Eco. Env. & Cons. 20 (3) : 2014; pp. (845-851)
Copyright@ EM International
ISSN 0971–765X

Calculate the flood hydrograph for Karun Basin, Iran

Saeid Shabanlou[1] and Ahmad Rajabi[2]

[1,2]Department of Water Engineering, College of Agriculture, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran

(Received : 7 May, 2014; accepted 15 June, 2014)

ABSTRACT

In structural and un-structural methods of flood control, it is necessary to predict flood potential in the water closed basin. In this research, the purpose is simulating flood in the basin of SCS hydrologic model of HEC-HMS and comparing with mod-Clark method by doing geographic information system (GIS) in Golestan watershed was performed. Finding a model that can properly predict floods at large and sensitive basins like Karun the largest river in Iran is necessary. Because of being prone to flooding, identifying areas prone to flood and flood production levels according to physical characteristics of the catchment is essential. In this research, hydrologic modeling was performed on the Karun Basin, and tried to estimate flood hydrograph through both lumped and distributed mathematical models to analyze how close they are in reality from Karun basin to Shalou Bridge. In this method by topography maps created basin DEM in the environment of (GIS) software. by used of created DEM, canals and sub-basin maps mine and with mixing soil hydraulic group maps it make ground user and data of previous moisture in (GIS) environment of CN (number curve) map of Karun under watershed then it measure and credit with raining data and observation running of watershed fixing in HEC-HMS model and at the end it compare by mod-clark method with in software environment of (GIS) geographic information system. Formation of precipitation and surface flow after rainfall and formation of hydrograph has been studied using both SCS lumped model and Mod-Clark (modified Clark) distributed model and it is identified the distributed model results are closer to the recorded hydrograph of the basin.

Key words : *Lumped methods, Distributed methods, Mod-Clark, SCS, HEC-HMS*

Introduction

Flooding problem has been one of the numerous Khuzestan plain problems that have been raised. Recorded and even nor recorded floods before the establishment of the hydrometric stations and the damage caused by them indicates the region to be prone to flooding. Comparing peak discharge and floods damage before and after the construction of Dez and Karun dams in the Khuzestan plain represents the dams' ability in flood mitigation and damage reduction of downstream floods.

Great national investment in the Khuzestan plain and the importance that this area has in agricultural and industrial development of the areas, the great Khuzestan plain protection from overflow and preventing the region from going under water has made it inevitable. In this context, flood forecasting using advanced methods and geographical data system to aggregate information for basins and their use in forecasting models is essential.

Following increase in population; increasing and consumption competition, conflict and contradiction in how the exploration of rivers would be is grow-

***Corresponding author's email:** saeid.shabanlou@gmail.com; ahmadrjb@yahoo.com
[1, 2]Ph.D. Hydrology and Water Resource

ing. True understanding of the country catchments and characteristic and the natural behavior of rivers in order to perform maintenance and good management for the health of rivers the life of society is essential and inevitable. The overall object of this research is also finding a model to predict a correct and close idea of a flood. Using computer hydrologic models such as HEC-HMS and GIS, a proper method to obtain desired information about flood damage can be presented. Also special and applied objectives of this research are identifying more accurate methods for calculating the hydrograph of the flood basin and comparing lumped and distributed models of basin outflow calculation.

Savant *et al.* (2004) examine the mentioned program ability and compared the extracted physiographic parameters in the Upper Rearl basin located in Mississippi river with USGS data. In this research the basin boundary and the extracted sub-basins were introduced as most important physiographic parameters and have been used as a benchmark for evaluating the method performance. The results of this study indicate that the application of HEC-Geo HMS is corresponding with data from the USGS. Saghafian and Khosrowshahi (2005) using satellite imagery GIS prepared Damavand basin vegetation map and then in the GIS environment using ArcView software combined user map of farms and soil hydrologic groups and calculated the curve number CN for the entire basin and sub-basins. Then using HMS hydrologic model and SCS method design got the hydrograph design caused by rainfalls (12-hour rainfall with are turn period of 50 years). They combined HMS model with three rainfall runoff observed events, and were calibrated to determine the flood-producing rainfall, average rainfall of each sub-basin at the time of flood in Arc View environment and was introduced to the model. In this study for the flood routing Muskingum method was used and finally, the intensity of sub-basins flood rise prioritized with regard to their participation in the total output discharge of the basin. Khalfe *et al.* (2006) developed a model to predict excessive shear in basin that used Hec-GeoHMS program to extract basin physiographic characteristics. After calibration and validation, the model results indicate the high accuracy of the model. Wang *et al.* (2006) emphasized on modifying DEM and fill the empty spaces of data and also provided a model based on the programming language C + +. The model accuracy is based on comparison with HEC-Geo HMS program. These comparisons suggest that the model has an acceptable accuracy. In Ankara University Department of Engineering Science, a study carried out on Yvachyk basin located in southeastern Turkey. Basin simulation using software HEC-HMS and HEC-GeoHMS took place. Using GIS information and maps of the area and after modeling, flood hydrographs were obtained (Yener and [a]Orman, 2008). Abu Hasan *et al* (2009) using HEC-HMS developed a hydrologic model for the Sangay Kiovara basin in Prague and evaluated this basin's hydrologic response to land use changes. They converted DEM to HEC-HMS import files using HEC-HMS. Then, they calibrated the hydrologic model for storms during 2004 and evaluated for storms during 1999 and consistency of the simulated model with observed data shows that HEC-HMS is a suitable model for predicting hydrological changes of the Kiovara basin. Khakbaz *et al.* (2009) calculated Clark instantaneous unit hydrograph and its Geomorphology instantaneous unit hydrograph GIUH parameters using GIS. They studied the basin located in northern Khorasan called Kardeh. He used GIS software to gain basin Hydrographic specification and then proceeded to calculate Clark instantaneous unit hydrograph. A joint was conducted investigation by the Department of Civil Engineering, Environmental Engineering, and Center for Remote sensing and Hydrometeorology of American University of California on Illinois River basin of Arkansas State. In this study, rainfall - runoff system of basin was stimulated by semi-distributed and lumped models. Then using the recorded output hydrograph of the basin, calibration was done and outflow discharges of the models were calculated (Khakbaz, 2009). Generally two categories of climatic and basin factors are involved in creating floods. Source of many floods, especially in arid and semi-arid regions is rainstorms with high intensity and relatively short persistence of events. Thus in storms review, continuation, intensity and their spatial and temporal distribution in flood formation should be considered. One of the most important basin factors, land use, geological situation, vegetation, area, and slope and drainage network could be noted. The level of participation of each of these factors in flood formation is called flood formation potential expressed that land use changes could have significant impact on basin hydrologic characteristics and also examined this effect in the Sungai Kuran basin based on flood

peak discharge using HEC-HMS. In this study, HEC-GeoHMS is used to extract the basin physiographic characteristics. After calibration and validation, the model results indicate the high accuracy of the model.

The overall goal of this research is to find a specific model to predict flood closer to reality. Also the specific goal of this study was identifying practical and more accurate method for calculating flood hydrograph of basin and comparing the Lumped and distributed model for computing flood of basin.

HMS Model

HMS model is the Windows version of HEC-1 model. HMS model was presented by the hydrologic center of US Corp of Engineers to supply the flood's hydrograph in 1981 and after that, so many changes were made on that and finally in 1998 presented as HMS and under the license of a Windows. HMS is one of the computer mathematical models which consists of some subcategories as runoff sections, the surface flow, the base flow and the total flow and they are used to simulate the hydrologic behavior of the basins. His model includes three main sections by the names of Basin Model, Meteorological Model and Control Specification. In addition, this model is able to optimize and calibrate the parameters. This model can be used for simulation and predicting the effects of the parameters' variation after validation.

Model Calibration

Every model which exists in HEC-HM has some parameters. The amount for every parameter must be determined in order to estimate the runoff and the flood hydrograph. How can suitable adjustable values be chosen for every parameter? In case of having observable rainfall and runoff, calibration will be the answer of this question. Calibration makes use of the observable hydroclimate data in order for the parameters to be determined to make the best fit between the observable and simulated results in a systematic study. This study is often called optimization. Calibration starts with the collection of the data. The time periods of rainfall-runoff are the required data for the rainfall-runoff models. The model by means of the primary amounts can measure the considered output (the runoff hydrograph). In this research, the data of 10 floods, which had more complete hydrographs compared to the other floods happened, were chosen from 2001 to 2009. 5 floods among the 10 floods were chosen for calibration and the other 5 floods were used for validation assessment.

HEC-GeoHMS extension

HEC-GeoHMS is an extension used with Arc GIS. This program is software on GIS which was developed with ESRI to analyze all the spatial data for using on HEC-HMS. The version no. 4.2.93 of this program is procured by ESRI and HEC cooperatively.

This software has got some geographical data to be used in HEC-HMS. In addition, in this software environment, one can observe HEC-HMS output results graphically. This program makes the input file by means of the acquired data taken from ArcGIS shape files and DEM of the region under study. Thus, it is necessary to have a DEM described in a disordered triangular network mould. The layers made from these data are called HMS layers. The geographical data are deducted from the measurements carried out on these layers. The background drawings, the basin model files, the meteorological model files which can be used in HEC-HMS for hydrologic modeling are among the other capabilities of this model. The basin model file consists of hydrologic elements, their relation and also includes the surface of sub-basins and some other hydrologic parameters.

HEC-SSP Software

HEC-SSP software is a version under the license of Windows software, HEC-FFA, which is very strong software to perform statistical analyses of hydrologic data. It is also used to control the outliers. A proper return period is taken into consideration for these floods with respect to the floods happened earlier. HEC-SSP will make you able to have a statistical analysis of the hydrologic data to the users. The first official version of HEC-SSP was published in August, 2008 and also the version 2.0 was published in April, 2010 which made it easy to revise the data, show the results, reports and it also made it easy to analyze the volume-time frequency.

Results and Discussion

The Great basin of Karun in the Zagros highlands has surgical borders with Karkheh, salt lake, Zayandeh roud river, Bakhtegan - Maharlu and Zohreh-Jarahi basins. The basin in the division's of-

fice of water resources was marked as the third basin among Persian Gulf catchment. The Great Karun catchment consists of the Dez and Karun Rivers in the Zagros highlands are limited to geographical coordinates 00-48 to 30-52 degrees east longitude and 30-00 to34.05 degrees North longitude. The catchment area is 67,257 square kilometers, 67 percent of it is in mountainous areas and high plains are form its 33 percent of area.

Karun Basin to Shahid Abbas pour Dam is called Karun upstream catchment and our study zone is to Shalou bridge with the area of 23,400 square kilometers and the geographical location of 31-45 to 20-32 north longitude and 8 -50 to 40-51 east longitude. This range consists of three main sub-basins (Khorasan, Bazaft and upper Karun) and four minor sub-basins Vanak, Koohrang, Bazaft and Behesht Abad. (Fig. 1)

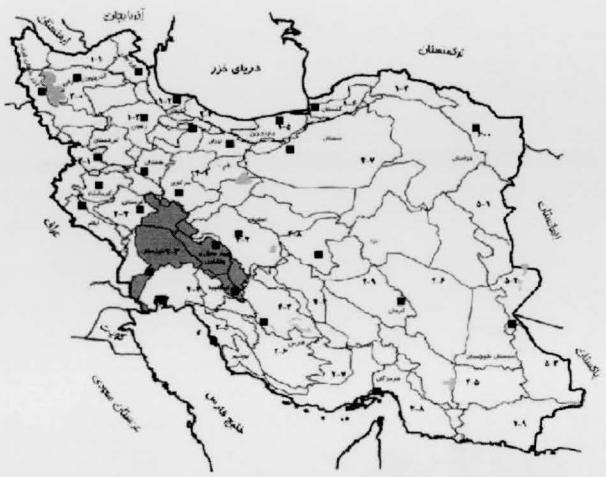

Fig. 1. Study area location in IRAN

The Highest Point in this region is the Dena with the height of 4409 meters and its lowest point is located in Shalou Bridge with the height of 700 meters. The study area is approximately 76% mountainous. 95% has over 1500 m elevation and 25% is above 2500 meters elevation. Over 14% of the area makes up the great alluvial fan. Hill areas are 4.7% and sedimentary plains 3.9% and river terraces 1.1% of all the area.

Research-based design method is based on using Clark developed method (Mod-Clark) in HEC-HMS environment for simulating peak flood of output hydrographs in the Karun catchment. In This method factors affecting runoff production and flooding in cell surface are identified and in the form of input data and mathematical models are quantified. Then by analyzing simulated hydrographs with this method with simulated hydrographs using SCS cumulative method are compared.

Modified Clark model (Mod-Clark) in HEC-HMS is a kind of distributed model. This model uses an explicit model to analyze the travel time changes to reach the output of the watershed of all catchment areas. As the Clark Hydrograph model, runoff calculations in the modified model explicitly and by considering conversion and storage are considered. Storage tank with the same amount of linear tank model that is used in the Clark model and the conversion process by using networks navigation time model are taken into account.

In the modified method of Clark, a hypothetical network is given on the basin. For each cell of the network that represents the basin, distance to basin outlet is determined. In this case to calculate the conversion time to the output the following relation is used:

(1)

$$t_{cell} = t_c \frac{d_{cell}}{d_{\max}}$$

t_{cell} = travel time for each cell

t_c = basin time of concentration

d_{cell} = distance to move from each cell to the outlet of the basin

d_{max} = movement distance for the cell that has the most distance to the outlet

Each cell area is marked and based on this area, the inflow volume to the linear reservoir for each period of time, which is due to excess rainfall, is calculated. Excess rainfall equals the difference between the Mean Areal Precipitation in each cell and the amount of cell loss. Inflow into the linear reservoir has been routed and creates output hydrograph for each cell. HEC-HMS combines the cells output hydrograph and determines the direct runoff hydrograph of the whole basin.

Among 226 stations with data available, 97 stations that have better data and shared with the hydrometric stations were statistically analyzed are located. Accordingly, 87 stations are within the Great Karun basin. Since the statistical periods are different in stations and since 1956 until recent years, some stations were opened .after analyzing and adequacy test of the data, statistical indicators

of the years 1963 to 2007 were selected. Among the stations mentioned some of them were newly established and some had too many missing statistics on their test results, as a result their statistics were not sufficient in the goodness fit test and were removed. Remaining stations were completed and verified.

Firstly, the discharges were measured in the available stations were revised and complemented. Then by sending them to the statistical software, HEC-SSP2.0, different discharges were measured with different returning periods. In the study area range 60 of the stations were equipped with rain gauges and to determine rainfall pattern the statistics of these stations were used, and rather important recorded rainfalls were extracted from these stations. The Basin physiographic parameters in the first stage using the HEC-GeoHMS software as an extension installed on ArcMap were calculated. With HEC-GeoHMS extension installation in ArcMap, the extension ArcHydro will also be installed.

The HEC-GeoHMS provides the basin model using Mod-Clark method for HEC-HMS software and can save all the necessary characteristics for flood calculation and routing within certain cells with desired dimensions. As mentioned above, the program input is the digital elevation model (DEM) of the basin after various stages, makes the basin model for the HEC-HMS program.

To simulate flooding by Mod-Clark distributed method CN raster maps should be obtained. At this stage, combining two layers of soil and land use by the Arc CN-Runoff application, land-use-oil type layer was created and then by providing Curve Number Lookup table, the data necessary to calculate and create CN raster map is formed (Fig. 2).

After the output file HMS was produced using HEC-GeoHMS software and refreshing it that consists of basin model and meteorological model, are lumped and distributed by different methods. For the Distribution method that the basin is divided into smaller levels and effective rainfall in each level is calculated and became direct runoff, the rainfall networking method is used and the related networking data will be chosen. In this file to describe each cell in the database, each cell location, navigation to the output gap, cell size and cell CN and precipitation of time are included. In the lumped approach, rainfall and loss are determined to the total average of the sub-basin. In this study to calibrate and validate the model, the hydrograph of all available floods have been investigated and finally, five events for calibration and five events for validation of the model were selected.

Conclusion

After calibration and considering the information that was mentioned and the maximum 24-hour rainfall per each return period of 2 to 100 years, we tried to estimate the peak and flood hydrograph in Mod-Clark distributed approach and SCS lumped approach. Fig. 3-5 and Table 1 below show flood hydrograph under the basins. These hydrographs by means of basin modeling and using HEC-HMS were obtained. Distributed hydrological models by having the ability to change spatial characteristics of the basin and rainfall data have high potential for improving flood hydrographs simulation. Accord-

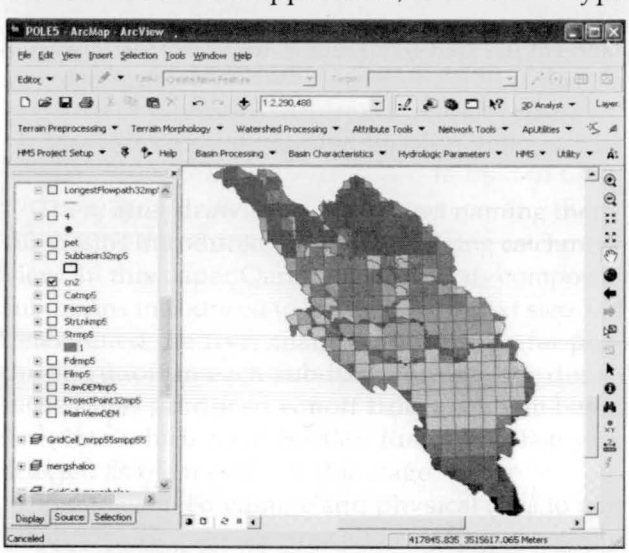

Fig. 2. Layer Networking Curve Number

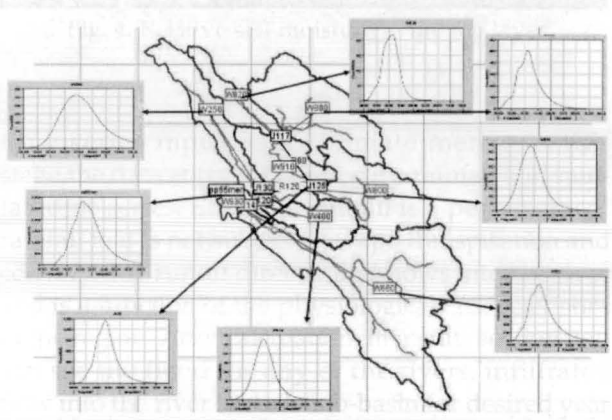

Fig. 3. Sub-basins hydrograph outline

Table 1. Floods discharge per different return periods

Return Period (year)													
100		50		25		10		5		2		Station	river
Mod.cl	SCS	Mod.cl	SCS	Mod.cl	SCS	Mod.cl	SCS	Mod.cl	SCS	Mod.cl	SCS		
470.2	485.9	364.6	377.6	272.7	285.5	175.6	189.2	125.5	138.2	75.2	88.4	Morghak	Bazeft
203.5	206.5	139.9	144.1	90.9	94	44.2	47.9	25.8	28.9	18.3	22.1	Lordegan	Lordegan
565.8	544.6	403.6	394.6	301.2	272.1	170.8	159.7	112.1	97.5	64.1	54	Barez	Khersan
739.5	752.8	553.8	560.9	386.6	395.3	207.3	218.9	124.2	130.1	40.9	48.3	Pol Karbas	Abvanak
248.8	256.4	182.2	185.8	121.9	126	63.1	65.3	31.7	36.8	11.3	13.4	Kaj	Kohrang
386.8	399.8	261.6	267.8	163.3	166.9	69.9	76.6	39.4	42.3	20.4	25.4	Behesh-tabad	Behesh0-tabad
2282.6	2308.5	1585.6	1610.6	1000.6	1036.8	572.7	597.7	371.5	385.6	168.1	193	Pol shalo	Karun
1297.8	1276.3	882.6	865.6	547.7	539.6	264.5	254.3	161.1	149.4	72.7	61.8	Armand	Karun

Mod. Cl. (Mod. Clarck)

ing to the following reasons distributed models and their results are closer to the recorded hydrograph in the basin:

Considering the range of changes of soil properties, hydrologic groups and finally the curve number in the basin, providing these characteristics for the model on spatial average in the entire basin as it is used in lumped method, would reduce the accuracy of forecasts. Particularly in the Karun basin precipitation across the basin according to elevation change is too severe. This is true for the curve number SCS determination.

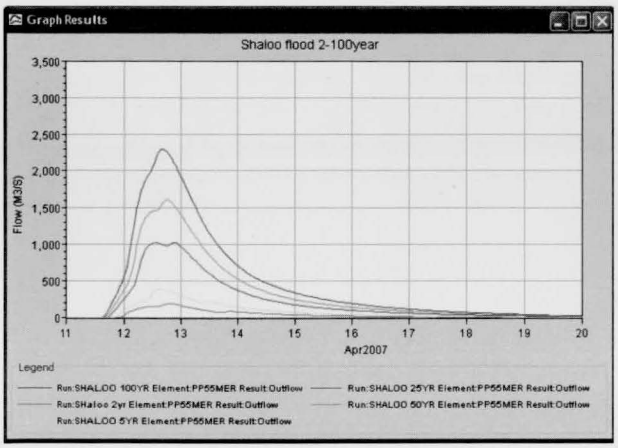

Fig. 4. Hydrographs in Shalou bridge per different return periods

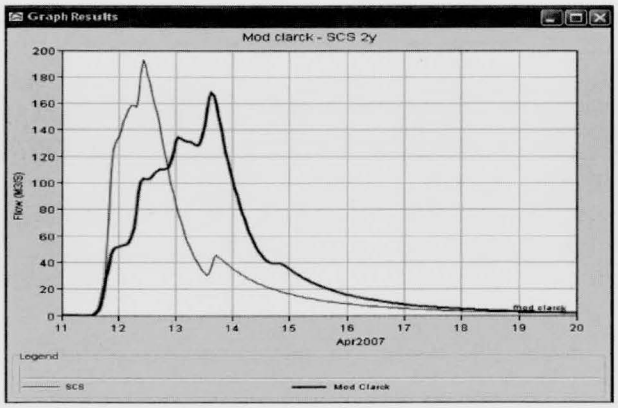

Fig. 5. Comparison of flood hydrographs in Shalou bridge using SCS and Mod-Clark

Due to powerful GIS tools like ArcGIS that different extensions applications about basin can be installed on, the usages of distributed models has a great importance and have made operations easier.

The drastic changes in recent years that created in basins such as land use changes, climate change and also the construction of dams and facilities has challenged predictions on lumped models. Impact of these changes easily forecasted considering the possibility of quick applying in GIS maps and the communication these maps have with distributed models.

Studies on various factors affecting the production of flood, like CN, permeability, indicators related to land and vegetation according to the GIS tools through modeling in distributed methods have been possible and will have high accuracy and its results will be beneficial.

References

Abu Hasan, Z., N. Hamidon and M. Suffian, 2009. Integrated River Basin Management (IRBM): Hydrologic Using HEC-HMS for sungai kuran basin, perak. International conference on water Resources. pp. 63-70.

Jahnson, C.A., A.C. Yange, K.R. Nixon and D.R. Legates. 2001. The use of HEC-Geo HMS and HEC-HMS to

perform Grid-based Hydrologic Analysis of a watershed, Dodson and Associates, INC-Hovston, Texas, USA. 135 p.

Khafle, T.P., M.K. Hazarika, K.G. Shrestha, K. Prathumchai and Samarakoon, L. 2006. Integration of remote sensing and GIS with flood simulation model for flood hazard mapping in the Bagmati River, Nepal, *Proc. Fifth International Symposium* on New *Technologies for urban safety of Mega Cities in Asia, Phuket,* Thailand. pp. 78-86.

Khakbaz, B., K. Hsu, B. Imam and S. Sorooshian. 2009. From lumped to distributed via semi-distributed: Calibration strategies for semi-distributed hydrologic models. *Journal of Hydrology.* 418–419: 61–77.

Saghafian, B. and M. Khosroshahi. 2005. Unit response approach for priority determination of flood source areas. *Journal of Hydrologic Engineering.* 10(4) : 270-277.

Savant, G., L. Wang and D. Traux. 2002. Remote Sensing and Geospatial Applications for Watershed Delineation. Conference Proceedings: Integrated Remote Sensing at the Global, Regional and Local Scale. *IAPRS.* Vol. XXXIV, Part 1, 182p.

Sunwan Werakamtorm, R. 1994. GIS and hydrologic modeling for management of small watersheds. *ITC Journal.* 4: 343-348.

Wang, L. and Lin, H. 2006. An efficient method for identifying and filling surface depressions in digital elevation models for hydrologic analysis and modeling. *International Journal of Geographical Information Science.* 20(2): 193-213

Wurbs, R.A. 2006. Methods for Developing Naturalized Monthly Flows at Gaged and Ungagged Sites. *Journal Hydrologic Engineering.* 11 : 55-64.

Yener, M. and A. ªOrman. 2008. Modeling Studies with HEC-HMS and Runoff Scenarios in Yuvacik Basin. Department of Civil Engineering, Middle East Technical University. 06531 Ankara/Turkey. 153p.