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Flash Flood Risk Assessment of the Eastern Coastal Basins in Kuwait Applying MCA

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ABSTRACT
Coping with the water scarcity in the arid and hyper-arid regions requires good management for the flash floods. This requires an accurate estimation for the hazard degrees and floods risk to minimizing the damage, danger and other hazards associated to it to human life, properties, environment and maximizing of water use in arid zones. In this study, Eastern Coastal Basins of Kuwait (ECBK) was chosen for this purpose applying Multi Criteria Analysis (MCA). MCA describes any structured approach used to determine overall preferences among alternative options, where the options accomplish certain or several objectives. MCA techniques were tested and evaluated for the purpose of flash flood risk assessment, hydro-morphological parameters for sample catchments in ECBK, were used in this analysis.

Drainage network and watershed boundaries of ECBK shape files was created using TOPAZ (Topographic Parameterization) technique from the 90 m Digital Elevation Model (DEMs). These data are used in Watershed Modeling System (WMS) package to automatically delineate basin boundaries and define stream networks. Forty basins in ECBK were delineated for the study of the hazard degree of flash floods. Cluster analysis, depending on 15 estimated hydro-morphological parameters, classifies the basins of ECBK into 5 groups. Fifteen chosen hydro-morphological parameters, have their direct effect on flash flooding, were used for estimating hazard scale depending on the MCA procedures. The proposed risk scale assumed category five for the high Weighted Standardized Risk Factor (WSRF) of three basins, while the category three (moderate WSRF) represents the middle sector of ECBK (2 basins). The class one represents 14 basins (low WSRF). Field measurements are highly recommended to verify the results of MCA procedure used in this paper.

KEY WORDS: Hydrology, Flash Floods, WMS, Multi Criteria Analysis, Eastern Coastal basins, Kuwait

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I. INTRODUCTION

Floods in the arid zone are generally unpredictable and infrequent as well (Reid et al. 1994). Rainfall is the most variable of meteorological measurements made in desert areas (Dolman et al. 1997). Therefore, flood frequency and severity in the desert vary from year to year as much as does the rainfall that causes the floods (Warner 2004). Desert rainfall is more spatially variable than that of humid regions and it is often described as “spotty” with the area affected often limited by the radius of the clouds (Laity 2008). Response of the surface-hydrologic system to rainfall in the desert is complex and precludes the hydrologic modeling (Reid & Frostick 1997). Warner (2004) argued that most floods in the desert occur because of the unusual character of the surface rather than that of the rainfall, since the latter is not likely to be of much greater intensity than what would be experienced from a similar type of storm in more humid areas. This is owing to many reasons (Warner 2004; Moawad, 2013): (i) less organic matter in the soil to absorb the rainfall; (ii) lack of vegetation means that raindrop impact can seal the soil surface; (iii) predominance of impervious rocks over vast areas of the drainage basin that have a high runoff potential; (iv) lack of animals, insects, and worms that make the soil permeable; (v) presence of biological and non-biological soil crust topping the surface that decreases surface retention and increases runoff potentiality.

However, several previous works gave special attention to the hydrologic model in areas lacking good coverage by rain gauges and/or having poor runoff records, a situation that is generally encountered in the Kuwait. In addition, sporadic thunderstorms occur near the centers of atmospheric depressions in the lower layers of the atmosphere, especially when entering the western Mediterranean plains. In the spring, as the Earth's surface temperature increases compared to the winter, thunderstorms become more active as various air drops enter different air regions in Kuwait state. In the Eastern Coastal Basins of Kuwait (ECBK), the rainfall considers the only local water resource for irrigation and domestic purposes. Surface runoff occurs in the form of flash floods through numerous basins dissecting the tableland plateau of Al-Ahmdi ridges to the west of the coastal plain. Water use maximization from flash floods is an important item in almost all development projects and an integrated aspect of the detailed design of all rain fed systems is the underlying consideration of safety. Hazards associated with flash flooding may be controlled under presence of appropriate management system. Therefore, a great intention was made to have design criteria for flash flood protection in design manuals and codes of practice (Gad et al. 2016 and Moawad et al.2016). Almost all of these manuals adopted the design recurrence interval as a measure for the safety level that will be considered during the design of flash flood protection system. This means that a flood event that may harm highly important element should have a design recurrence interval higher than that with less importance level (Stephen A. Nelson, 2004). This method of evaluating the flash flood risk level almost ignored the hydro-morphological parameters of the catchments and the flash flood event itself.

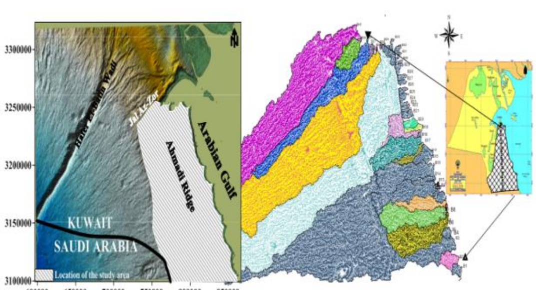

Fig. 1: Location map of the study area (left) and drainage network of the studied basins in ECBK (right).

Forty basins occupied the area of ECBK were selected based on the available rainfall records. It covers an area with dimensions 37 km width and 95 km length, between longitudes 42˚ 47′ 38.21″ & 25˚ 48′ 26.08″ E and latitudes 22˚ 29′ 3.22″ & 32˚ 28′ 39.89″ N with total surface area of magnitude 3515 km^2 (Fig.1).

Climatic conditions of the study area are characterized by a temperate Arabian Gulf climate. The Gulf region is experiencing strong air drops with three strong declines during November and from December to March of every year. The semiarid climate of Kuwait is characterized by two seasons: a long, hot, humid summer, and a relatively cold, short winter. Summer temperatures range from 29-45°C, with relatively high humidity. The prevailing shamal winds from the northwest bring severe dust and sand storms from June to early August, with gusts up to 100 km/ hr. winter temperatures range from 8-18°C. Occasionally samum winds (meaning poison wind, describing the extremely hot and dry winds from the Sahara that can reach 55°C bring more heat to people's bodies than can be removed by transpiration, and they lead to many cases of heatstroke. These winds come from the southwest during November. Annual precipitation averages 11.4 mm and rapidly infiltrates the sandy soil, leaving no surface water except in a few depressions. Most of the limited rainfall occurs in sudden squalls during the winter season. The average recorded value of pitch evaporation reaches 2863 mm/year. The recorded maximum relative humidity varies from 73% to 63% (in July and March respectively). The study area is characterized by short rainy season (Nov.-Feb.). December is the rainiest month (32 mm).

Geomorphological setting

Most of Kuwait is a flat, sandy desert. There is a gradual decrease in elevation from an extreme of 300 m in the southwest near Shigaya to sea level. The southeast is generally lower than the northwest. The geomorphology of the study area is classified into four geomorphological units, Coastal hills, Sand dune fields, Flat desert surfaces and hydrographic basins (Al-Sarawi 1982, El-Baz & Al-Sarawi 1996, El-Baz & Al-Sarawi 2000 and Al-Sulaimi and Al-Ruwaih 2004) (Fig.2). The coastal hills occupy the northern and southern parts of Kuwait, which are a hard, flat desert with shallow depressions and small conical hills with an average height of about 40m. The principal hills in the north are Jal al-Zor (145 m) and the Liyah ridge. Jal al-Zor runs parallel to the northern coast of Kuwait Bay for a distance of 60 km. The Ahmadi Hills (125 m) are the sole exception to the flat terrain. The sand dune fields and dust accumulation pattern occupy an area covering 350-500 km^2. The dunes at umm Al-Neqqa are crescent-shaped barchan dunes with an average width of 170 m and average height of 8 m. Those near Al-Huwaimiliyah are smaller, averaging 20 m wide and 2 m height, and are clustered into longitudinal dune belts. The only other valley of note is Ash Shaqq, a portion of which lies within the southern reaches of the study area. Small playas, or enclosed basins, are covered intermittently with water. During the rainy season they may be covered with dense vegetation; during the dry season they are often devoid of all vegetation. Most playas range between 200-300 m in length, with depths from 5 to 15 m. The hydrographic basins form striking feature of the study area. They are of variable density and nature. They are of few numbers, shallow reaches and short lengths. Runoff occasionally occurs mainly in the lower part of the basins and on their benches which consist of low permeable, massive calcareous crust.

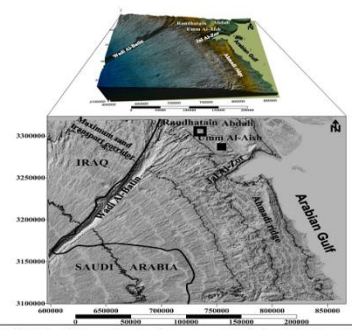

Fig.2: Shaded relief map showing the geomorphological units in the study area

Geological setting

The sedimentary cover of Kuwait ranges in age from Quaternary to post-Eocene of about 200 m thickness. Based on the literature studies (Owen and Nasr 1958, Milton 1967, Fuchs et al.1968, Burdon and Al-Sharhan 1968, Omar et al.1981, Clarke 1988, Al-Sulaimi 1988, Amer et al. 1989, Al-Sulaimi and Pitty 1995, Krishnamurthy, et al. 1996, Srinivas, G., Jayaraman, V. and Chadrasekhar, M. G. (1996) Mukhopadhyay et al. 1996, Al-Sulaimi and Mukhopadhyay 2000, Al-Sulaimi and Al-Ruwaih 2004, Alalati and GAD 2018) the unconsolidated to semi-consolidated clastic Dammam Formation and Kuwait Group are the major sedimentary units in Kuwait. The Dammam Formation is a limestone–dolomite sequence of Middle Eocene age. It is underlain by Middle Eocene Rus evaporites and is overlain unconformably by the clastic sediments of the Kuwait Group (Fig. 3-left).

In addition, Kuwait lies between the Arabian Shield and Zagros fold belt at the periphery of the Arabian platform. Structures associated with the Kuwait Arch noticeably control the subsurface configuration of the Dammam Formations and, hence regulate the distribution of the overlying Kuwait Group sediments (Al-Sulaimi and Al-Ruwaih 2004 and Gad et al. 2017). The Dammam Formation was deposited on a shallow marine shelf experiencing minor fluctuations from lagoon to tidal flat and swamp environments. This tectonically stable period was interrupted by small pulses in the source land and minor fluctuations in the sea level, which caused alternating transgressive and regressive cycles.

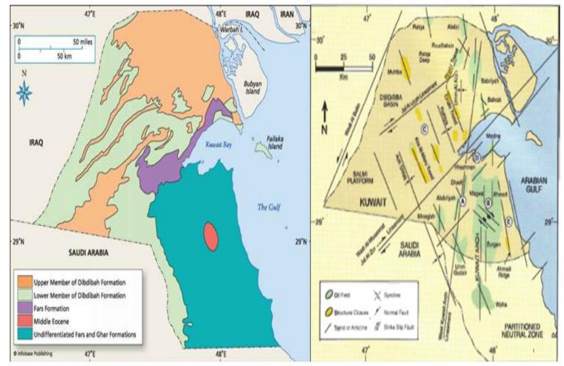

Fig3 : Geological map- lift (after HGG 1981) and structural map-right of Kuwait

Moreover, the structural arches in Kuwait are part of a regional set of north-trending arches known as the Arabian folds (Fig.3-right). These arches are at least mid-Cretaceous. The orientation of the Arabian folds has been interpreted to be inherited from older structures in the Precambrian basement, with possible amplification from salt diapirism. The north-south trends may continue northward beneath the Mesopotamian basin and the Zagros fold belt. The northwest trending anticlinal structures of the Ahmadi ridge and Bahra anticline are younger than the Arabian folds, and related to the Zagros collision, initiated in post-Eocene times. The Kuwait arch has a maximum structural relief in the region between Burgan and Bahra, with closed structural contours around the Wafra, Burgan, Magwa, and Bahra areas, and a partial closure indicating a domal structure beneath Kuwait City and Kuwait Bay. The superposition of the Kuwait arch and the shallow anticlinal structure of the Ahmadi ridge forms a total structural relief of at least 1.6 km.

The northwest-trending Dibdibba arch represents another subsurface anticline in western Kuwait. The ridge is approximately 75 km long, and is an isolated domal structure.

In the other side, the paleo-drainage channels in EBCK, which were formed in the Pleistocene Al-Sulaimi and Mukhopadhyay 2000, are carved in the Upper and Lower Dibdibba and the undifferentiated Fars and Ghar formations. Presently, they are filled with gravel and sand and are not readily observed on flat terrain where they are only manifested as micro-relief with the surroundings. Moreover, the relative abundance of paleo-drainage channels in the north and south-west is due to the underlying hard calcretic and gypcretic gravelly deposits of the Dibdibba Formation. Conversely, the paucity of wadis in the south is due to the friable sandstone of the Undifferentiated Fars and Ghar Formation, which was not as ideal for developing and preserving the drainage channels. The south-west-north-east trending drainage pattern closely follows the present relief variations (Al-Senafy et al. 2016).

II. MATERIALS AND METHODS

Probability analysis of rainfall

The materials used in this paper were collected through carrying out 2 field trips in ECBK during the year 2017 to collect the basic hydrologic data. Most precipitation in the study area occurs during winter with relatively low-intensity. It represents the greater part of annual rainfall. Rainfall intensity is defined as the ratio of the total amount of rain (rainfall depth) falling during a given period to the duration of the period. The obtained rainfall records used in this work consist of monthly rainfalls only, many of which were incomplete and broken, although some were continuous over 4 years. These records show that the geographical distribution of the precipitation during the period 1998-2002 has considerable variability (Gad 2009 a&b). An analysis of only 4 years of observations is inadequate as these 4 values may belong to a particularly dry or wet period and hence may not be representative for the long term rainfall pattern. So, free downloads for monthly rainfall records (1998-09) produced by NASA hosted at: http://disc2.nascom.nasa.gov/Giovanni/tovas/ solved this problem. The monthly accumulated rainfall depth based on the field records beside the NASA records for 12 seasons (1998-09) was performed (Fig. 4).

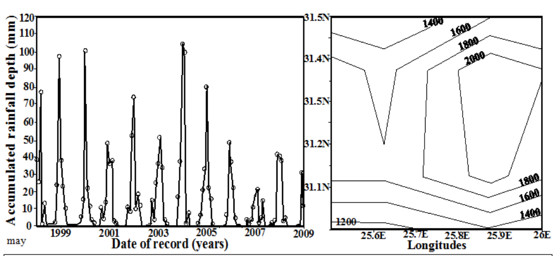

Fig.4: Monthly accumulated rainfall depth (mm) during the period Jan. 1998-Jan. 2009 (left graph) and the isohyetal map of the study area (based on records of 1998-2009, right map)

These rainfall records were used in estimating the recurrence period T and rainfall event distribution in ECBK according to Weibull, (1932) ranking method and Raghunath, (1990) (Fig.5). The statistical analysis of the rainfall records during the period 1998-09 (12 seasons), the recurrence period T and the probability of exceedence P_r, was estimated based on the following relations (Bennett & Doyle 1997);

$$T = (N + 1) / M \quad \ldots\ldots(1)$$

$$P_r = 100 \cdot M / (N + 1) \quad \ldots\ldots(2)$$

Where P is probability in % of the observation of the rank M, M is the rank of the observation (dimensionless), N is the total number of observations used (dimensionless) and T is the recurrence period (T). Equation 1 is recommended for N = 10 to 100. The analysis of the long-term data of rainfall intensity during the period 1998-09 was obtained (Gad et al, 2002).

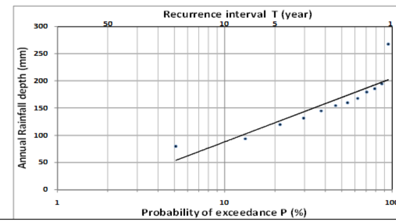

Fig 5: Probability of exceedance P (%) and the recurrence period T (years) of the annual rainfall in the study area during the period Jan. 1998-Jan. 2009

Ground configuration

The United States Geological Survey (USGS) has converted the topographic maps of Kuwait into digital elevation model (DEM) files. These files represent the land surface as a matrix (grid) of elevation values at a given space (resolution) apart. The 1:250,000 map series has been converted into 3 arc-second (approximately 90 m) resolution DEMs. Free downloads for these DEM files beside land use, soil textural classification, and image data are available from the World Wide Web (www). This website is hosted at: http://www.emrl.byu.edu/gsda.The methodological approach for ground configuration used in this paper is based on the mathematical modeling techniques applying Watershed Modeling System (WMS, version 7.1) and STATISTICA version 10 computer programs. DEM data is used in WMS to automatically delineate basin boundaries and define stream networks. WMS is a comprehensive environment for hydrologic analysis. The United States Department of Agriculture (USDA) program TOPAZ (Garbrecht, and Martz, 1993 and Martz and Garbrecht 1993) is launched from WMS to define flow directions and flow accumulations for each DEM cell. This information is used to trace and convert the stream networks and basin boundaries to lines and polygons of the WMS drainage coverage (Nelson et al, 2000). The polygon and stream network shown in (Fig. 6) were delineated in WMS using this method.

The drainage characteristics of terrain surfaces of the forty selected basins required for flash flood hazard assessment are automatically computed applying WMS. These parameters include basin area (A), basin slope (BS), average overland flow (AOFD), basin length (L), basin perimeter (P), shape factor (Shape), sinuosity factor (Sin), mean basin elevation (AVEL), mean flow distance (MFD), maximum flow slope (MFS), maximum stream length (MSL), maximum stream slope (MSS), distance from centroid to stream (CTOSTR), centroid stream distance (CSD), and centroid segment slope (CSS).

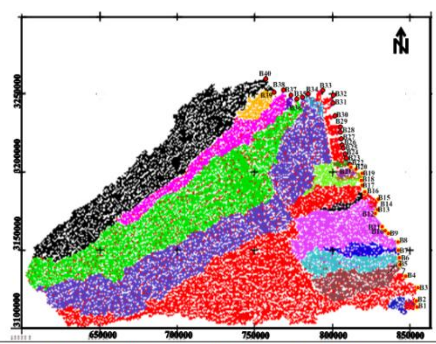

Fig. 6: Drainage network of the selected 40 basins extracted from DEM file by WMS software

These hydro-morphological parameters of the different selected basins in the ECBK were statistically analyzed by using Pearson's correlation coefficient in order to differentiate and confirm the interpretation of them. The Pearson's correlation coefficient is the most applicable one of the most multivariate correlation (Davis, 1975). By using these ten hydro-morphological variables, basic statistics and correlation matrix of the transformed data input of these different variables are obtained. Moreover, the cluster analysis was carried out on the non transformed input data matrix of 40 selected basins with ten hydro-morphological parameters applying STATISTICA software V.10. The results are given as R-mode and Q-mode dendrograms with amalgamation rule of single linkage and Euclidean distance.

Undoubtedly that, as any area under development that is subjected to flash flood hazards had to be protected against flood events, these events are estimated based on a certain recurrence interval. However, some basins may be subject to more danger than other basins. This is why a risk assessment from the flash flood event point of view, has to be carried out prior the design or proposing the storm protection scheme (USDT, 1996). As a result, the high-risk locations will receive more intention than basins with low risk or even their protection works may be designed with a higher recurrence interval. The criteria adopted in this study for risk analysis was based on hydro-morphological parameters that may result in more loss in surface water and damage to the crossing locations. These selected parameters are the basin drainage area (A), basin slope (BS), average overland flow (AOFD), basin length (L), basin shape factor (Shape), basin sinuosity factor (Sin), basin average elevation above mean sea level (AVEL), basin maximum stream length (MSL), basin maximum stream slop (MSS) and basin centroid stream distance (CSD).

In the other side, Multi Criteria Analysis (MCA) was used for statistical analysis after standardization of the selected ten hydro-morphological parameters applying STATISTICA software (v.10). MCA was appeared in the 1960s as a decision-making tool. It was used to make a comparative assessment of alternatives or heterogeneous measures. With this technique, several criteria can be taken into account simultaneously in a complex situation. The method is designed to help decision-makers to integrate the different options, reflecting different factors of the addressed problems, into a prospective or retrospective framework. The results are usually directed at providing advice or recommendations for future activities. MCA describes any structured approach used to determine overall preferences among alternative options, where the options accomplish certain or several objectives. In MCA, desirable objectives are specified and corresponding attributes or indicators are identified. The actual measurement of indicators need not be in monetary terms, but are often based on the quantitative analysis (through scoring, ranking and weighting) of a wide range of qualitative impact categories and criteria (Baptista et al., 2007). MCA provides techniques for comparing and ranking different outcomes, even though a variety of indictors are used.

Standardization of hydro-morphological Parameters

The selected ten hydro-morphological parameters obtained for each watershed are expressed in different units. It is therefore difficult to compare across criteria. For many of the arithmetic MCA techniques, it is necessary to reduce the scores to the same unit. This is called standardization. The difference between the actual parameter and that of the lowest value is divided by the difference between the parameters of the highest value and that of the lowest value. This led to standardized factors that reflect the degree of risk for each parameter compared to the same parameter in the other sheds (Heun, 2008 and Baptista et al., 2007). The following relations show the mathematical equation by which each morphological parameter is defined.

Basin Drainage Area Standardized Risk Factor (A_{SRF}) $= \dfrac{A - A_{Min}}{A_{Max} - A_{Min}}$ (3)

Basin Slope Standardized Risk Factor (BS_{SRF}) $= \dfrac{BS - BS_{Min}}{BS_{Max} - BS_{Min}}$ (4)

Basin Average Overland Flow Standardized Risk Factor ($AOFD_{SRF}$) $= \dfrac{AOFD - AOFD_{Min}}{AOFD_{Max} - AOFD_{Min}}$ (5)

Basin Length Standardized Risk Factor (L_{SRF}) $= \dfrac{L - L_{Min}}{L_{Max} - L_{Min}}$ (6)

Basin Shape Ratio Standardized Risk Factor ($Shape_{SRF}$) $= \dfrac{Shape - Shape_{Min}}{Shape_{Max} - Shape_{Min}}$ (7)

Basin Sinuosity Ratio Standardized Risk Factor (Sin_{SRF}) $= \dfrac{Sin - Sin_{Min}}{Sin_{Max} - Sin_{Min}}$ (8)

Basin Average Elevation above mean sea level Risk Factor ($AVEL_{SRF}$) $= \dfrac{AVEL - AVEL_{Min}}{AVEL_{Max} - AVEL_{Min}}$ (9)

Basin Maximum Stream Length Risk Factor (MSL_{SRF}) $= \dfrac{MSL - MSL_{Min}}{MSL_{Max} - MSL_{Min}}$ (10)

Basin Maximum Stream Slop Risk Factor (MSS_{SRF}) $= \dfrac{MSS - MSS_{Min}}{MSS_{Max} - MSS_{Min}}$ (11)

Basin Ccentroid Stream Distance Risk Factor (CSD_{SRF}) $= \dfrac{CSD - CSD_{Min}}{CSD_{Max} - CSD_{Min}}$ (12)

Where; Max. refers to the maximum value of the mentioned parameter and Min. refers to the minimum value of the mentioned parameter. The weighted sum was then applied to standardized parameters. The principle is that the standardized parameters for the individual criteria are added up, leading to a single factor. And to express the importance of certain parameter compared to others the individual standardized factors were multiplied by a weight coefficient (W), that was assume in this study constant for all factors and equal to 1/(No. of parameters) for simplification, before being added up. The resulted sum is the Weighted Standardized Risk Factor (WSRF).

$$W_{SRF} = W \times (A_{SRF} + BS_{SRF} + AOFD_{SRF} + L_{SRF} + Shape_{SRF} + Sin_{SRF} + AVEL_{SRF} + MSL_{SRF} + MSS_{SRF} + CSD_{SRF}) \quad (13)$$

In addition, Box plot technique is useful to display differences between populations without making any assumptions of the underlying statistical distribution. It is non-parametric. Spacing between the different parts of the box help indicate the degree of dispersion (spread) and skewness in the data, and identify outliers. The box plot technique was applied to test all the data for values that are extremely high outlier. An outlier is an observation that is numerically distant from the rest of the data which may lead to biased results. The mild and extreme higher outlier was calculated for each data set and all watersheds that have their parameters values above the extreme higher outlier were considered as the highest risk watersheds.

Mild higher outlier = UQ + 1.5 IQR ……………………………………………………..……(14)

Extreme higher outlier = UQ + 3 IQR IQR = UQ – LQ ……………………………..……...(15)

Where; UQ is the upper quartile, LQ is the lower quartile and IQR is the inter-quartile range for each data set. Then the extreme higher outlier was considered as the highest parameter value when calculating WSRF. This technique was adopted for all other parameters and the WSRF for each of them was recalculated and their risk level was estimated based on the new results.

III. RESULTS AND DISCUSSION

Based on the statistical analysis of the long term period of rainfall (12 seasons) (Table 1 and Fig.5), it is noticed that the rainfall depth of 11.5 mm more than the mean value of initial abstraction recurs every 3 years with probability 33.3%. During this period the maximum daily rainfall is 29.6 mm/day and the seasonal rainfall is 208.9 mm/year. In addition, the rainfall amount of 16.5 mm/hour recurs after 15 years, where the maximum daily rainfall is 70.6mm/day and the seasonal reaches 274.6 mm with probability 6.6% . The monthly rainfall amount of 147 mm recurs after 50 years, where the maximum annual rainfall reaches 276.8mm with probability 1.9

Table 1: The results of the estimated recurrence periods and probability of exceedence of rainfall events based on the records of the interval 1998-2009

Return Period (T)	12 years base-period (1998-2009) Max. rainfall depth (mm)				40 years base-period Max. rainfall depth (mm)		
	One hour	Daily	Annually	Probability (%)	Annually	Monthly	Probability (%)
3	11.5	29.6	208.9	33.3	154.8	63.4	33.3
5	14	33.4	256.1	20	208.9	78.7	19.6
7.5	15	53.7	263.9	13.3	224.8	122	13.7
15	16.5	70.6	274.6	6.6	263.9	86.8	5.8
25	–	–	–	--	274.6	125.1	3.9
50	–	–	–	--	276.8	147	1.96

In addition, the drainage characteristics of terrain surfaces of the 40 selected basins in ECBK required for flash flood risk assessment, which automatically computed applying WMS (Table 2), reflect great tendency of these catchments to receive flash floods with peak runoff as a result of weathered and fractured nature of the Ahmadi Ridge bedrock. The basic statistics of the selected hydro-morphological parameters show that the drainage area (A) of the studied basins ranges from 7.55 to 5325.1 km^2 (Ard El-Desht basin and El-Manteka El-Horra basin respectively) with mean value of 648.4 km^2 and standard deviation of 1473 (Table 2 & 3).

Otherwise, the basin slope (BS) ranges from 0.006 (North Al-Kheiran basin) to 0.022 (North Al-Ade'omi Basin) with mean value 0.0001 and standard deviation 0.0001. The high BS value characterizing North Al-Ade'omi Basin reflects high tendency to generate great runoff and sediment load yields (Gad and Abdel-Latif, 2003). The basin length of overland flow (AOFD) can be described as the length of flow of water over the surface before it becomes

Table 2: The estimated hydro-morphological parameters of terrain surfaces of the 40 selected basins in

BasinNo.	Basin Name	A	BS	AOFD	MFD	MFS	CMFD	CSD	CSS	MSL	MSS	L	P	Shape	Sin	AVEL
B1	Had El-Hemara basin	55.02	0.008	343.7	13772	0.0023	127.3	6121.1	8E-04	13158	0.002	10102.9	46931	1.855	1.3024	12.1163
B2	North Had El-Hemara basin	134.69	0.009	323.6	25576	0.0016	0	11996.7	6E-04	24670	0.001	19023	83205	2.6868	1.2968	18.9679
B3	South El-Akrabi basin	5123.2	0.007	329.9	341494	0.0011	180	158133	0.002	340790	0.001	229622	968504	10.2917	1.4841	229.8639
B4	El-Akrabi basin	45.21	0.008	342.4	11981	0.0022	402.5	5289.26	1E-04	10768	9E-04	9020.23	38470	1.7999	1.1937	9.9621
B5	North El-Akrabi basin	433.61	0.008	349.8	80949	0.0023	829.8	45305.9	0.002	80080	0.002	56451.2	223798	7.3493	1.4186	94.2692
B6	Khour Eskandar basin	321.09	0.008	331.1	69258	0.0024	509.1	40102.6	0.002	68299	0.002	46429.6	171584	6.7137	1.471	69.9421
B7	North Khour Eskander basin	635.88	0.009	336.9	81693	0.0026	63.64	47907.7	0.002	80750	0.003	60752.4	226959	5.8043	1.3292	108.1532
B8	Khour El-Meftah basin	28.02	0.008	305.1	17264	0.0018	524.8	6974.77	0.001	16215	0.002	11701.4	44505	4.887	1.3857	10.7961
B9	Al-Kheiran basin	267.23	0.008	331.6	59539	0.0026	0	26888.8	0.002	58617	0.002	46174.3	159348	7.9785	1.2695	59.8555
B10	North Al-Kheiran basin	56.44	0.006	365.8	16068	0.0017	63.64	6367	4E-04	15528	0.002	12436	48311	2.7401	1.2486	8.6266
B11	South El-Banaya basin	18.71	0.008	328.3	12316	0.0078	190.9	6361.06	0.013	11633	0.008	9419.52	34797	4.742	1.235	15.2332
B12	Gabal El-Banaya basin	393.38	0.009	322.4	61985	0.0028	63.64	32399.9	0.002	61206	0.003	44798.8	173768	5.1017	1.3662	76.4737
B13	Al-Gohanamiya basin	62.53	0.008	315.1	30986	0.0024	63.64	13379.1	0.002	30154	0.002	21657.1	75632	7.5006	1.3923	37.5705
B14	North Al-Gohanamiya basin	843.66	0.01	339.4	91345	0.0022	318.2	48208.5	0.002	90423	0.002	62907.4	286018	4.6907	1.4374	116.2924
B15	Al-Salou'a basin	126.66	0.008	325.5	25422	0.002	324.5	10194	9E-04	24627	0.002	17293.6	79316	2.3612	1.4241	13.6315
B16	North Al-Salou'a basin	103.8	0.01	332.7	42781	0.003	254.6	20681.5	0.003	41837	0.003	32212.1	112194	9.9962	1.2988	54.158
B17	South Sawlah basin	545.92	0.009	358.8	70999	0.0028	63.64	37261	0.002	70422	0.003	50818.1	187444	4.7306	1.3858	98.903
B18	Sawlah basin	267.18	0.008	32052	65662	0.0023	17716	5525.67	0.001	5870.2	9E-04	39423.3	175895	5.8171	0.1489	71.1428
B19	North Sawlah basin	47.26	0.009	334.2	22377	0.0037	402.5	9374.85	0.002	21291	0.004	16635.4	61519	5.8552	1.2798	27.6413
B20	South Ras Al-Zour basin	62.73	0.011	379.8	18152	0.005	201.3	10559.8	0.003	17537	0.005	13434.4	48795	2.8773	1.3054	36.336
B21	Ras Al-Zour basin	41.54	0.013	422.5	14367	0.0065	0	6507.45	0.005	13678	0.006	10419	40161	2.613	1.3128	45.0461
B22	North Ras Al-Zour basin	15.25	0.014	437.9	11773	0.0082	201.3	5441.03	0.008	10888	0.008	9412.21	28304	5.8083	1.1568	51.9306
B23	South Beniat Al-Zour basin	11.21	0.014	373.5	10595	0.0094	180	5969.92	0.01	9560.9	0.01	8350.14	26689	6.2197	1.145	68.7122
B24	Beniat Al-Zour basin	16.03	0.017	365.8	10555	0.0095	0	5203.81	0.01	9775.7	0.01	8651.71	27638	4.6695	1.1299	59.9355
B25	North Beniat Al-Zour basin	31.06	0.019	421.3	12475	0.0138	270	7709.95	0.016	11366	0.014	9813.71	34685	3.1012	1.1582	62.172
B26	South Al-Ade'omi Basin	23.57	0.021	474.8	10994	0.0159	509.1	7179.78	0.018	10215	0.015	8891.34	28224	3.354	1.1489	59.8595
B27	Al-Ade'omi Basin	17.15	0.019	445.6	10095	0.0176	360	5920.35	0.02	9263.1	0.017	8280.49	27074	3.9986	1.1187	53.1233
B28	North Al-Ade'omi Basin	27.22	0.022	442.4	11990	0.0147	284.6	5928.31	0.019	10836	0.014	9432.84	30334	3.2684	1.1487	46.5053
B29	South Ard El-Desht basin	29.01	0.017	389.1	11419	0.0142	63.64	5563.78	0.021	10513	0.015	8631.09	33062	2.5683	1.218	55.8116
B30	Ard El-Desht basin	7.55	0.016	428.8	5478.3	0.0213	90	2750.07	0.031	4736.5	0.023	4829.91	15586	3.0901	0.9807	19.525
B31	North Ard El-Desht basin	14.98	0.014	372.7	10900	0.0127	180	5003.01	0.018	9745.9	0.013	8805.29	29447	5.1769	1.1068	28.2623
B32	South Ras El-Gale'ah basin	20.96	0.013	309.8	9003.1	0.0035	127.3	4666.57	0.002	8351.3	0.003	7564.82	30034	2.7299	1.104	17.739
B33	Ras El-Gale'ah basin	85.94	0.013	342.7	26109	0.0032	190.9	14076.5	0.002	25329	0.003	19148.2	71967	4.2664	1.3228	33.0159
B34	North Ras El-Gale'ah basin	17.29	0.01	339.3	9868.7	0.0101	360	6137.67	0.014	9074.1	0.01	7736.34	29981	3.4625	1.1729	21.5567
B35	El-Manteka El-Horra basin	5325.1	0.006	323.5	357790	0.001	270	197303	0.001	357176	0.001	212249	948530	8.4599	1.6828	234.1885
B36	Al-Heshan basin	5219.3	0.006	314.8	316262	0.0012	284.6	155085	0.002	315701	0.001	209372	820902	8.399	1.5078	258.7694
B37	West Al-Heshan basin	35.19	0.012	313.4	15111	0.0028	180	7242.89	0.001	14332	0.003	9664.01	41626	2.6536	1.483	14.9142
B38	East Al-Sulaiokhat basin	1143.2	0.007	333.4	183056	0.0017	284.6	83893	0.003	182351	0.002	135957	473496	16.1691	1.3412	205.0711
B39	Al-Sulaiokhat basin	264.48	0.015	426.8	40009	0.0044	509.1	19867.2	0.005	39230	0.004	28855.8	112338	3.1483	1.3595	105.0159
B40	West Al-Sulaiokhat basin	4016.7	0.006	319.1	250708	0.0015	270	126592	0.002	250094	0.002	189248	695553	8.9165	1.3215	265.427

A= Basin area (km^2), **BS** = Basin slope, **AOFD** = Average overland flow (m), **MFD** = Maximum flow distance (m), **MFS** = Maximum flow slope, **CMFD** = centroid to maximum flow distance (m), **CSD** = Centroid stream distance (m), **CSS** = Centroid stream slope, **MSL** = Maximum stream length (m), **MSS** =

concentrated in definite stream channels (Krishnamurthy et al. 1996). It ranges between 305.1 and 32052 km with mean value 1151.1 and standard deviation 5011.3 (Khour El-Meftah and Sawlah basins respectively). In addition, the basin maximum flow distance (MFD) ranges from 5478.3m (Ard El-Desht basin) to 357790 m (El-Manteka El-Horra basin) with mean value 62204.4 and standard deviation 93283.4 while the basin maximum flow slope (MFS) ranges from 0.001 (El-Manteka El-Horra basin) to 0.0213 (Ard El-Desht basin) with mean value 1E-4 and standard deviation 1E5.

Moreover, the basin centroid maximum stream distance (CMFD) of the studied basins ranges from zero to 17716 m (North Had El-Hemara basin and Sawlah basin respectively) with average value of 672.9 m and standard deviation 2769.6. As a general, the basin centroid stream distance (CSD) of the 40 extracted basins ranges from 2750.07 to 197303m (Had El-Hemara basin and West Al-Sulaiokhat basin respectively) with average value of 30676.8 m and standard deviation 47288.4, While the basin centroid stream slope (CSS) for the studies basins ranged from 0.0001 to 0.031(El-Akrabi basin and Ard El-Desht basin) with mean and standard deviation of zero. Moreover, the basin maximum stream length (MSL) ranges from 4736.5m (Ard El-Desht basin) to 357176 m (El-Manteka El-Horra basin) with mean value 59902.3 and standard deviation of 93761.4. The basin maximum stream slope (MSS) ranges from 0.0009 (El-Akrabi basin) to 0.023 (Ard El-Desht basin) with mean value 1E-4 and standard deviation 0.00003.

Table 3: The basic statistics and Euclidean distance between 15 hydro-morphometric parameters of the 40 studied basins

Basic Statistics		Euclidean distance															
Mean	Std. Dev.	Variable	A	BS	AOFD	MFD	MFS	CMFD	CSD	CSS	MSL	MSS	L	P	Shape	Sin	AVEL
648.4	1473.0	A	0	10072	33165	693230	10072	19905	343631	10072	687661	10072	462221	1896076	10050	10068	9532
0.0	0.0	BS	10072	0	32131	702955	0	17812	353347	0	697415	0	471833	1905797	37	8	633
1151.1	5011.3	AOFD	33165	32131	0	699535	32131	14400	353150	32131	696741	32131	469043	1901944	32123	32131	32036
62204.4	93283.4	MFD	693230	702955	699535	0	702955	700637	353776	702955	60025	702955	236151	1203895	702926	702950	702360
0.0	0.0	MFS	10072	0	32131	702955	0	17812	353347	0	697415	0	471833	1905797	37	8	633
672.9	2769.6	CMFD	19905	17812	14400	700637	17812	0	352617	17812	696613	17812	469774	1903356	17803	17811	17712
30676.8	47288.4	CSD	343631	353347	353150	353776	353347	352617	0	353347	346166	353347	134191	1555754	353320	353343	352757
0.0	0.0	CSS	10072	0	32131	702955	0	17812	353347	0	697415	0	471833	1905797	37	8	633
59902.3	93761.4	MSL	687661	697415	696741	60025	697415	696613	346166	697415	0	697415	234912	1213362	697388	697410	696825
0.0	0.0	MSS	10072	0	32131	702955	0	17812	353347	0	697415	0	471833	1905797	37	8	633
43140.6	61640.3	L	462221	471833	469043	236151	471833	469774	134191	471833	234912	471833	0	1436147	471804	471828	471229
169815.6	252097.2	P	1896076	1905797	1901944	1203895	1905797	1903356	1555754	1905797	1213362	1905797	1436147	0	2E+06	2E+06	1905202
5.2	2.9	Shape	10050	37	32123	702926	37	17803	353320	37	697388	37	471804	1905768	0	31	601
1.3	0.2	Sin	10068	8	32131	702950	8	17811	353343	8	697410	8	471828	1905792	31	0	627
71.9	70.5	AVEL	9532	633	32036	702360	633	17712	352757	633	696825	633	471229	1905202	601	627	0

In addition, the minimum value of basin length factor (L) reaches 4829.91m (Ard El-Desht basin) and the maximum value reaches 229622m (South El-Akrabi basin) with mean 27678.61 and standard deviation 17426.37. The basin hydro-morphological perimeter parameter (P) of the studied basins shows great range. Its minimum value reaches 15586m in Ard El-Desht basin and the maximum value gives 968504 (South El-Akrabi basin) with mean 27678.61 and standard deviation 17426.37 .This large difference reflects more or less great tendency to form flash flood with hazard degrees. The basin shape factor (Shape) ranges between 1.7999 and 16.1691 (El-Akrabi basin and East Al-Sulaiokhat basin respectively) and mean value of 5.2 while the standard deviation reaches 1.78. The basin sinuosity factor (Sin) ranges from 0.1489 (Sawlah basin) to 1.6828 (El-Manteka El-Horra basin) with mean value 1.36 and standard deviation 0.19 reflecting lithological and structural control. The mean basin elevation (AVEL) ranges from 8.6266m (North Al-Kheiran basin) to 265.427 m (West Al-Sulaiokhat basin) with mean value 120.64 and standard deviation 34.87.

Moreover, the close inspection of correlation matrix was useful because it can point out associations between variables that can show the overall coherence of the data set and indicate the participation of the individual hydro-morphological parameters in several influence factors, a fact which commonly occurred in ECBK. Pearson correlation analysis between the different hydro-morphological parameters in Table 4 shows that the marked correlations are significant at probability less than 0.05. This means that the basin catchment area (A) is direct positively correlated with L, Sin, AVEL, MSL and CSD (0.9, 0.46, 0.53, 0.92 & 0.93 respectively). The Basin Slope (BS) is direct positively correlated with AOFD and MSS (0.41 & 0.58 respectively) and reverse correlated with A, L, Shape, Sin, AVEL, MSL and CSD (-0.3, -0.46, -0.16, -0.35, -0.55, -0.45 and -0.43 respectively). The Basin length factor (L) is direct positively correlated with A, Sin, AVEL, MSL and CSD (0.9, 0.52, 0.7, 0.96 & 0.96 respectively) while Sin factor is direct positively correlated with Area, L, AVEL, MSL and CSD (0.46, 0.52, 0.37, 0.63 & 0.55 Respectively). The Basin Shape factor (Shape) is direct positively correlated with MSS (0.21) while Sin factor is direct positively correlated with Area, L, AVEL, MSL and CSD (0.46, 0.52, 0.37, 0.63 & 0.55 Respectively). Moreover, the correlation coefficient of 0.98 characterized to the relation between basin Max Stream Length (MSL) and Centroid Stream Distance (CSD) reflects the effect of the geological structures of these streams to form peak flow and receives flash floods (Gad, 2001 and Gad 2010).

Table 4: The correlation coefficients between the selected hydro-morphologic parameters of the studied ECBK

Parameters	A	BS	AOFD	L	Shape	Sin	AVEL	MSL	MSS	CSD
A	1.00	-0.30	-0.21	0.90	-0.31	0.46	0.53	0.92	-0.60	0.93
BS	-0.30	1.00	0.41	-0.46	-0.16	-0.35	-0.55	-0.45	0.58	-0.43
AOFD	-0.21	0.41	1.00	-0.31	-0.15	-0.40	-0.60	-0.32	0.34	-0.31
L	0.90	-0.46	-0.31	1.00	-0.17	0.52	0.70	0.96	-0.73	0.96
Shape	-0.31	-0.16	-0.15	-0.17	1.00	-0.35	0.07	-0.19	0.21	-0.18
Sin	0.46	-0.35	-0.40	0.52	-0.35	1.00	0.37	0.63	-0.70	0.55
AVEL	0.53	-0.55	-0.60	0.70	0.07	0.37	1.00	0.63	-0.46	0.64
MSL	0.92	-0.45	-0.32	0.96	-0.19	0.63	0.63	1.00	-0.79	0.98
MSS	-0.60	0.58	0.34	-0.73	0.21	-0.70	-0.46	-0.79	1.00	-0.76
CSD	0.93	-0.43	-0.31	0.96	-0.18	0.55	0.64	0.98	-0.76	1.00

In the other side, cluster analysis comprises of a series of multivariate methods which are used to find true groups of data or stations. In clustering, the objects are grouped such that similar objects fall into the same class (Danielsson et al., 1999). The hierarchical method of cluster analysis, which is used in this study, has the advantage of not demanding any of prior knowledge of the number of clusters, which the non-hierarchical method does. A review by Sharma 1996 suggests Ward's clustering procedure to be the best, because it yields a larger proportion of correct classified observations than do most other methods. Hence, Ward's clustering procedure is used in this study. As a distance measure, the squared Euclidean distance was used, which is one of the most commonly adopted measures (Fovell and Fovell 1994). The output of the R-mode cluster analysis is given as a dendrogram (Fig.7) and the Euclidean distances is given in Table 3. R-mode exhibits two major clusters. The first cluster domains the hydro-morphological parameters of A, BS, MFS, MSS, CSS, Sin and Shape beside AOFD and CMFD, while the second represents MFD, MSL, CSD and L with basin perimeter (P) as independent variable. This first cluster reflects the impact of both A and BS to generate peak flow (Gad, 2009 and Hassan and Gad, 2010). The second cluster reflects the impact of the slope on runoff generation.

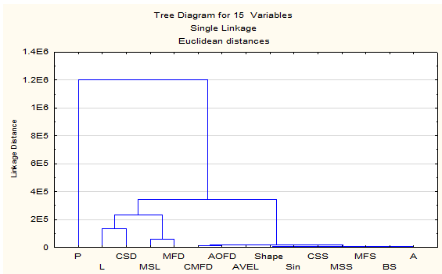

Fig. 7: Vertical icicle plot of the studied 15 hyro-morphometric parameters (R- mode) based on Euclidean distance

Moreover, the output of the Q-mode cluster analysis is given as a dendrogram (Fig.8). It is noticed that there are four major clusters when interpreted at similarity level with a distance 5000.

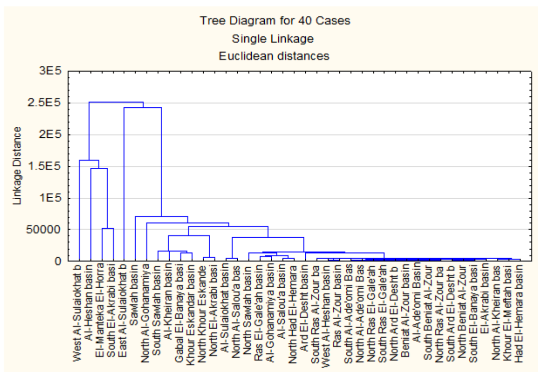

Fig. 8: Vertical icicle plot of the studied 34 basins (Q- mode)

The first cluster domains the basins south Ras Al-Zour, West Al-Heshan, Ras Al-Zour, South Al-Ade'omi, North Ade'omi, North Ras El-Gale'ah, South Ras El-Gale'ah, North Ard El-Desht, Beniat Al-Zour, Al-Ade'omi, South Beniat Al-Zour, North Ras Al-Zour, South Ard El-Desht, North Beniat Al-Zour, South El-Banaya, North Al-Kheiran, Khour El-Meftah and Had El-Hemara, with Ard El-Desht basin as independent variable. This cluster exhibits the minimum values of A (less than 70 km^2) and maximum values of BS (more than 0.01) and reflecting a tendency to form flash floods. The second cluster involves the basins North Had El-Hemara, Al-Salou'a, Al-Gohanamiya, Ras El-Gale'ah with Sawlah basin as independent variable. This cluster is characterized by small tendency to form flash floods and high tendency to recharge the shallow groundwater aquifers. The third cluster domains the basins North Al-Salou'a, Al-Sulaiokhat, North El-Akrabi, North Khour Eskander, Khour Eskander, and Gabal El-Banaya, with Al-Kheiran, South Sawalah, North Al-Gohanamiya, Sawalah and East Al-Sulaiokhat basins as independent variables. This cluster is characterized by its moderate potentiality to form flash flood. The fourth cluster domains South El-Akrabi and El-Manteka El-Horra basins. The independent cases involve Al-Heshan and West Al-Sulaiokhat basins. Their independence may attribute to the effect of geologic structure since the fault systems in the Ahmadi Ridge affect the eastern limestone plateau (Gad et al. 2017 &Gad and Abdel-Latif, 2003).

In the other side, Table 5 represents the results of the MCA technique for the watersheds of the 40 selected basins in the ECBK. The W_{SRF} was classified into 3 categories on a quantile basis. As a general, W_{SRF} values of the studied basins to receive disasters from flash floods (Table 5) exhibit high risk of basins Nos. B3, B35 and B36 (South El-Akrabi basin, El-Manteka El-Horra basin and Al-Heshan basin), while low risk basins (category two) represents 28% of the studied basins (14 basins). The rest of the studied basins belong to the moderately low and high risk category.

Table 5: The results of Multi Criteria Analysis (MCA) of the selected ECBK

Basin No.	A_{SRF}	BS_{SRF}	$AOFD_{SRF}$	MFD_{SRF}	MFS_{SRF}	$CMFD_{SRF}$	CSD_{SRF}	CSS_{SRF}	MSL_{SRF}	MSS_{SRF}	L_{SRF}	P_{SRF}	$Shape_{SRF}$	Sin_{SRF}	$AVEL_{SRF}$	W_{SRF}	Hazard degree
B1	55.02	0.008	343.66	13772.2	0.0023	127.28	6121.1	0.0008	13158	0.002	10103	46930.7	1.855	1.3024	12.1163	1.312	**low**
B2	134.7	0.009	323.63	25576.1	0.0016	0	11997	0.0006	24670	0.0013	19023	83205	2.6868	1.2968	18.9679	1.601	**low**
B3	5123	0.007	329.91	341494	0.0011	180	158133	0.0015	340790	0.0011	229622	968504	10.2917	1.4841	229.864	9.115	**high**
B4	45.21	0.008	342.39	11981.2	0.0022	402.49	5289.3	0.0001	10768	0.0009	9020.2	38469.9	1.7999	1.1937	9.9621	1.089	**low**
B5	433.6	0.008	349.77	80948.8	0.0023	829.76	45306	0.0017	80080	0.0022	56451	223798	7.3493	1.4186	94.2692	3.601	**mod low**
B6	321.1	0.008	331.06	69257.9	0.0024	509.12	40103	0.0017	68299	0.0023	46430	171584	6.7137	1.471	69.9421	3.215	**mod low**
B7	635.9	0.009	336.94	81693.2	0.0026	63.64	47908	0.0023	80750	0.0025	60752	226959	5.8043	1.3292	108.153	3.539	**mod low**
B8	28.02	0.008	305.05	17264.1	0.0018	524.79	6974.8	0.0012	16215	0.0017	11701	44505.4	4.887	1.3857	10.7961	1.69	**low**
B9	267.2	0.008	331.6	59538.7	0.0026	0	26889	0.002	58617	0.0024	46174	159348	7.9785	1.2695	59.8555	2.983	**mod low**
B10	56.44	0.006	365.84	16068.1	0.0017	63.64	6367	0.0004	15528	0.0015	12436	48311.5	2.7401	1.2486	8.6266	1.171	**low**
B11	18.71	0.008	328.25	12315.7	0.0078	190.92	6361.1	0.0127	11633	0.0079	9419.5	34796.6	4.742	1.235	15.2332	2.477	**low**
B12	393.4	0.009	322.4	61985.3	0.0028	63.64	32400	0.0021	61206	0.0026	44799	173768	5.1017	1.3662	76.4737	2.957	**mod low**
B13	62.53	0.008	315.1	30985.9	0.0024	63.64	13379	0.0024	30154	0.0023	21657	75632.5	7.5006	1.3923	37.5705	2.457	**low**
B14	843.7	0.01	339.42	91345.1	0.0022	318.2	48209	0.0022	90423	0.0022	62907	286018	4.6907	1.4374	116.292	3.756	**mod low**
B15	126.7	0.008	325.45	25421.7	0.002	324.5	10194	0.0009	24627	0.0018	17294	79315.7	2.3612	1.4241	13.6315	1.598	**low**
B16	103.8	0.01	332.67	42781.1	0.003	254.56	20681	0.0026	41837	0.003	32212	112194	9.9962	1.2988	54.158	3.163	**mod low**
B17	545.9	0.009	358.83	70999.1	0.0028	63.64	37261	0.0024	70422	0.0028	50818	187444	4.7306	1.3858	98.903	3.243	**mod low**
B18	267.2	0.008	32051.9	65662.2	0.0023	17715.6	5525.7	0.0012	5870.2	0.0009	39423	175895	5.8171	0.1489	71.1428	3.573	**mod low**
B19	47.26	0.009	334.23	22377	0.0037	402.49	9374.9	0.0019	21291	0.0037	16635	61519.5	5.8552	1.2798	27.6413	2.203	**low**
B20	62.73	0.011	379.84	18151.7	0.005	201.25	10560	0.0029	17537	0.005	13434	48795	2.8773	1.3054	36.336	2.121	**low**
B21	41.54	0.013	422.49	14366.8	0.0065	0	6507.5	0.0054	13678	0.0064	10419	40161.1	2.613	1.3128	45.0461	2.374	**low**
B22	15.25	0.014	437.9	11773	0.0082	201.25	5441	0.0081	10888	0.0083	9412.2	28303.6	5.8083	1.1568	51.9306	2.976	**mod low**
B23	11.21	0.014	373.45	10594.6	0.0094	180	5969.9	0.0103	9560.9	0.0096	8350.1	26689.3	6.2197	1.145	68.7122	3.254	**mod low**
B24	16.03	0.017	365.79	10554.8	0.0095	0	5203.8	0.0099	9775.7	0.0099	8651.7	27637.9	4.6695	1.1299	59.9355	3.2	**mod low**
B25	31.06	0.019	421.27	12474.7	0.0138	270	7710	0.0155	11366	0.0138	9813.7	34684.7	3.1012	1.1582	62.172	3.782	**mod low**
B26	23.57	0.021	474.84	10994.4	0.0159	509.12	7179.8	0.0175	10215	0.015	8891.3	28223.9	3.354	1.1489	59.8595	4.183	**mod low**
B27	17.15	0.019	445.61	10095	0.0176	360	5920.4	0.02	9263.1	0.0171	8280.5	27074.4	3.9986	1.1187	53.1233	4.277	**mod low**
B28	27.22	0.022	442.43	11990.3	0.0147	284.6	5928.3	0.019	10836	0.014	9432.8	30333.6	3.2684	1.1487	46.5053	4.089	**mod low**
B29	29.01	0.017	389.12	11419.4	0.0142	63.64	5563.8	0.0211	10513	0.0146	8631.1	33061.8	2.5683	1.218	55.8116	3.823	**mod low**
B30	7.55	0.016	428.81	5478.31	0.0213	90	2750.1	0.0307	4736.5	0.0232	4829.9	15585.8	3.0901	0.9807	19.525	4.448	**med**
B31	14.98	0.014	372.72	10900.4	0.0127	180	5003	0.0176	9745.9	0.0133	8805.3	29446.9	5.1769	1.1068	28.2623	3.47	**mod low**
B32	20.96	0.013	309.78	9003.11	0.0035	127.28	4666.6	0.0015	8351.3	0.003	7564.8	30033.6	2.7299	1.104	17.739	1.63	**low**
B33	85.94	0.013	342.67	26108.6	0.0032	190.92	14076	0.0023	25329	0.0029	19148	71967	4.2664	1.3228	33.0159	2.301	**low**
B34	17.29	0.01	339.25	9868.7	0.0101	360	6137.7	0.0142	9074.1	0.01	7736.3	29981.2	3.4625	1.1729	21.5567	2.702	**mod low**
B35	5325	0.006	323.54	357790	0.001	270	197303	0.0013	357176	0.001	212249	948530	8.4599	1.6828	234.189	9.316	**high**
B36	5219	0.006	314.8	316262	0.0012	284.6	155085	0.0018	315701	0.0011	209372	820902	8.399	1.5078	258.769	8.61	**high**
B37	35.19	0.012	313.41	15111.3	0.0028	180	7242.9	0.0013	14332	0.0026	9664	41626.5	2.6536	1.483	14.9142	1.839	**low**
B38	1143	0.007	333.38	183056	0.0017	284.6	83893	0.0028	182351	0.0017	135957	473496	16.1691	1.3412	205.071	6.596	**med**
B39	264.5	0.015	426.81	40008.7	0.0044	509.12	19867	0.005	39230	0.0043	28856	112338	3.1483	1.3595	105.016	3.137	**mod low**
B40	4017	0.006	319.06	250708	0.0015	270	126592	0.0022	250094	0.0015	189248	695553	8.9165	1.3215	265.427	7.552	**mod high**

The low risk category includes the rest of the studied basins (14 basins with 28%). From the results in Table 5, it was found that all catchments with large drainage area have a high W_{SRF} value, and as a result, it causes skewness to the resulted W_{SRF} values for all the other sheds (Fig.9-left chart).

Therefore, almost all of watersheds have a low to moderate flood risk factor (category 2). The drainage area (A), as a main parameter directly affecting the value of flood peak flow, was plotted to test it for extreme high values that may affect the results (Fig. 9).

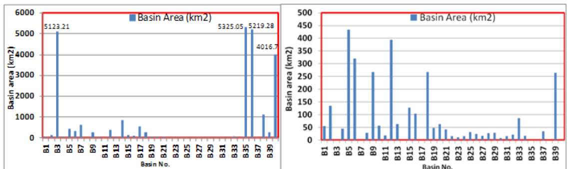

Fig. 9: Plot of hydro-morphological outliers values of A (left chart) and BS (right chart) of the selected ECBK

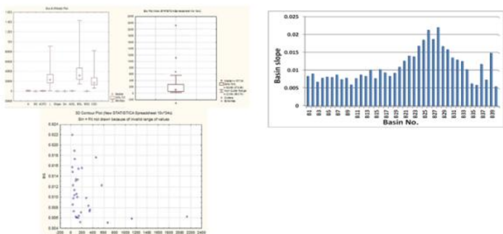

Fig. 10: Box plot of non-parametric hydro-morphological variables (extremely high basin area A showing its skewness in upper chart) and the relation between A and BS (lower chart) of the studied ECBK

Otherwise, from (Fig.9), it was noticed that three main basins area is extremely high (more than 5000 km^2) while all the other values falls below 500 km^2. In addition, the Basin Slope (BS), as another main parameter directly affecting the value of flood peak flow, was noticed from Fig. 10 that two main basins areas are extremely high (more than 0.02) while all the other values falls below 0.01. More over, box plot technique (Fig.10) is useful to display differences between populations without making any assumptions of the underlying statistical distribution. It is non-parametric. Spacing between the different parts of the box help indicate the degree of dispersion (spread) and skewness in the data, and identify outliers.

IV. CONCLUSION AND RECOMMENDATIONS

Flash flood protection measurements depending solely on recurrence interval have been adopted for long time without giving weight to the hydro morphological parameters of the watersheds that cause such floods. The paper presented the use of multi criteria analysis technique to use these parameters when defining the design flash flood events. It was noticed during the analysis that the drainage basin area and basin slope have great effect on the floods generated at its outlet while other factors have less effect than the drainage area and basin slope such as the shape factor and sinuosity factor.

During the analysis, a higher limit for all the parameters values was adopted based on the sample that was concerned during the analysis to calculate the standardized factors. The box plot test represented a very useful, easy to use and quick tool when trying to exclude extremely high parameter that may lead to unrealistic risk factor especially for small parameter values. However, using regression techniques, a maximum values can be calculated/estimated for any region for the purpose of defining the upper limit of each parameter depending on the meteorological characteristics of this region.

The weighted standardized risk factor obtained can be used during the design of flash flood protection measurements and /or the calculation of design of peak flows for crossing structure. This may lead to more economic design procedure that can be adopted in drainage design guidelines and manuals. However, further studies should be made concerning the environmental hazard of the flash flood events and special intention should be made when trying to control floods to keep the environment. Field measurements are highly recommended to verify the results of MCA procedure used in this work.

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