FLOOD PLAIN MITIGATION IN ARID REGIONS CASE STUDY: SOUTH OF AL-KHARJ CITY, SAUDI ARABIA

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ABSTRACT

Most of Saudi Arabia can be considered a typically arid region where the annual average amount of rainfall varies between 50 and 100 mm. Higher amounts of rainfall are restricted to the Red Sea escarpment and to the north of Riyadh where annual average values reach 600 mm and 200 mm respectively.

The current study aims at presenting the characteristics of the watersheds affecting the southern urban area of Al-Kharj, south of Riyadh, almost completely located inside the flood plain of wadiAlkharj and evaluating the flood hazards associated with higher rainfall events. Detailed field studies were conducted for the study area to inspect the existing drainage works, the conditions of neighboring areas, and the characteristics of the effective wadis. The hydrological study has been carried out utilizing the available data and the flow from wadis affecting the study area were routed through the main paths using the Muskingum approach to evaluate the hydrograph flowing through of study area and the effect of existing dams were also investigated to test their effect on the flood flow hydrograph. In this work, the flood risks were studied and the results are considered the baseline data required to designate the required protection system against these risks.

Key words: *Southern Riyadh; Alkharj ; Hydrological studies; Flood plain mitigation.*

1. INTRODUCTION

Although evidence for Quaternary environmental changes in the Arabian Peninsula is now growing, research has mostly been conducted in the United Arab Emirates (UAE) and in the Sultanate of Oman. There have been virtually no recent studies in Saudi Arabia, especially in the central region such as around Al-Quwaiayh Sue, J. et al., 2008 [7].In some places in arid and semi-arid regions settlements take place very close to the wadis flood plains and in some cases are totally inside it. The south urban area of Al-Kharj city is one of those cases that needed to be studied for problem assessment and a preliminary solution to be suggested.

For that purpose site visits were conducted for the area of study to assess and study the flood path and to investigate the effects of the flood on the existing drainage structures and results have been considered during the work.

Then full hydrological studies were conducted through the hydrometeorology, hydro morphology, and hydrological analysis of the wadis striking the study area using collected data which include: meteorological data, topographic maps, satellite images, geological maps and data of land use and surface cover.

2. STUDIED AREA AND LOCATION

The studied area is located in the South-East of Riyadh province, Figure (1), between latitudes 24.00^o and 24.20^o North and longitudes 47.15^o and 47.25^o East and. It is located above the sea level 1360 m and its area is about 20.000 km ^{2} and has a population of more than 600,000 people.

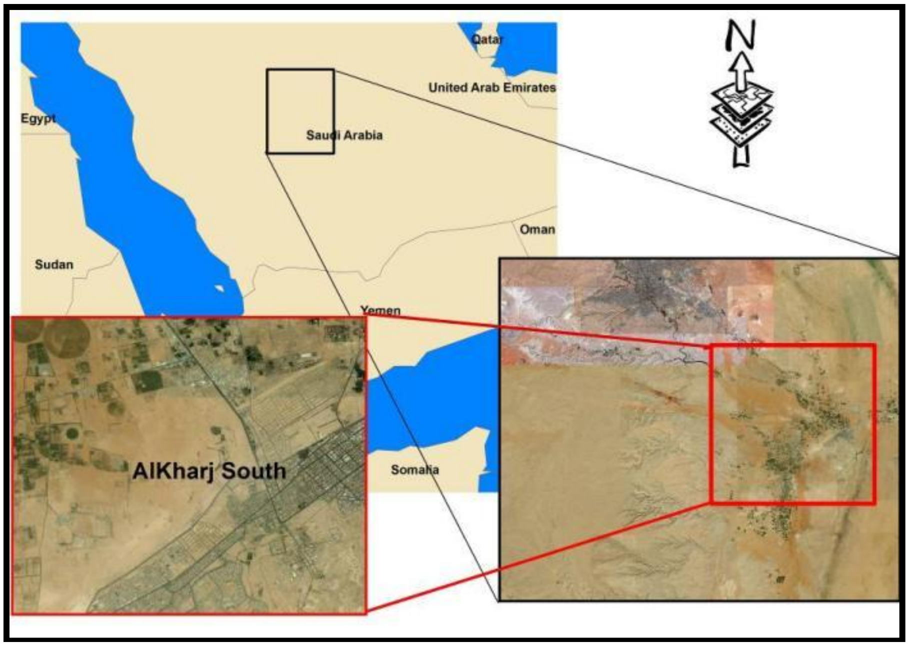


Figure (1):General Location for Alkharj South

3. GEOLOGICAL SETTING

Many geological studies had been done by many authors among them Bramkamp and Ramirez 1958[1], Power and others 1966[2] , power 1968[3], Al khatieb 1981[4], Enay et al and others 1986[5], Vaslet, D. et al 1985[6].Geological studies aimed to explainthe effect of geological and structural events on the topographical and geo-morphological feature. Geologically, the studied area is located in Arabian Shelf rocks; Figure (2).The Shelf is mainly formed of a sedimentary sequence lying uncomfortably on the shield rocks and dipping away towards the Arabian Gulf. The sedimentary sequence starts with detrital deposits of the Cambro-Ordovician Saq Formation, and ends with the Quaternary-Recent deposits.

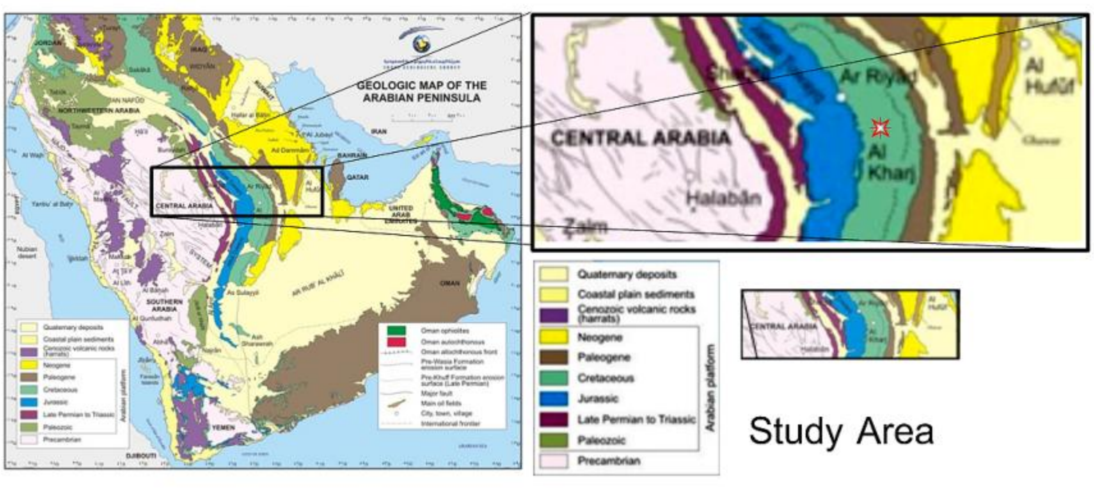


Figure (2): Geological Map of the Arabian Peninsula
http://www.sgs.org.sa/english/geology/phanerozoic/pages/default.aspx .Febraury 2012

Figure (3) the geologic map of the studied area in 3 Dimensional view shows the presence of sedimentary sequence related to Mesozoic Era (Jurassic and Cretaceous ages).Cenozoic Erais presented by Tertiary and Quaternary periods.

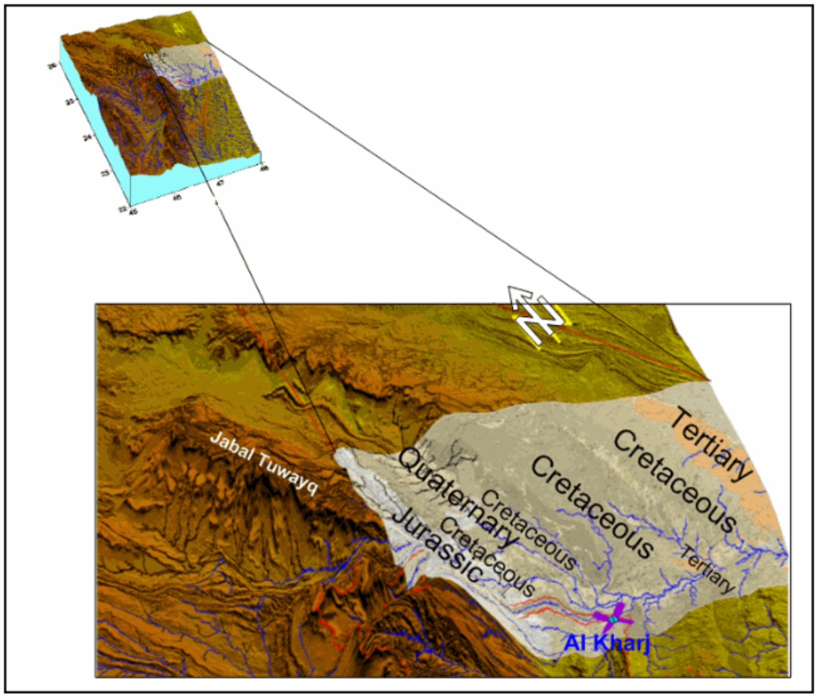


Figure (3): 3-D Geologic map of the Study Area
Geologic map of Al Riyadh Quadrangle, Sheet 24I, Kingdom of Saudi Arabia, Ministry of Petroleum and Mineral Resources, Directorate General for Mineral Resources, A.H.1412, A.D.1991.

Figure (4) shows the subsurface geologic cross section of sequence of layers follow up layers starts from the Arabian Shield rocks in the west to the Arabian Gulf to the east passing the Arabian shelf rocks.

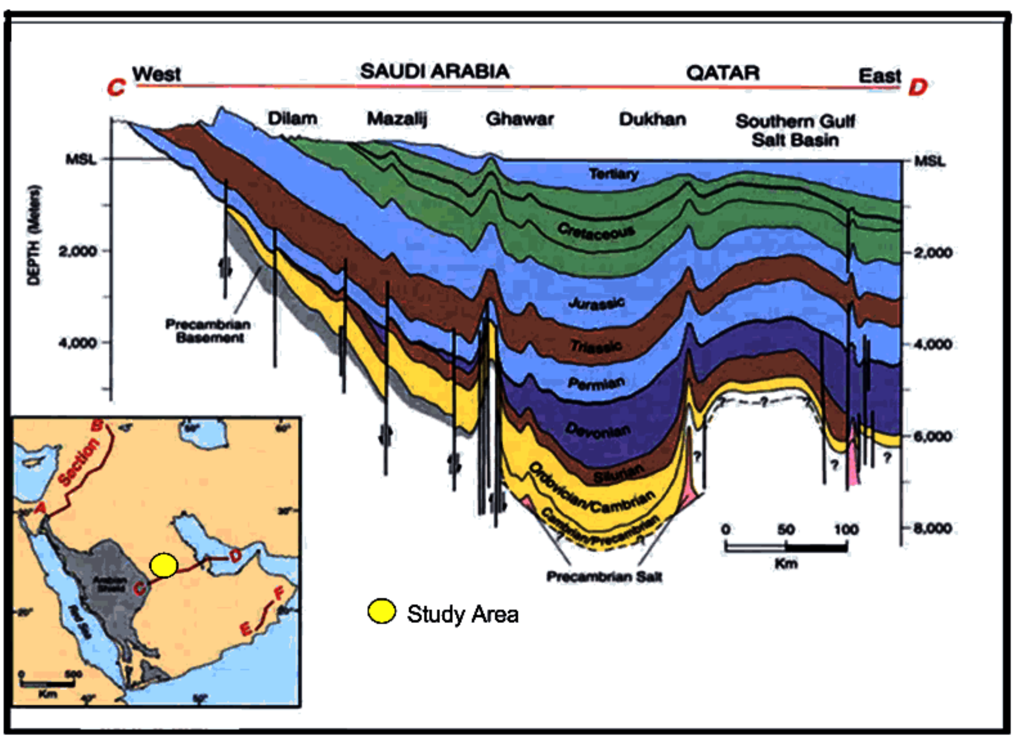


Figure (4): Geological Cross Section of the Study Area
http://faculty.kfupm.edu.sa/ES/mmhariri/Material/REGIONAL%20GEOLOGY1.ppt(Vaslet, D, et al 1991)

The most important faults affecting the study area can be shown in Figure (5).

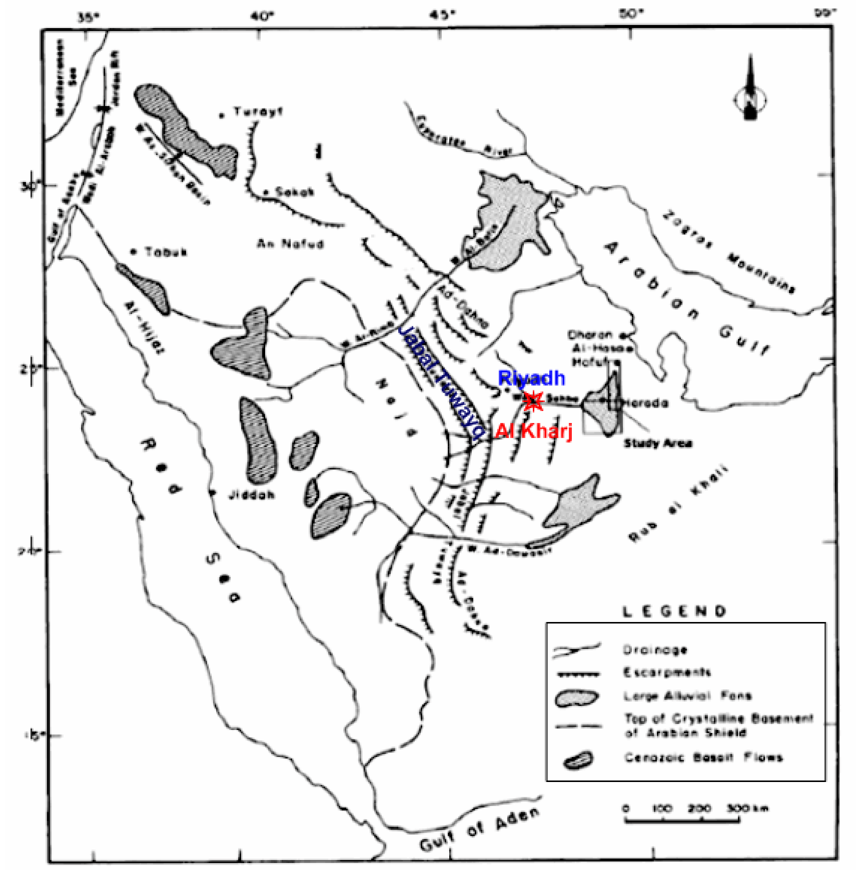


Figure (5): Main Structures in the Study Area

Study area is affected by tectonic event; this event was responsible for formation of canyons as well as mountains. The Topographic maps of the studied area show elevation variation from 312 m to 1360m. Figure (6) shows an example for this variation.

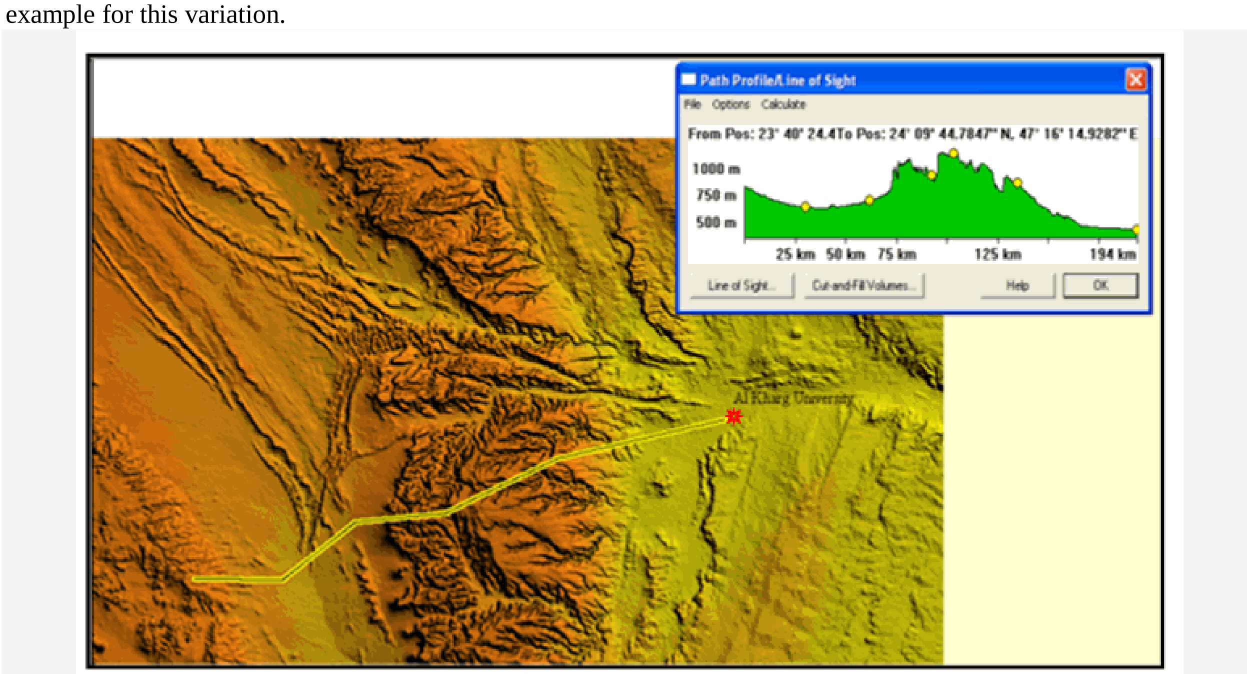


Figure (6): Topographic Profile from South- West Study Area to Al-Kharj Universty. SRTM:http://srtm.csi.cgiar.org.March2012

In general, Al-kharj plain divided into two parts first northern section which receives waters from the valleys of the Hanifah, Sulaiy and Hannia second southern section which receives waters from the valleys Nisah, in Belgan, Al Ain and Raghib, which represents all of the valleys and Mawan Oethelan and whip. Figure (7) and (8).

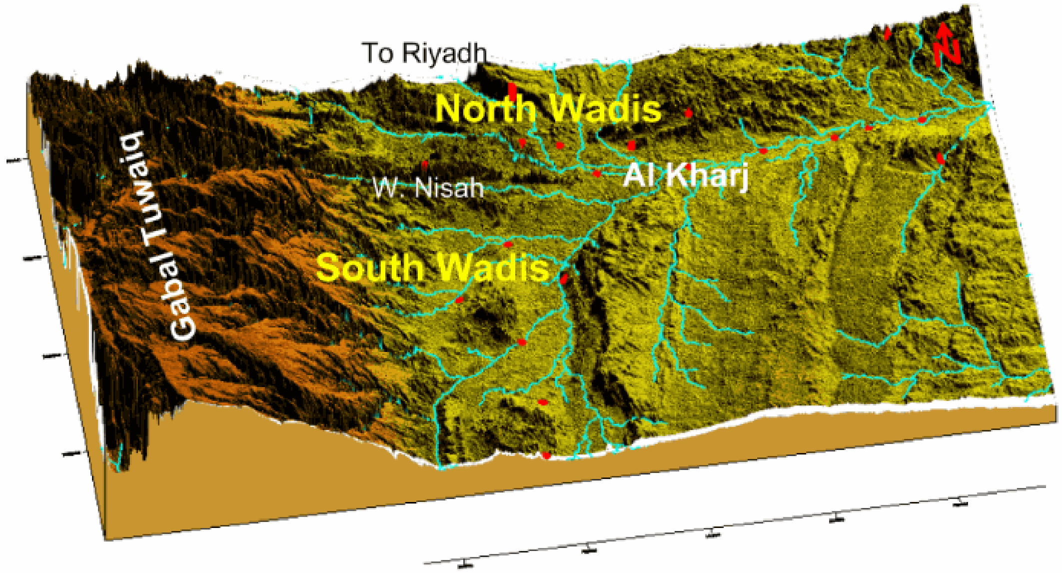


Figure (7): 3-D of the South and North Wadis in the Study Area
http://srtm.csi.cgiar.org/ .March 2012

Figure (8): Main Wadis in the Study Area
SRTM: http://srtm.csi.cgiar.org/ March 2012

4. METEOROLOGICAL ANALYSIS

The average annual rainfall depth on Saudi Arabia is shown in Figure (9). It is clear that averages ranging between 0 and 100 mm on the various parts and reach over 200 mm on the West coast of the Red Sea Hills West while not exceeding 160mm on the study area.

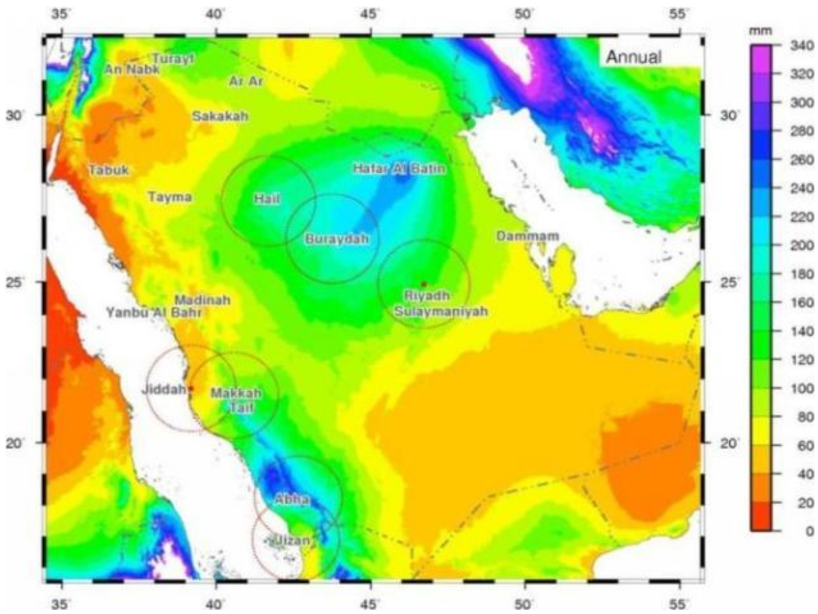
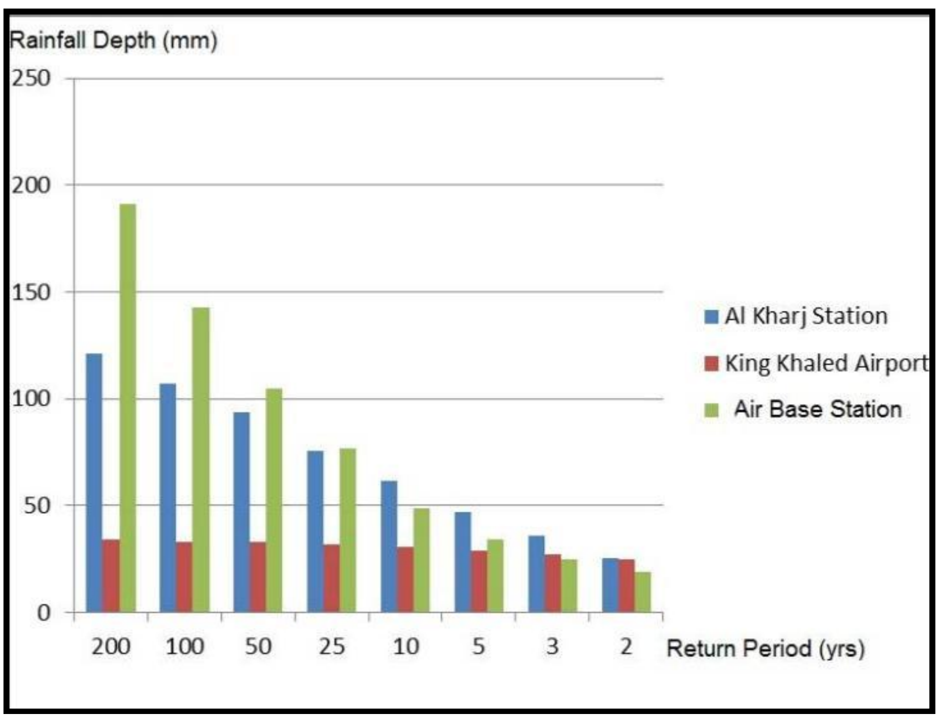


Figure (9): Average annual rainfall depth 1998-2008

HyFrAn (Hydrological Frequency Analysis) program had been used for the available rainfall data to obtain the corresponding rainfall depth values of the probabilities for different frequency.
As shown in Figure (10) Al kharj station which is located in the domain of the catchment that affect the studied area, has the second highest reading comparing to the other stations for the higher return periods and the highest rainfall depths for the lower return periods. This is why its data was used in the further analysis work.



Figure(10): Rainfall Analysis Results

5. MORPHOLOGICAL ANALYSIS

For each basin, the topographic maps scale 1: 50,000, satellite images and digital maps were used to delineate the different basins and to determine the morphological parameters for each basin.

Figure(11)shows the surface elevations of the region under consideration and the surrounding area, which is inferred from satellite digital images (Digital Elevation Model-DEM) which can be obtained through satellite imaging results, Aster imaging satellites and Earth observation was used in this study.

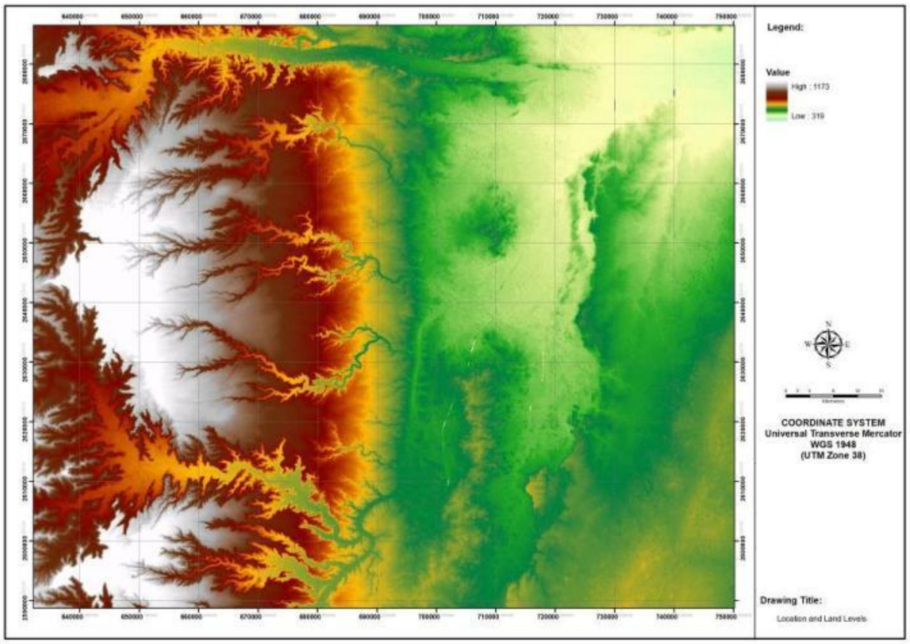


Figure (11): Digital Elevation Model of the study area, Source ASTER Satellite.

The study area is the crossroads of several valleys ranging from small to medium for the namespaces collection basins. It is found that major watershed basins affect the studied area are more than ten basins and congregate in two main wadies; wadi Nisah which attacks site from the West and the other is Wadi Al-kharj which attacks the site from the South. Figure (12) shows these basins, their effective area and the main flow paths.

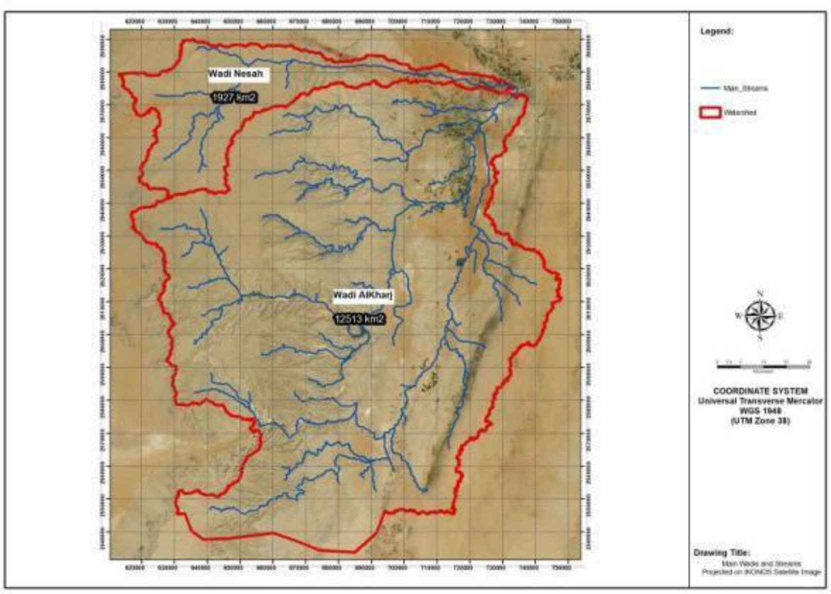


Figure (12): Nesah and AlKharj wadis boundaries on IKONOS satellite image

As shown the figure of Wadi Nsah is approximately 1930 square kilometers while the area of Wadi Al-kharj is approximately six times larger and is about 12,500 square kilometers.

The morphological parameters were computed numerically using Geographic Information Systems (GIS) to be used in calculation of the flood discharge values and hydrographs affecting the studied area. The morphological parameters, table 1, include the following:

(i) Basin boundary
(ii) Basin length along its main course
(iii) Basin area
(iv) Basin slope
(v) Basin shape
(vi) Time of concentration

Table 1:Main watersheds morphological parameters.

Basin	**Watershed Name**	**Perimeter (m)**	**Watershed Area (km^2)**
Nesah	Nesah	500,083	1,927
AlKharj	Biljin	142,336	441
	Al Ain	262,887	988
	Al Ragheb	225,396	400
	AlEkaimee	194,494	627
	AlKhariza	158,395	489
	Moan	175,951	863
	AlHariq	269,565	1,757
	AlSout	236,439	889
	Thilan	150,933	632
	Bajid	257,691	1,977
	Birk	177,463	930

6. COMPUTATION OF PEAK RUNOFF FLOW:

There are several methods of determining the rate of runoff. The choice between these is based on the availability and type of rainfall data and the size of catchments being considered.

The (Soil Conservation Services (SCS),1940)SCS method[9] universally acknowledged in hydrological practices permits to obtain the peak discharge as well as the complete flood hydrograph based on a number of variables and parameters. The Soil Conservative Service (SCS) method is seldom utilized, particularly in few academic studies in KSA H. Al-Nofai 2010[10].

The variables used as inputs to the SCS model are the cumulative rainwater depth, the catchment area and the time of concentration Tc based on the Kirpich formula, and the runoff coefficient (CN), that determines the relationship between excess precipitation transformed into runoff and the precipitation applied to the catchment area which is a function of soil characteristics, of the land use and the antecedent soil moisture content.

7. HYDROLOGICAL MODELING OF MAIN WADIS (NISAH AND ALKHARJ)

Flood modeling usually involves approximate descriptions of the rainfall-runoff transformation processes, based on empirical, or physically-based, or combined descriptions of the physical processes involved. The resulting models are quite useful in practice since they are simple and provide adequate estimates of flood hydrographs L. Sherman 1932[8].A hydrological model, Figure (13), was built for rainfall-runoff transformation of the flood flow and water transfer through main wadis and water courses that resulted from the morphological analysis. Through the model generation, Muskingum method was used for flood hydrograph routing through main water courses. This method needs two main parameters to be used during the analysis, the lag time and the storage coefficient. The lag time was calculated from the routing lags through the water courses and using Kirpich formula while the storage coefficient was represented using the soil curve number (CN).

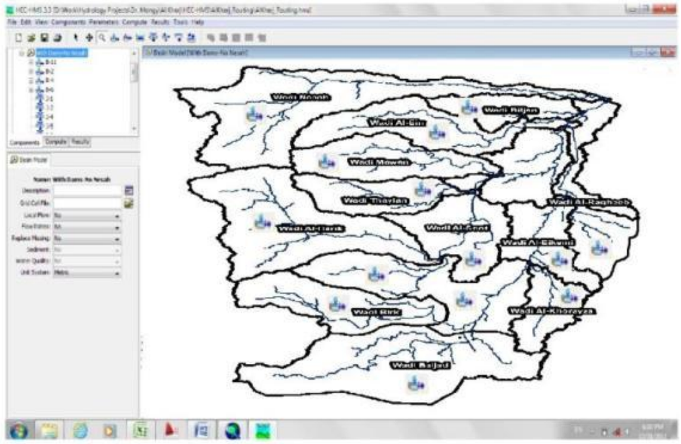


Figure (13): The Model interface for wadi Alkharj

The next Figure (14) shows the resulted routed hydrograph of wadi Al kharj (and the hydrographs resulted from each sub watershed in dashed lines). The figure shows a reduction of about 25% of the peak flow than that of the total water if treated as one unit without the study of routing effect.

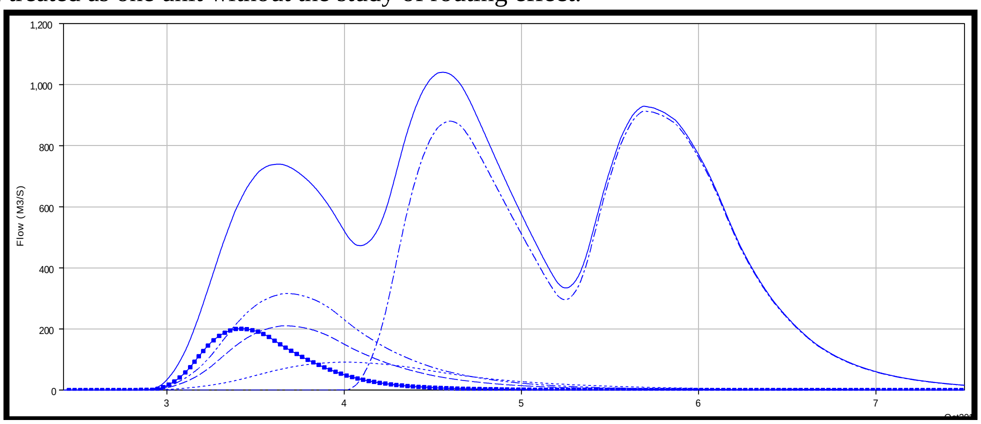
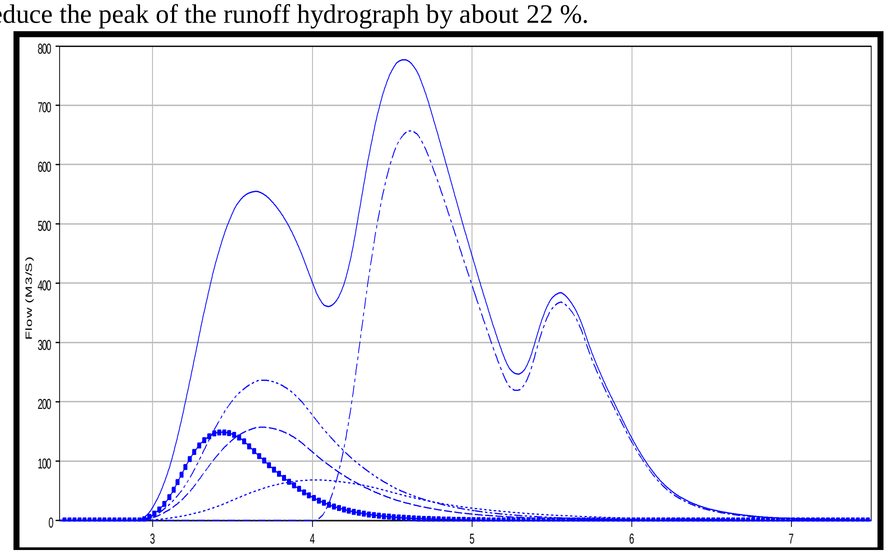


Figure (14): The 100 year routed hydrograph of wadi Alkharj

The effect of the presence of Al Dolam dam on Wadi Al Harik was tested to see the effect of such structure on the hydrograph shape, mainly peak and duration. The results, Figure (15), showed that the existence of the dam affect the hydrograph later peak significantly as it is located very close to the downstream of the main catchment however it is still could reduce the peak of the runoff hydrograph by about 22 %.



Figure(15):Aldolam Dam's effect on the runoff hydrograph

8. CONCLUSION

- The city of Alkarj is located almost in the midpoint of major wadis intersections (i.e. wadi Al kharj, WadiNesah, WadiHanifah, and Wadi Al Sulaiy)
- The southern valleys (represented in Al Kharj Valley) are the valleys of the most influential on the studied area followed by Nisah Valley from the west.
- Northern valleys (Hanifah and Sulaiy) significantly affect the city center from north, but do not reach the impact site to the south of the city.
- Floods attacking the city from the south have a specific path while Nisah valley has no clear path which makes it difficult to determine the wadi main flow direction.
- The existence channel cannot accommodate a flood flow resulting from a storm similar to or greater than the 50 year event
- Al-Dolam dam was tested through the hydrological model and it was found that it has minor effect on the peak flow coming to the south part of the city.

9. RECOMMENDATION

- Barriers on both sides of the existing main flood channel should be constructed in south west of the city extends from south to north in order to accommodate floods with higher return period that is of high risk on the south part of the city.
- WaterfromNisah valley could be conveyed to the original stream at the north east of the city through interceptor channel to the west that can convey the flood flow through main carriers that could be covered in some parts if needed.
- The capacity of the existing main flood channel of Wadi Al Kharj should be increased by one or all of the followings; reshape the main course for more smooth alignment, any obstructions inside it should be removed, bed should be compacted to reduce the roughness coefficient, and all side slopes to be lined.
- Implementation of south dams on the tributaries of AlKhja Valley (the eye,Thilan, and Moines) was tested in the hydrological model and it was found that this will improve the state of flow during the flood channel south-east the city.

10. REFERENCES

[1]. Bramkamp, R.A., and Ramirez, L.F., 1958, Geologic map of the Northern Tuwayq quadrangle, Kingdom of Saudi Arabia: U.S. Geological Survey, Miscellaneous Investigations Map I-207A (scale 1:500,000).

[2]. Powers, R.W., Ramirez, L.F., Redmond, C.D., and Elberg, E.L., Jr., 1966, Geology of the Arabian peninsula: Sedimentary geology of Saudi Arabia: U.S. Geological Survey Professional Paper, 560-D, 147 p.

[3]. Powers, R.W., 1968, Lexique stratigraphique international: Saudi Arabia: vol. III, Asie, fasc. 10 b 1: Centre National de la Recherche Scientifique, Paris, 177 p.

[4]. Al-Khatieb,S.O., 1981, Detection of surface evidence of subsurface structures by interpretation methods of Iandsat imagery in the sedimentary rocks of Central Saudi Arabia: Ph.D. Thesis, University of London, Department of Geology, Royal School of Mines, London, 317 p.

[5]. Enay, R., Le Nntdre. Y.M. Mangold. C..Manivit, J., and Veslet, D. 1986. The Jurassic of Central Saudi Arabia: new data on lithostratigraphic units, paleoenvironments, ammonite fauna. ages and correlations: Saudi Arabian Deputy Ministry for Mineral Resources. Jeddah. Technical Record BRGM-TR- 8.06-3, 65 p.

[6]. Vaslet, D., Pellaton, C., Manivit, J., Le Nindre, Y.M., Brosse, J.M., and Fourniguet, J., 1985, Geologic map of the Sulayyimah quadrangle, sheet 21 H, Kingdom of Saudi Arabia (with text): Saudi Arabian Deputy Ministry for Mineral Resources, Jeddah, Geoscience Map GM-100A

[7]. Sue J. McLaren1, Farhan Al-Juaidi, Mark D. Bateman, Andrew C. Millington, 2008, “First evidence for episodic flooding events in the arid interior of central Saudi Arabia over the last 60 ka”, J. Quaternary Sci., Vol. 24 pp. 198–207. ISSN 0267-8179.

[8]. L. Sherman, “Stream Flow from Rainfall by the Unit Graph Method,” *Engineering News Record*, No. 108, 1932, pp. 501-505.

[9]. SCS (US Soil Conservation Service), “Sec. 4 of National Engineering Handbook,” Soil Conservation Service, U.S. Department of Agriculture, Washington, D.C., 1972.

[10]. H. Al-Nofai, “Estimating Runoff and Flood Hazards in the Upper Basin of Oranah Valley, East Makkah, through Remote Sensing and Geographic Information Systems (In Arabic),” MSC Thesis, Umm Al-Qura University, Makkah, 2010.