producing Stream and contour lines can be drawn. Also, the longitudinal and transverse sectors were produced to determine the most suitable location for dams, as shown in figure (6 to 8).

3.1 SPATIAL ANALYST

The spatial analyst in ArcGIS has many functions can be used for 3D analysis, such as producing a contour layer and many other layers of DEM data [13].

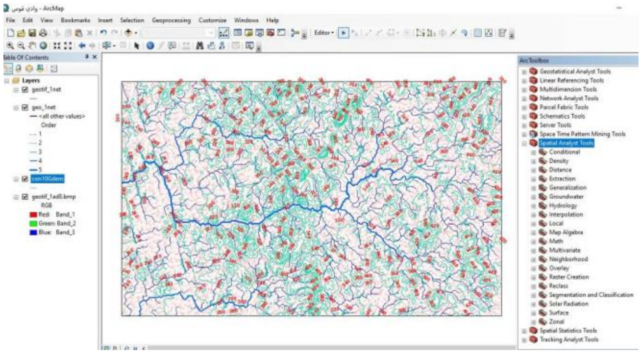

Fig. 6: *Illustrate Spatial Analyst Tools in ArcGIS and contour lines for study area*

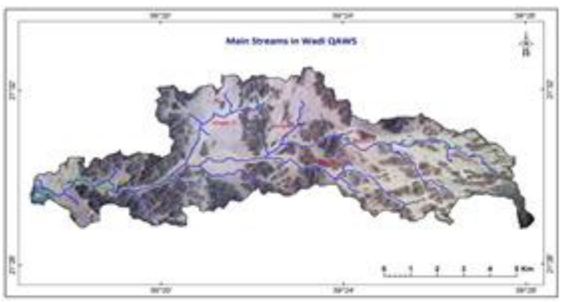

Fig. 7: *Topographic map and main Streams of Wadi QAWS*

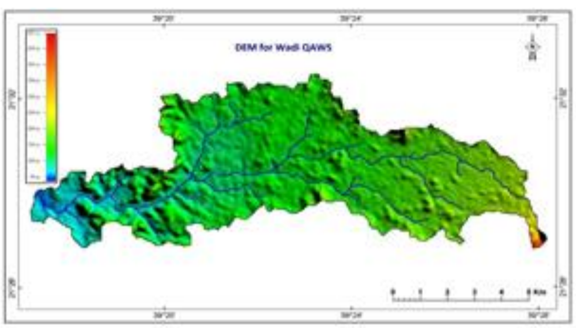

Fig. 8*: DEM and Main Streams of Wadi QAWS*

Study all the natural phenomena that affect the region, is a very important procedure beside topographic, geological and geomorphological phenomena, using the latest technologies to define the basins and surface drainage networks of the valleys [14]. Investigating using satellite imagery, DEM and topographic maps of the study area, determining the topographical characteristics of the study area (Figures 6, 7, and 8), it was clear the following: -

1. Wadi QAWS streams in the far east of a mountainous area with a height of about 440 meters from the sea level, until it reaches a level of 75 meters at lowest area.
2. The basin is characterized by an area of 63. 7 km2 and a length of 16.9 km, and its slope is about 4%, noting that the calculations are estimated for the basin until lowest area.
3. Wadi QAWS extends from east to west, and it takes a rectangular shape, with an average basin width of about 5 km.
4. The various streams are converging on the narrow region, which starts from the beginning of the Al-Harazat area from the Jeddah side, to the region of the SWAAID zone, forming a stream of one valley with an average width of 100 meters.
5. The path of the valley bends several times, between the heights that surround it from both sides of the strait.
6. As for the streams in the assembly area, they are characterized by the presence of four main streams, as in the form (7, and 8). Two from the east to the west in the eastern part of the valley, and a third stream to the north-east is added to them, before the Al-Harazat region from the east, then a fourth stream from the north to the north-east to the west of the Al-Harazat region.

3.2 Analyzing the Meteorological Data and Calculating Flood

The average rainfall in the KSA (excluding the Rub Al-Khali desert) is 110 mm / year, and the south - western region is characterized by the abundance of its rains, compared to the rest of the Kingdom, where the average rainfall is more than 400 mm / year in some locations as in the mountains FIFA near to the GEZAN region as shown in figure (9) [15].

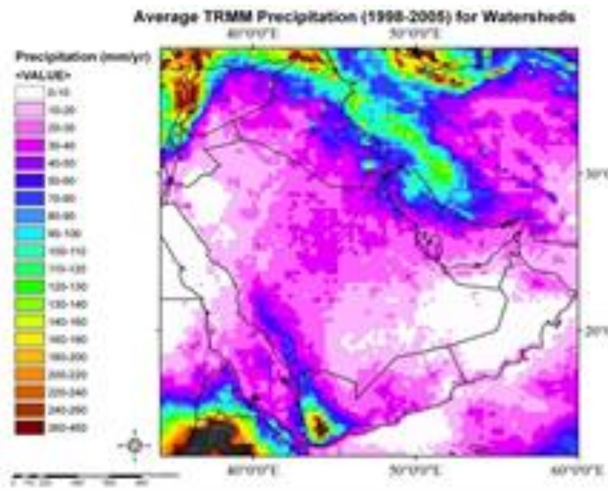

Fig. 9*: Rain rates for the KSA during the period (1998-2005) [16].*

Jeddah region is generally located within the arid climate areas, which are characterized by high temperatures in general, lack of rain, lack of vegetation, and precipitation in general during the winter. To determine the required climatic factors, a number of Hydrometric and climatic measurement stations were identified around the study area, and four stations near the study area were identified, which are stations No. J102, J134 and J221 of the Ministry of Water and Electricity, and the Jeddah 41024 climate station, affiliated to the Presidency of Meteorology and Environment as shown in Figure (10).

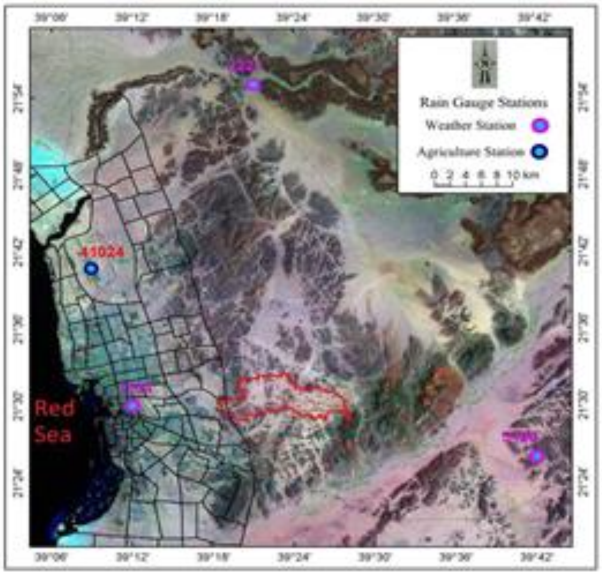

***Fig. 10**: The locations of rain gauge stations and climate factors around the city of Jeddah.*

Due to the lack of information completely and for a long time in the stations of the Ministry of Water and Electricity, in this research the information available in the station 41024 was applied, which included information covering the period from 1970 to 2009 on a daily. As is always the case in dry and have same weather, the annual rates of rain for Jeddah in the period from 1970 to 2009 recorded change and variation, where the lowest amount of rain was recorded during the year 1982 and was estimated at about 1 mm / year, while the highest amount of rain was recorded in the region during The year 1996 was estimated at 284 mm / year as shown in Figure (11) [17].

Total annual rainfall during the period from 1970 to 2009

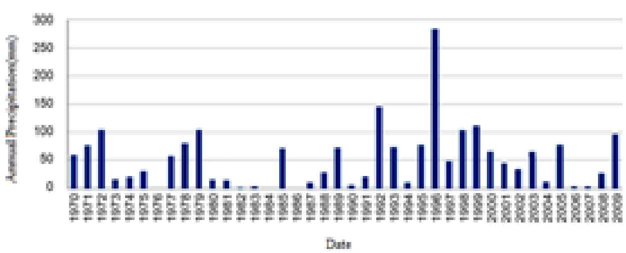

***Fig. 11:** The annual rain amounts.*

Estimate the amount of rain through the data of the Presidency of Meteorology and Environment by reviewing the historical data recorded one can find that the highest measure of the value of rain was on 11/3/1972, when it reached 83 mm, as recorded on 16/16/1979, 80 mm. While in November of 1996, the highest the amount of precipitation, which amounted to about 285 mm during 11 days, the highest value was on 11/25/1996, where the value was recorded at 55 mm, while on November 25, 2009, 70 mm. Table (1) shows the large rates For rain in the city of Jeddah [17].

TABLE 1

The maximum rainfall recorded at the station Jeddah 41024

Year	Month	Day	Rainfall (mm)
1972	11	3	83
1979	1	16	80
2009	11	25	70
1978	2	17	67
1977	12	13	56
1996	11	25	55
1992	11	2	52
1971	2	4	48
1996	11	16	46
1995	2	14	45
2003	11	10	44
1996	11	19	42
1992	1	10	40
2000	11	16	40
2005	4	28	39
1985	11	18	38
1970	1	10	36
1996	11	15	32
2005	1	22	32
1995	11	2	32
1999	1	12	28
1993	12	23	28

Rainfall intensity is considered the main factor influencing the formation of the floods and therefore must be taken into account when planning construction and development projects [18]. And it is also possible to identify rain intensities by identifying rainstorms that can be devastating, so a rain intensity curve is created (Rainfall frequency curve) for any area to avoid the large rain values that might alter these projects, which is effective on design the project elements such as channels and dams. The available rain data were analyzed by the Presidency of Meteorology and Environmental Protection, and the expected rain intensity was calculated at 10, 25, 50, 100, and 200-year frequency. Table (2) shows the results, the probability distribution of the maximum daily rain information, where the analysis showed that the maximum possible value of the intensity of rain that can occur every 5 years is 48.9 mm, while we find that the probability value of occurring every 100 years is 131.95 mm and the potential value every 200 Year is 146.68 mm.

TABLE 2

Rain intensity for different iterative times, based on the information of the General Presidency of Meteorology and Environment

Station ID		Return period (years)					
Station #	Station Name	5y	10y	25y	50y	100y	200y
41024	Jeddah	48.9	70.52	97.17	115.44	131.95	146.68

3.3 GEOLOGICAL SETTING

The geological map of the Jeddah City as shown in Figure 12, demonstrates that Wadi QAWS cut through different rock types mainly igneous rocks, including basaltic to andesitic lavas, hornblende tonalite, massive hornblende granite, quartz diorite, quartz monzonite, and trondhjemite. In addition, some structural features are also presented such as dykes and faults. The general trends of the structural faults are north – south (N-S) and northeast – southwest (NE-SW) direction. Regarding the dykes, two main types are represented which are felsic and mafic dykes. The NE-SW direction is the major trend of the two types of dykes.

3.4 Geological Data

After carrying out geological data can be used to establish a geographical database of this data to produce a geological map of the study area as shown in figure (12) for East of Jeddah.

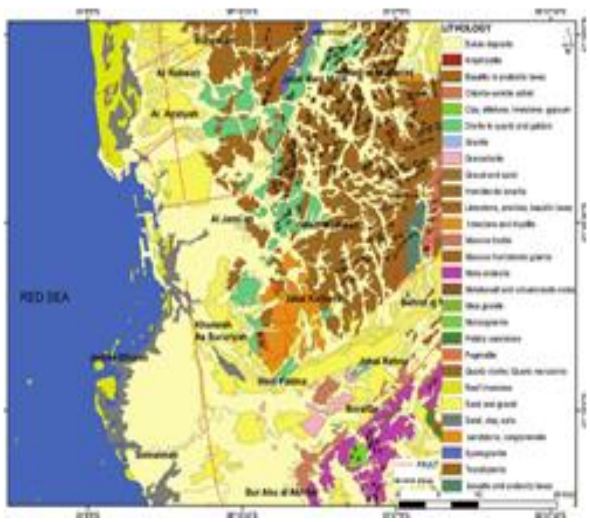

Fig. 12: Geological map of Jeddah City [8].

4 DAM SELECTION CRITERIA

There are many factors were considered when choosing dam locations such as [19],[20]:

I. The location should be characterized by a smallest of width.
II. The valley must be distinguished by the presence of high sloping sides.
III. The sides of the valley must be characterized by high elevations in order to be sufficient to accommodate the height of the dam.
IV. The lake area behind the proposed dams must have a high capacity to accommodate the amount of water collected.
V. The choice of the spillway must be in a suitable topographic area.

Beside the previous topographic factors, the geological and Geotechnical factors should be achieved too, as the following: -

VI. The soil should be strong or the subsurface rocks have to close.
VII. The rocks forming the shoulders must be strong.
VIII. The site should be about major structures far from the faults and shear bands.

5 Methodology of Spatial Analyst by using ArcGIS

The ArcGIS has the spatial analyst tools are used for modeling the vector and raster data [21]. The spatial analyst has many sub-tools according to its functionality. The hydrology spatial analyst tools are concerned to model the water flow passing through the area. Also, a hydrology tool can be applied either individually or sequentially to create a network of different streams in different order or define watersheds [22]. The DEM represents the surface height of the study area in a grid image. Hence, the analysis of these data is used for many engineering applications such as hydrology, environmental, and geographical engineering.... etc. Also, the DEM data for hydrological characteristics of the study area are used to determine its main and sub basins, and knowledge of its direction Water flow and accumulation of water surface following the rain and watershed by the analysis Hydrology by using the GIS [23].The figure (13) illustrates the methodology which was followed to use the ArcGIS spatial analyst to produce the water basin for the study area. Also, figure (14) will be shown the water basin of Wadi QAWS.

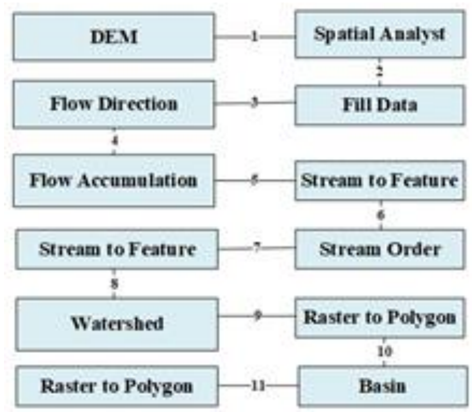

Fig. 13: Methodology of Spatial Analyst by using ArcGIS

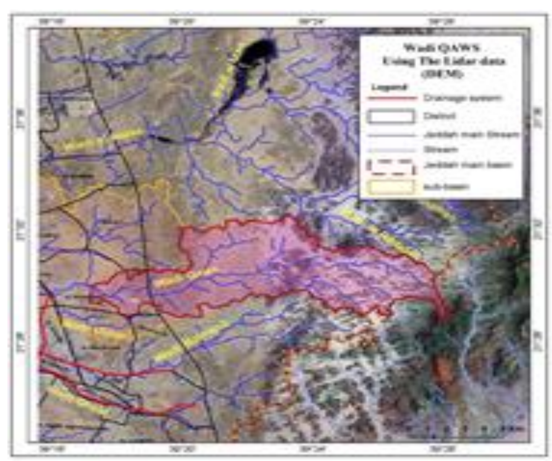

Fig. 14: The water Basin of Wadi QAWS

Finally, When the criteria which mentioned before in section 4 is applied synchronously with the available spatial database. The spatial database which contains all pervious data discussed above, such as: accurate DEM (from ground surveying or any suitable source), geological, geophysical and Geotechnical data then the best location of the dam will be achieved. In this context, the accurate chose of the dams will save the time and cost for the data collection and design of the dams [24].

6 DATA PROCESSING, RESULTS, AND ANALYSIS OF OBTAINED RESULTS

According to the previous analysis and data based on field and information analysis, urgent solutions were identified to ward off the risk of flooding in the Wadi QAWS region which included the following:

1. Construction of several dams in different locations to protect the city from potential dangers (Figure 15).
2. Connecting these dams to drainage channels that are suitable for the size and capacity of the current flood drainage channels.

After determining the locations of the dams, several tests which have been carried out regarding the location of the dams as check and making sure stability, of this an actual selected location, as the following:

- Final Geophysical studies.
- Geotechnical studies of rocks and soil.

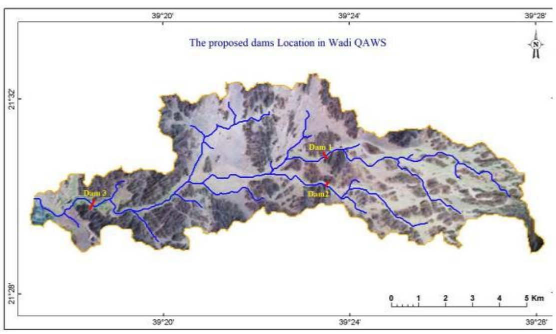

***Fig. 15:** The proposed dams Location in Wadi QAWS.*

6.1 SELECTED DAMS LOCATION

According to the factors which were effective for choosing dams locations the results of applied these factors will be shown in the figure (16).

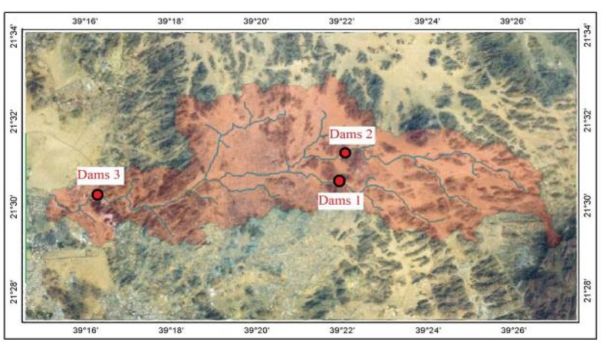

***Fig. 16:** Selected Location of Dam 1, Dam 2 and Dam 3*

7 RECOMMENDATION AND CONCLUSIONS

a) There are recommendations for a necessity of supporting the selected locations with other required studies, such as collecting geological, geotechnical, and geophysical data to complete this work.
b) The remote sensing satellite images and Geographic information system (GIS) ArcGIS, using spatial analysis is carried out to identify the best dam location and it is an effective tool for flood studies.
c) The results are depending on the accuracy of DEM study area.
d) The accuracy of the meteorological data with their period is very important to calculate the volume of storage lake of the dam synchronous with its height.
e) The results of geological, Geotechnical and Geophysical must be done for the proposed location of the dams and it is enough in selected locations only.
f) Finally, the results obtained indicate that careful selection of the dam's location based on the accuracy of the DEM with spatial analysis of GIS saves time and cost for all other studies such as geological, Geotechnical, geophysical, and field surveys, focusing on specific areas and not spending effort and time in useless locations.

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