Assessment of Zonation of Watersheds Based on Flooding Risks Using GIS (A case study of Varband River Basin in Larestan, Fars, Iran)

Marzieh Mogholi

***Abstract*—**Uncontrolled development of urban establishments and settlements due to population growth and land use changes without a proper management in the past and present years has led to a hydrologic imbalance and flooding intensity in watersheds. The current research aims at flood zonation by SCS method, remote sensing techniques, and Geographic Information System (GIS) applying Erdas8.7 and ArcGis9.2 in Varband watershed of Lar city. The main purpose of this research is to develop and change Land use, determine the watershed morphometry and efficient geomorphologic conditions for flooding, and identify flood zones in an area of 925.50 km^2.

In order to analyze morphometric features and effective geomorphologic conditions for the watershed flooding condition, we used Digitize data of 1.25000 obtained from Iranian Survey Organization with DEM by Tpss method with an accuracy of 5 m and prepared maps of slope, hypsometry, time of concentration, Isohyet, hydrologic and geomorphologic units, borders of various morphometric and geomorphologic units with precise ground control and land use using IRS P6 satellite pictures of 2006. For the assessment of curve number map, we used maps of Land use and hydrologic groups, prepared map [1]
of soil Retention indices and map of runoff depth using SCS method, and finally performed zonation of lands with flooding conditions through modeling in GIS environment. High gradient of the watershed, improperness of constructional formations, high degree of evaporation and transpiration, soil tiny-graind texture, high intensity of thundershowers, land use changes, low-dense vegetation, and poorness of pasturelands are of the efficient factors in the watershed flooding condition.

Evaluation of each morphometric parameters of the basin indicates that gradient ,erea,shape of basin ,time of concentration of percentage of waterway compression are of the major effective factors in the flooding of the basin . The presence of precipitations with a duration of 15 minutes for 6-hour showers is the main factor in the destruction of soil structure and acceleration of surface accumulative water flow in varband water basin.The basin flooding potential slood prone areas map has been offered in4 classes of very small average and large.The results of this research showed that the total water flow in this basin is 42283 796.6 m3 from wich N,K and a sub-basins with 11,7,113 and 10,01 precent recpectively include a high flooding while m subbasin with 4/3 percent has the least a mount of flooding.

Marzieh Mogholi , Assistant professor, Islamic Azad University, Larestan branch, Iran. Email:mmoghali@yahoo.com Tel:+98-781-2249840,Fax:+98-781-2249845.

***Keywords*—**SCS,RS GIS models.curve number,surface water flow,Flooding slood prone areas,morphometry,Lar Varband catchment.s.

I. Preface

GLOBAL studies show that the rates of flood events and losses due to them are constantly increasing. UN SCAP U84 has reported in industrial and developed as well as developing countries, there is an annual rising trend of such losses. World, Water, and Environmental Engineering journals (1984) published in London have proclaimed that water is the origin of more than half of natural disasters and most of floods account for disasters with a natural origin.

Although natural floods usually occur in humid climates, dangerous floods can also happen in dry conditions. Whereas total annual rainfall in such areas may be low, its intensity during short periods can produce runoffs and eventual floods. In recent years, population growth in cities adjacent to flood planes especially on riverbanks has endangered inhabitants and utilities in those regions. In other words, urban developments and similar activities in river margins have mostly led to a reduction of waterway capacities. On the other hand, development of urban areas has caused increment of surface runoffs leading to an increase in their input volumes and peak flow and this in turn has produced floods and intensified losses due to them.

Assessment of environmental factors causing such events indicate that human interference with the natural water cycle through removing vegetations in watershed fields, irregular land use, development of impenetrable surfaces, etc has increased the possibility of flood events in different regions. Consequently, more lands are influenced at the time of overflow, even those places occupied in the past. River surroundings have nowadays been threatened by floods. Flood events have caused several problems for different parts of the society while urban areas face direct and indirect losses. Furthermore, they impose great expenses on national profits, which we can point out costs of relief, reconstructions, and compensations for losses.

In such conditions, it is necessary to formulate rules and regulations in order to identify lands that may be exposed to the risk of flooding and designate their use accordingly.

Undoubtedly, suggestions and guidelines in this research can play a practical role for civil, provincial, and country's managers and planners particularly through GIS for the assessment of morphometric, geo-hydrologic, and vegetative changes, evaluation of the amount of wastewater produced in the mentioned basin, and creation of a Data Base Management System (DBMS) from satellite pictures of the study region.

Geographical location

Features of the study region

Lar city as the study region is located at 27° 41′ N latitude and 54° 20′ E longitude with the average height of 900 m above sea level to the south of Fars Province. Based on the study carried out in Larestan International Airport Synoptic Station in a statistical period of 50 years (1957-2006), average rainfall in

this city has been 200 ml more than 70% of which relates to a cold annual period of Western and Mediterranean currents and 18% of which is due to southeastern monsoon winds. Rainfalls due to the latter are usually associated with thunderstorms resulting in severe floods and overflow of regional rivers. Subsequent to each shower, great losses are resulted.

Larestan Township is a passage for huge and important floods imposing great losses on agricultural lands and residential areas. Furthermore, because of poor vegetation and hot deserts in the region, it is threatened by risk of flooding with the beginning of seasonal rainfalls. With regard to the fact that Lar city is constituted of two parts called Shahr-e-ghadim (the old section) and Shahr-e-jadid (the new section), both districts are equally threatened by floods during heavy rainfalls.

The threatening factor in the old section relates a seasonal river called Varband originating from northern and northwestern highlands while residential and agricultural areas in the new section can be exposed to risk by Khur and Tang-e-asad floodways.

II. Features of Varband River Basin

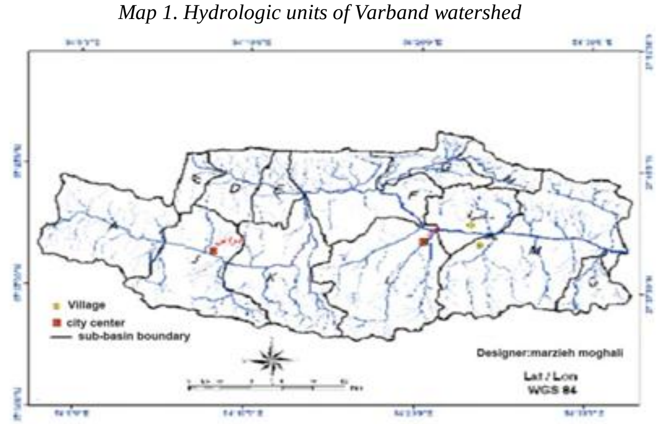
Varband river on the sides of which the primary map of Lar city has probably been designed has played an important role in the existence of ancient Lar. The study region consists of Lar field watershed located at the southeastern part of Fars Province and central part of Larestan. It is known to be a sub-basin of Kal Shur river and thus Varband River is considered as one of its most important head-branches. The watershed itself is divided into several sub-basins illustrated in the following table.

Table I

Elementary features of work units in Varband watershed, Lar

Name of unit (parcel)	Type of unit	Area (square kilometer)	Circumference
Western Gerash sub-basin (A)	hydrologic	98.83	46.4
Western Anagh field sub-basin (B)	hydrologic	17.61	20.43
Tang-e-gani sub-basin (C)	hydrologic	25.82	27.38
Central Anagh field sub-basin (D)	hydrologic	39.74	32.79
Eastern Anagh field sub-basin (E)	hydrologic	26.42	25.92
Gachestan sub-basin (F)	hydrologic	96.15	53.99
Posht-e-sangar sub-basin (G)	hydrologic	36.94	41.93
Bigh-e-shalu sub-basin (H)	hydrologic	22.38	25.91
Latifi sub-basin (I)	hydrologic	48.65	32.23
Central Gerash sub-basin (J)	hydrologic	95.07	52.80
Eastern Gerash sub-basin (Tang-e-laghar, Lar dam) (K)	hydrologic	106.78	58.34
Western Lar field sub-basin (L)	hydrologic	128.26	54.99
Eastern Lar field sub-basin (M)	hydrologic	181.80	77.11
Total watershed	hydrologic	925.50	171.5

Map 1. Hydrologic units of Varband watershed



Source: Digitize map of 25000, Iranian Survey Organization

III. Research Data and Methods

Morphometric study of Varband watershed is aimed at the identification of natural conditions of the watershed level and all the effective parameters in the production of runoffs in areas with flooding conditions such as area and circumference of the watershed, its shape index, ratio of surface distribution to height, its gradient, and concentration of waterway networks.

Thus, regarding the above-mentioned goals and using remote-sensing (RS) techniques, Geographical Information System (GIS), ILWIS, and Autocad and ArcGis software, we offered data resulted from physiographic studies, which provide a deeper understanding of Varband watershed.

Moreover, the base map used in this research includes topographic maps of 1/25000 (2D12 3d) inserted into GIS after edition. In order to divide the watershed into hydrologic and non-hydrologic units, we used maps of 1/25000 and a Height Digitize Model as well as satellite pictures. We also divided the ground into more detailed work units based on a 3d model in order to facilitate the study of Varband watershed. Accordingly, we parceled and divided it into 13 work units. Naming of units is based on a clockwise direction and their order of location in proximity to other units. Name, area, and circumference of each work unit and dispersion map of parcels are offered in table 1 and map 1, respectively.

Generally, research method of this article is based on an analytical method where environmental data and effective geomorphologic-hydrologic variables in flooding behavior were analyzed through a scientific classification using a theoretical adjustment and analogical method.

We evaluated and concluded the differences of the function of each variable as Dependency and Independency variables. Thus, all the results were prepared by Digitize maps with GIS and RS software.

Since there was no hydrometric station in the watershed of interest, we used an SCS method for the assessment of flooding in the watershed expanse. We prepared position map of meteorological stations to gain rainfall information from Meteorological Stations of Power Ministry and Meteorological Organization and evaluated data accuracy. Then, we made a statistical analysis through statistical prolongation, estimated the above equation by the use of height-rainfall gradient, and evaluated map of rainfall changes by land height DEM (Digitize Model).

To provide land height DEM, we used TPSs (Tein Plate Smoothing Splin) methods through the interpolation of data layers of height points, level lines, hydrograph network, and borders of the watershed. Moreover, other climatic parameters such as type of climate, intensity, duration, frequency, and time and spatial distribution of rainfall were assessed.

To evaluate the role of slope in the increase and decrease of duration of concentration by the use of land height DEM, we prepared maps of gradient and land use with pictures taken by IRS satellite in 2006 and percentage map of vegetation density through vegetation index.

In addition, we assessed effective factors in producing runoffs such as basin area, gradient, coefficient of shape, and waterway concentration and tributary coefficient for the evaluation of the watershed's morphometry.

Using map of land units and geologic map, we prepared maps of soil hydrologic groups and through their union with different types of land use, we made map of CN (Curve Number) of the watershed in the environment of GIS.

We also estimated the amount of runoffs produced in each sub-basin by assessing flood hydrographs in different return periods and finally performed spatial analyses on the resulted data by GIS and prepared map of risk of flooding in the watershed for a return period of 25 years.

With these, we used a descriptive analysis method to explain geomorphologic features of the watershed. With the aid of geo-hydrologic studies, we were able to provide particular and systematic boundaries of the watershed through which we converted descriptive data into quantitative data and then combined the results of meteorological and climatic measurements as statistical data with the watershed's morphometric data

IV. RESEARCH FINDINGS

Assessment of each morphometric parameter of the watershed indicates the basin area, circumference, shape, average height, time of concentration and percentage of waterway concentration are of the main influential factors in the watershed's flooding condition, which are explained as follows:

A. Area and circumference of the watershed

Total area of the study watershed is 925.50 km2 based on table 1. Sub-basins of K, L, M with 181.8, 128.26, and 106.87 km2, respectively include the most Weighed area and B, C with 17.61 and 25.82 km2, respectively have the least hydrologic surface. Meanwhile, its circumference is totally 171.5 km out of which sub-basin B with 20.43 km includes the least circumference while the most circumference is related to sub-basin M with 77.14 km.

B. Coefficient of the watershed shape

Based on indices relevant to shape and Circle coefficients represented in table 2 and diagrams 2, extension coefficient of Varband watershed has produced several tributary gullies each of which provides a runoff towards the output ravine.

C. Coefficient of the watershed shape

Based on indices relevant to shape and Circle coefficients represented in table 2 and diagrams 2, extension coefficient of Varband watershed has produced several tributary gullies each of which provides a runoff towards the output ravine.

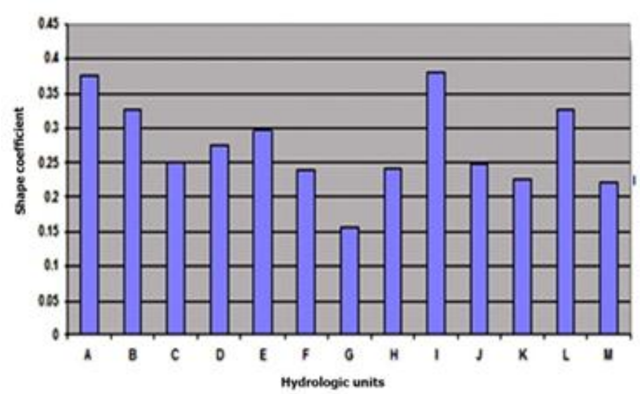


Diagram. 2 Shape coefficient of Varband watershed with sub-basin divisions

TABLE II
AMOUNTS OF SHAPE INDICES IN VARBAND WATERSHED

Corresponding diameter	Corresponding rectangle		Rates collected	Shape coefficient	Circumference(km)	Area(km^2)	Name of work unit	Unit no
	width	length						
11/22	7/06	18/78	1/3	0/3762	46/4	98/83	A	1
4/74	2/82	8/60	1/23	0/3276	20/43	17/61	B	2
5/74	3/08	12/25	1/51	0/2513	27/38	25/82	C	3
7/12	3/96	14/32	1/45	0/2763	32/79	39/74	D	4
5/8	3/23	11/18	1/41	0/2967	25/92	26/42	E	5
11/1	5/84	24/40	1/54	0/2395	53/99	96/15	F	6
6/86	3/20	20/28	1/93	0/1578	41/93	36/94	G	7
5/34	2/83	11/68	1/53	0/2424	25/91	22/38	H	8
7/87	4/99	13/06	1/29	0/3822	32/23	48/65	I	9
11	5/89	23/68	1/52	0/2485	52/80	95/07	J	10
11/66	6/04	26/63	1/58	0/2269	58/34	106/78	K	11
12/78	7/60	23/19	1/36	0/3279	54/99	128/26	L	12
15/22	7/81	35/37	1/60	0/2209	77/11	181/80	M	13
-	-	-	extended	-	171/5	925/50	sum	

D. *Average height of the watershed*

Results of surface distributions of hypsometry with sub-basin divisions in Varband watershed displayed in diagram 4 and map 2 reveals that 431.3 km^2 of the basin surface possesses a hypsometry of 1000-1200 m equal to 46.1 % of the watershed surface. These areas include Dune with poor vegetation. 276.6 km^2 of the basin equal to 29.7 % include a hypsometry of less than 1200 m. A high degree of unevenness (Dune and high lands) corresponding to 70.1 % of the watershed area has led to an increase of runoff velocities. This parameter is of an important morphometric factor in the occurrence of floods in the watershed. Thus, we lave further introduced the study watershed hypsometry in map 2.

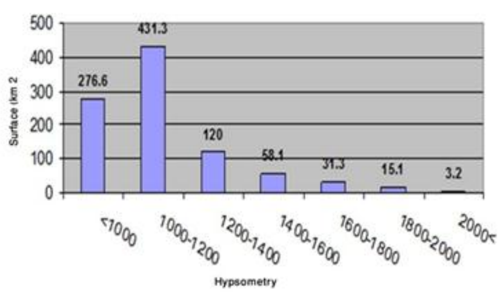
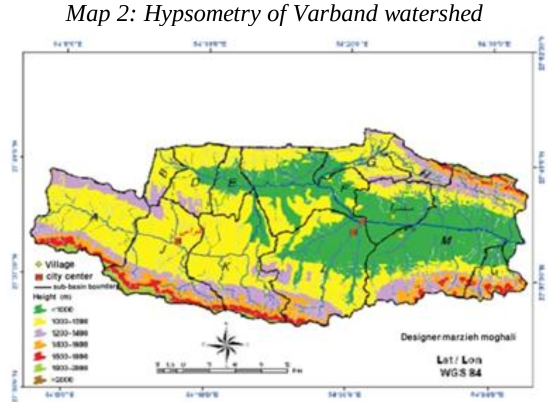


Diagram. 4 Surface distribution of hypsometry with sub-basin divisions in Varband watershed

Map 2: Hypsometry of Varband watershed



Source: Digitize map of 25000, Iranian Survey Organization

E. *Slope of the watershed*

Slope is one of the most important effective morphometric factors in the production of runoffs and flowing of floods in watersheds. With theincrement of mountainside slopes, runoff velocities increase and peak Discharge raises when they enter waterways. This factor is of a special significance in arid and semiarid climates in which time and spatial distributions of rainfall are not regular. Table 3 displays the most surface of the watershed in the slope class of 5-0 % equal to 324.3 km^2 and the least surface in the slope class of 15-10 % equal to 96.4 km^2. This is also shown in diagram 5.

TABLE III
SLOPE DISTRIBUTION IN THE WHOLE VARBAND WATERSHED IN LAR

Cumulative area		**Partial area**		**Hypsometry class(%)**
percent	**Km^2**	**percent**	**Km^2**	
34/7	324/3	34/7	324/3	0-5
49/8	465/5	15/1	141/2	10-5
60/1	561/9	10/3	96/4	15-10
73/5	686/9	13/4	125	15-25
88/1	823/8	14/6	136/9	25-45
100	935/5	11/9	111/7	45<
		100	935/5	مجموع

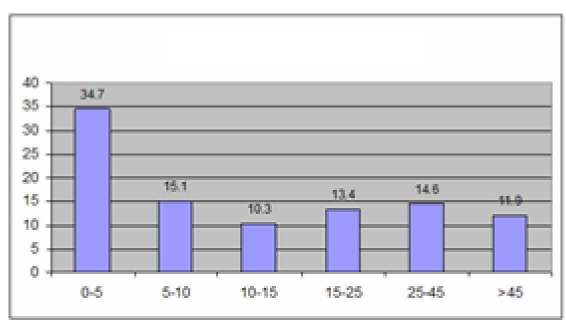
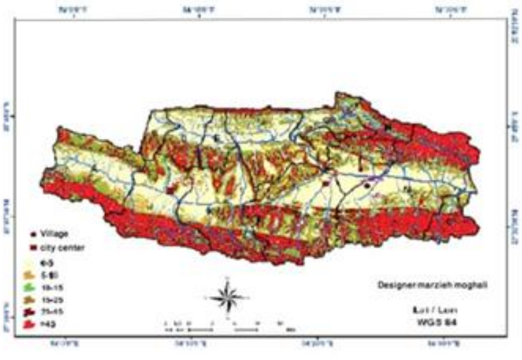


Diagram 5 Percentage distribution of slope classes of Varband watershed

Diagram 5 is indicative of the fact that over 50 % of the watershed surface is with the slope class of more than 10 %, which is known as the factor of reduction in the duration of concentration of hydrologic units. This problem is important when rainfalls with high intensities occur in a less duration in the watershed. Thus, high slope, unsuitable soil features, low percent of vegetation Crest, sensitivity of constructions to erosion, land use changes and false cultivation are of the main factors in the increase of runoff depth in Vrband watershed. Slope classes in the study watershed are shown in map 3.

Map 3: Slope classes in Varband watershed



F. *Concentration of waterway network of the watershed*

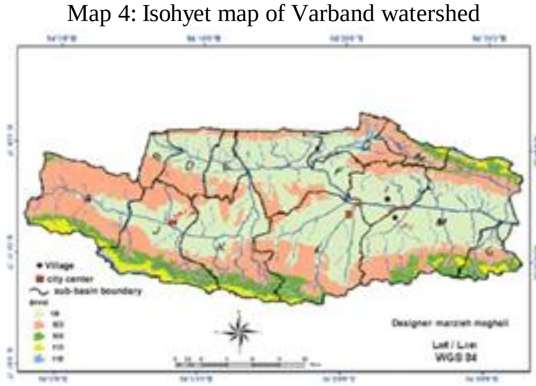
Waterway concentration in any basin is of the most important representation in the identification of morphometric and geomorphologic features.

Considering the fact that the sub-basin gullies of Varband River are joined making a unit gully, the study area possesses only one main gully due to its particular extension.

V. METEOROLOGY

In the flooding zonation of a river's basin, the most important parameter is time and spatial distribution of rainfalls. Assessment of Lar average rainfall displayed in table 4 shows its annual average rainfall equals 203.8 mm which is also shown in map 4 representing a Isohyet map of Varband river basin.

Map 4: Isohyet map of Varband watershed



Source: Digitize map of 25000, Iranian Survey Organization

TABLE IV
ANNUAL RAINFALL OBTAINED FROM SELECTED RESEARCH STATIONS IN MILLIMETER

Water year (mm)	Lar(mm)
60-61	268
61-62	274.6
62-63	43.4
63-64	113.1
64-65	107.4
65-66	199.2
66-67	178.7
67-68	92.2
68-69	148.8
69-70	165.1
70-71	263.6
71-72	634.1
72-73	107.3
73-74	164.2
74-75	596.3
75-76	247.5
76-77	291.9
77-78	144.5
78-79	25.1
79-80	98.1
80-81	117.1
81-82	141.2
82-83	192.1
83-84	208.8
84-85	140.3
avrege	203.8
Standard Deviation	156.1
Coefficient of variation	77

TABLE V
DAILY MEAN EVAPORATION FROM THE BUCKLE FOR EACH MONTH IN LAR SYNOPTIC STATION (MM/DAY)

Esfand	Bahman	Day	Azar	Aban	Mehr	Shahrivar	mordad	Tir	khordad	ordibehesht	farvardin
4.6	3.1	2.8	3.9	7.0	9.9	12.4	14.9	15.9	14.2	10.7	7.1

VI. AMOUNT OF EVAPORATION AND TRANSPIRATION

Evaporation and transpiration indirectly influence on flooding behavior. Evaluation of table 5 and diagram 6 in Lar station indicates minimum daily evaporation from a buckle in Day, Bahman, and Azar months corresponding to 1.7, 2.2, and 2.3 mm, respectively. Thus, an increase in runoff depth leads to an increase of flooding condition during these seasons due to a low profile of soil Retention coefficient, low vegetation Crest in shrub societies, and increment of runoff peak range.

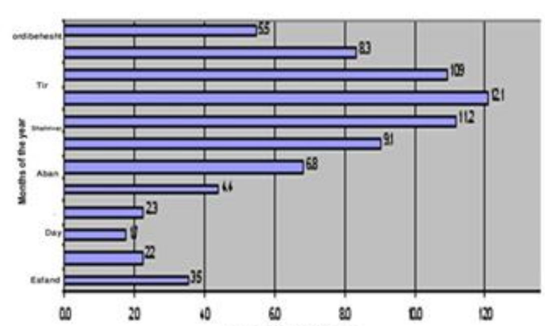


Diagram 6: Diagram of daily mean evaporation from the buckle for each month in Lar Synoptic Station (mm/day)

VII. SOIL LITHOLOGY

Diagram 7 shows with regard to the unsuitability of the region's formations and soil, 53 % of the soil lie in hydrologic group D with an undesirable condition of permeability and 5.7 in hydrologic group C. Therefore, these two groups constitute 58.7 % of the watershed soil. Soil distribution with such hydrologic features in the areas of a gradient over 10 % is the main factor of the increase in the watershed runoff velocities. Despite the fact that there is a suitable penetrability of soil in lower areas, permeability of soil has reduced due to land use and constructional changes in addition to filling of pores and perforations   (Map 5 demonstrates soil hydrologic groups in Varband watershed).

Results of diagrams 8 reveal 69.7 % of the watershed surface possesses the least profile of soil Retention in incorporating 65335 hectare of the whole watershed. Since soil Retention coefficient has a direct relation with soil physical and chemical characteristics (soil texture, structure, penetrability, organic materials and vegetation and reverse relation with slope, it seems that due to heavy soil, high gradient, and high intensity of rainfalls on the watershed, soil does not find a proper opportunity to store runoffs. Map 6 displays profile classes of soil Retention in Varband River basin.

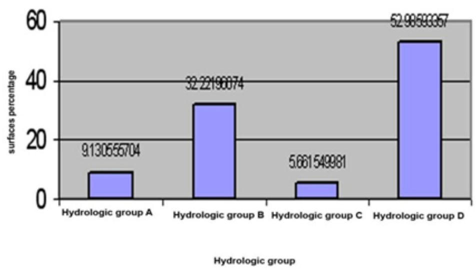
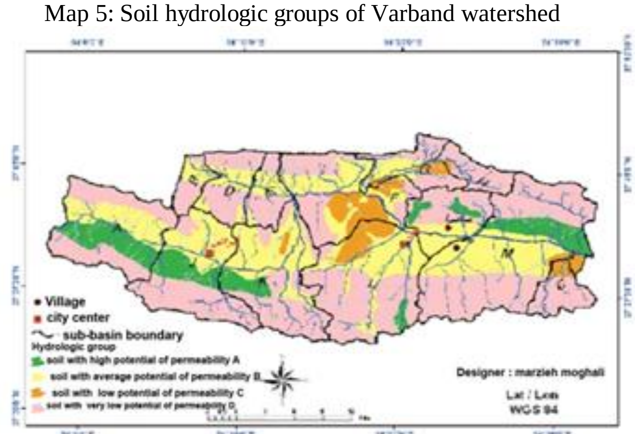


Diagram 7: Percentage of dispersion surfaces of hydrologic groups of the watershed

Map 5: Soil hydrologic groups of Varband watershed



Source: General Organization of Natural Resources and Watershed Management of Fars Province

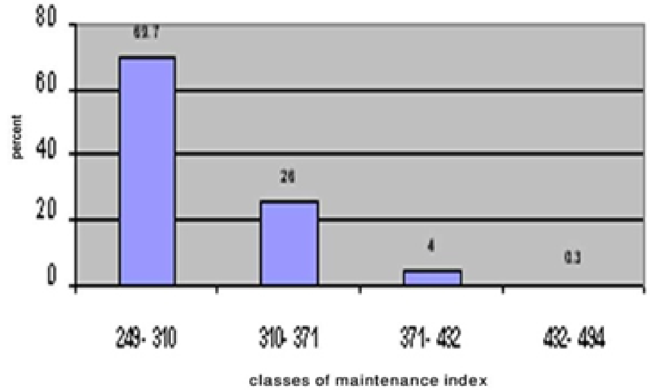
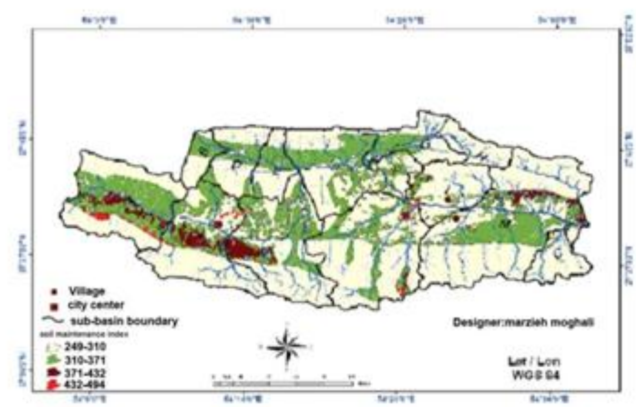


Diagram 8: Percentage of soil Retention indices of Varband watershed

Map 6: Classes of soil Retention indices with sub-basin divisions



Source: Digitize map of 25000, Iranian Survey Organization

Results of diagrams 10 show 49 % of the watershed include runoff depth of more than 6 mm, which is known as the main factor in producing floods. Accordingly, 45358 hectare of the watershed consists of runoff classes 6-9 more than 9 mm. Map 7 displays zonation of Varband watershed with sub-basin divisions.

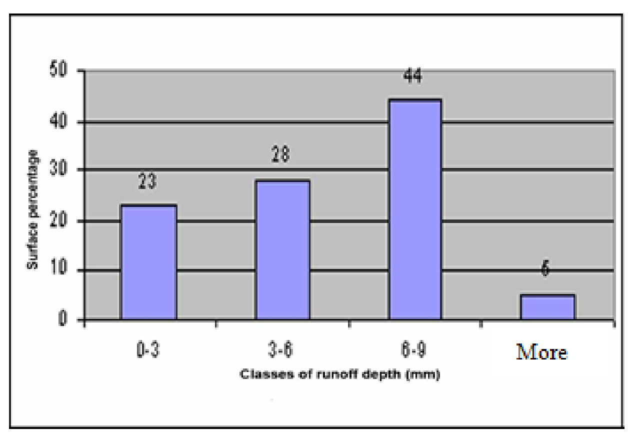
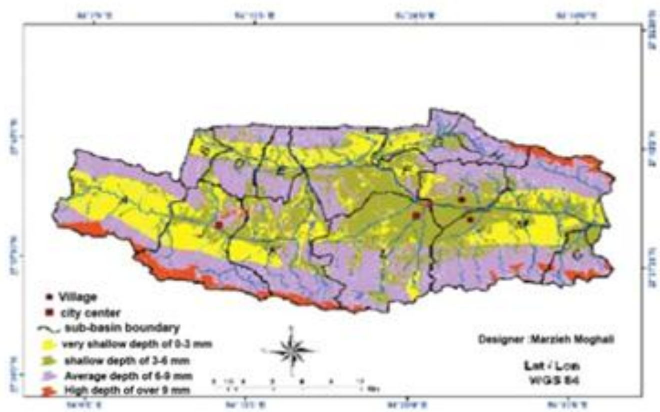


Diagram 10: Dispersion percentage of runoff depth levels in Varband watershed

Map 7: Flooding zonation with sub-basin divisions of Varband watershed



Source: Digitize map of 25000, Iranian Survey Organization

Results of diagrams 12 represent sub-basins M, K, and A with 4946742.3 m^3, 4775652.3 m^3, and 4232423.63 m^3, respectively including a high degree of flooding behavior while sub-basin C with 290577.9 m^3 has the minimum degree. Sub-basins M,K, and A with 12.3, 11.3, and 10.07, respectively include a high level of flooding behavior while sub-basin C, and G with 4.3 and 5.28 have the minimum degree. In sub-basin A, factor of watershed shape causes a decrease in the time of concentration and an increase of peak flooding.

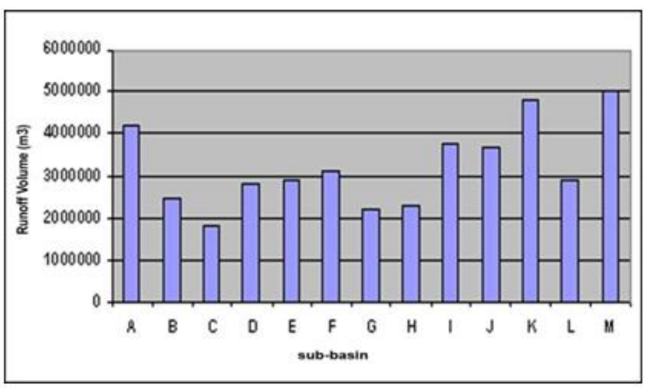


Diagram 12: Distribution of runoff volumes with sub-basin divisions

VIII. Conclusion

Main results of the research are as follows:

- Results of this research demonstrate the occurrence of floods in Varband River basin first depends on geomorphologic and morphometric features and then climatic conditions specially rainfall regime of the watershed.
- Of the influential factors of flooding behavior in the watershed are unsuitability of constructional formations, high degree of evaporation and transportation, tiny-grained soil texture, high intensity of thundershowers, land use changes, low density of vegetation Crest, and poorness of pasturelands.
- Evaluation of each morphometric parameter of the watershed represents factor of gradient, area, watershed shape, time of concentration, and the degree of waterway concentration are of the major effective factors in the watershed flooding behavior.
- Occurrence of rainfalls with the duration of 15 minutes and 6-hour thundershowers are the main factors of destroying soil structure an acceleration of cumulative flow of surface runoffs in Varband watershed (answer to question 3 of this research).
- Results of zonation map of flooding potential of the watershed showed the total amount of runoff produced in this basin is 42283796.6 m^3. Sub-basins of N,K, and A with 11.7, 11.3 and 10.01%, respectively include a high flooding potential and sub-basins C and M with 0.69 and $3/4$ %, respectively possess minimum flooding potential.
- Background of flooding occurrence in Varband River basin with the intervals of 15 to 20 years indicates its repetition in a short- term return period is not unexpected.
- In recent years, raise of land prices within this watershed, urban development and land use changes have led to an increase in runoff volumes, change of feeding degree of rainfalls, change of maximum water-yielding of floods, increment of peak Discharge, occurrence of floods in a shorter period, and the possibility of floods and water flow over lower regions.
- Based on maps and Fig.s, in Varband River basin represent 69.7 % of the surface of this watershed has minimum soil including 65335 hectare of the whole watershed. Since, there is a direct relation between Retention coefficient and physical and chemical soil features (soil texture, structure, permeability, and organic materials) and vegetation and an inverse relation with slope, it seems that soil does not find a good opportunity for runoff storage because of a heavy soil, high gradient and high intensity of rainfalls in the watershed.

IX. Guidelines

Nowadays, the philosophy of perverting floods in most countries implies this fact that we should not let floods accelerate their velocities. In other words, plans should be considered to reduce their speed or obstruct their flowage.

The systemic factor in this viewpoint is building pools in suitable places in the route of important floods (of course at the upper parts) so as to let them exit through narrow gullies with a speed which usually accelerates due to dynamic energy and thus prevent them from entering city bodies and destroying humans and their properties.

Hence, we are able to solve many problems through storing floods and gradually using them after their occurrence based on a controlled plan.

Thus, the following guidelines are suggested:

1. Building pools for attraction and repulsion of floods at upper parts of Varband River basin provided that it would be dredged, otherwise, this intensifies floods and causes damage
2. Providing a plan for the assessment of flooding conditions of basins similar to Varband watershed
3. Improvement of gullies flowing through the city
4. Providing a comprehensive plan for the repulsion of floods and surface water flowing through Lar city
5. Precise enforcement of a sewage plan in the city especially along the river banks and in Shar-e-ghadim in order to increase the efficiency of surface water network
6. Considering multi-purposes in allocating urban land use accounting for the control of floods such as application of green spaces and parks at the margins of Varband River as well as building transitory or permanent storage pools in the route of urban surface water
7. Planning of constructional actions relevant to control of urban floods and allocation of special financial credits for this project by those responsible
8. Necessity of particular attempts for creating urban protective establishments in the way of floods just like embankments, dikes and riverbank walls
9. Considering gullies originating from rivers of Lar City specially those of Varband as important though they are dry during most of the year and even remain dry or with little water during several successive years. Hence, there is a necessity for determining particular limits for them in comprehensive maps of Lar city based on hydrologic and hydraulic standards.
10. Keeping clean the gullies of Lar City rivers especially Varband from disposing garbage as much as possible in order to maintain the extension of canals and rebuilding them at particular intervals or after significant floods especially those walls being exposed to destruction
11. Precise assessment of water surface profile with regard to building of new bridges and streets along Varband River and determination of the heights of the river walls

Undoubtedly, one way of protecting the region from floods is particularly building concrete or mud walls in susceptible places. For this purpose, a precise action should be taken in building walls along Varband River banks so that no changes occur in the width of the gully and the canal capacity and surface profile do not reduce in turn.

References

[1] Afshar, Abbas, 1369. Engineering Hydrology, University Publication Center, p. 459.
[2] Behbahani, Seyyed Mohammad Reza, 1380. Surface Water Hydrology, Tehran University Publications, pp. 221-250.
[3] Refahi, Hossein Qoli, 1382. Erosions Due to Water and Ways of Controlling Them, Tehran University Publications, 4th edition, p. 671.
[4] Ziaee, Hamid, 1380. Principles of Watershed Engineering, Astan Qods Razavi Publications, 1st edition, pp. 347-350.
[5] Alizadeh, Amin, 1379. Principles of Applied Hydrology, Astan Qods Razavi Publications, 12th edition, p. 622.
[6] Kardavani, Parviz, 1374. Issues of Water Resources in Iran, Tehran University.
[7] Kousar, Seyyed Ahang, 1374. Introduction to Flooding Control and Its Exploitation, Forests and Pasturelands Research Institute Publications, p. 530.
[8] Moqaddam Nia, Ali, 1376. Analogical Assessment of Concentration Time, Delay Time, and Arrival Time to Flooding Peak Based on Empirical Methods and Hydrograph Analysis in Two Climatic Regions, A thesis on Watershed for an M.A. degree, College of Natural Resources, Teachers' Training University, p. 163.
[9] Mahdavi, Mohammad; Jamali, Ali Akbar; Ayubzadeh, Seyyed Ali; Vafakhah, Mehdi, 1381. Sensitivity Assessment of Several Hydrological Empirical Methods to Watershed Levels in Peak Debi Estimation in Some Watersheds in Iran, Iranian Natural Resources Magazine, volume 57, no. 3, 1383, pp. 403-414.
[10] Mahdavi, Mohammad, 1381. Applied Hydrology, 2nd volume, Tehran University Publications, 3rd edition, p. 441.
[11] Najafi, Mohammad Reza (translator), 1381. Hydrological Systems (Precipitation-Runoff Modeling), 1st and 2nd volumes, Tehran University Publications, 1st edition, p. 1056.
[12] Yazdani, Mohammad Reza, 1380. Determination of Maximum Flood Debi Using SCS Schematic Method in Small Watersheds, Iranian Natural Resources Magazine , volume 54, no. 4, 1380, pp. 355-367.