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EVALUATION OF THE HEC-1 MODEL FOR FLOOD FORECASTING AND SIMULATION IN THE HORMOZGAN PROVINCE, IRAN

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Frequent flood occurrences in the Hormozgan province in the south of Iran cause immense damage to infrastructure, parts of cities and numerous villages, and also claim a number of lives. To study floods of this province, and a means to control them, an integrated plan in a multidisciplinary perspective was formulated with a focus on the hydrology of the province. The main obstacle for hydrology studies was the availability of discharge data. Because of this problem, rainfall-runoff simulation was identified as the better way to analyze flood hydrographs and frequency. To acquire data, more than 90 rainfall stations and 20 discharge stations in the province and surrounding areas were analyzed. For proposed simulation we assessed different models, and from them we selected HEC-1. Results of wide implementation of this package to the study area show its good performance for flood simulation and prediction, but some points should be considered. These are discussed in the paper.

INTRODUCTION

Hormozgan province is located in the south of Iran on the Persian Gulf. Although the average of annual rainfall is less than 250 mm, severe floods frequently occur in the province causing huge damage. The main reasons for these high flood peaks could be its special location, which is influenced by several rain systems, physiographic conditions, and lack of vegetation cover. The watershed of the province includes three main watersheds, namely the Shaheli, Kol and Minab. These watersheds include several subbasins, and have a combined area of 100,000 km^2. Figure 1 shows location of the study area, streams and their tributaries.

Numerous discharge-gauging stations exist in the study area, but unfortunately most of them have short-term records. In many cases the stations were destroyed during flood events and they could not record the flood hydrographs. The locations of some of the discharge–gauging stations are also shown in Figure 1.

The flood which occurred during 4th to 8th of February 1992 was a unique flood which had never occurred before in the province, given the area affected and size of the flood. For this flood, 12 hydrographs and 16 hyetographs have been recorded. In addition 45 rain-gauge stations during the period recorded the daily rainfall depths. These data, together with some local information, some of which was obtained from eyewitnesses to the flood, made it possible to use the HEC-1 model. Some similar data were also prepared from previous floods.

THE HEC-1 MODEL

HEC-1 is a computer model for rainfall-runoff analysis developed by the Hydrology Center of the U.S. Army Corps of Engineers (USACE, 1985). This program simulates discharge hydrographs for either historical or hypothetical events for one or more locations in a basin. The basin can be

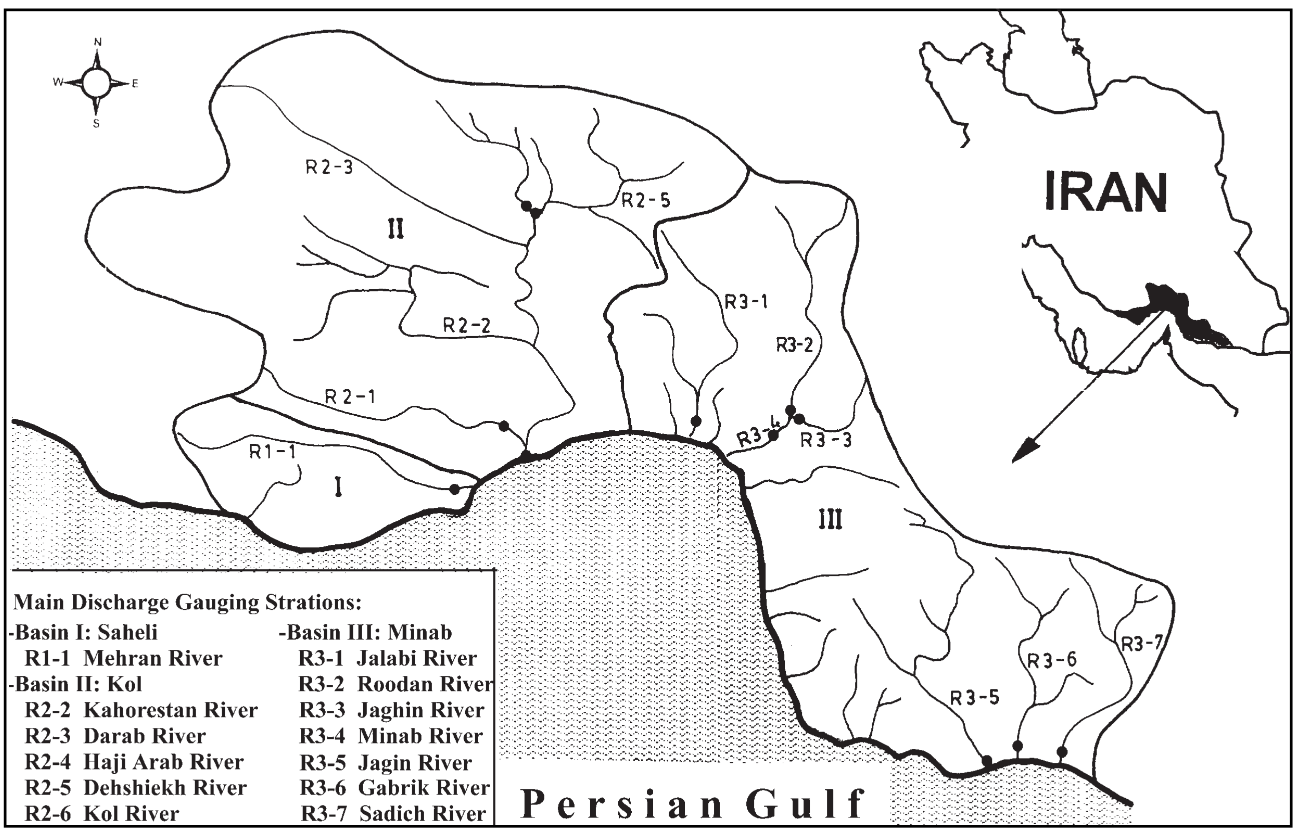

Figure 1. Location of Hormozgan Province and its main rivers.

subdivided into many subbasins. Uncontrolled reservoirs and diversions can be accommodated as well.

The available program options include the following: calibration of unit hydrograph and loss-rate parameters, simulation of snowpack processes and snowmelt runoff, dam safety applications, multiplan/multiflood analysis, flood damage analysis, and optimization of flood-control system components.

The 1990 version of HEC-1 (USACE, 1991) also has the capability to communicate with a data storage system (DSS) file. The DSS is a database system that is designed for efficient storage and utilization of time series data between various Hydrologic Engineering Center Programs. In this version, the problem of working with SI units that existed in the 1985 version has been solved.

Conversion of Rainfall to Flood, Using the Unit Hydrograph

For this option HEC-1 needs rainfall data and its temporal pattern, which has a significant impact on the flood hydrograph shape. Regarding the rainfall losses and unit hydrograph, HEC-1 uses various methods of which the Curve Number (CN) and Snyder methods were applied for these purposes. This option of HEC-1 was employed for the basins with area less than 5000 km^2.

Parameter Calibration

The calibration option in HEC-1 is one of the unique capabilities of this model. Given the simultaneous flood and rainfall, the model calibrates the required parameters for simulation such as CN and the unit hydrograph parameters.

Conversion of Rainfall to Flood, Using the Flood Routine

This option of the HEC-1 was used for basins of area more than 5000 km^2. The model offers different methods for this task. The Kinematic Wave method was selected because of the possibility of preparing its parameters.

ASSESSMENT OF THE HEC-1 MODEL

In this section, we present results of the application of various options that were mentioned earlier. A brief justification and inference for them is also given.

Calibration

To estimate required parameters (for converting rainfall to flood, using unit hydrograph), including CN, Tp and Cp, 18 floods and their corresponding hyetographs were used for calibration.

For assessment of this option, results of two runs are shown in Figures 2 and 3. For the flood of February 1992, an instantaneous peak of 4682 cubic meters per second (cms) has been recorded, and for the same period the estimated peak was 4323 cms, which are very close together. For this flood event, estimated CN, Cp, and Tp are 82, 41 and 25 respectively, which are very logical. But for another event that occurred in January 1993, the observed and estimated floods are 239 and 1620 cms and the estimated CN, Cp, Tp are 41, 0.01 and 1.83 respectively, which are not reasonable. We obtained the same results from applying the calibration option in the same rivers and at the same stations.

By analyzing the results, it was found that for the observed hydrograph with bell shape, the results are good and logical. But for the extraordinary hydrograph form, having very sharp shapes or fluctuation in peaks this option is not able to calibrate the parameters properly. Table 1 shows the results of parameter calibration for some of the province floods.

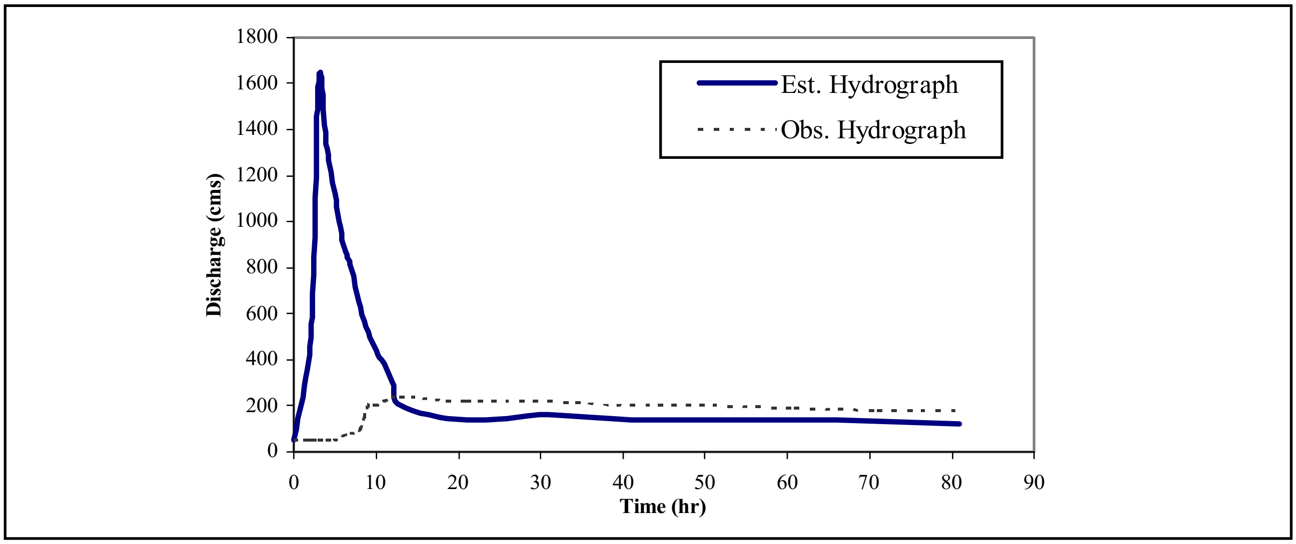

Figure 2. Estimated and observed flood of January, 1992.

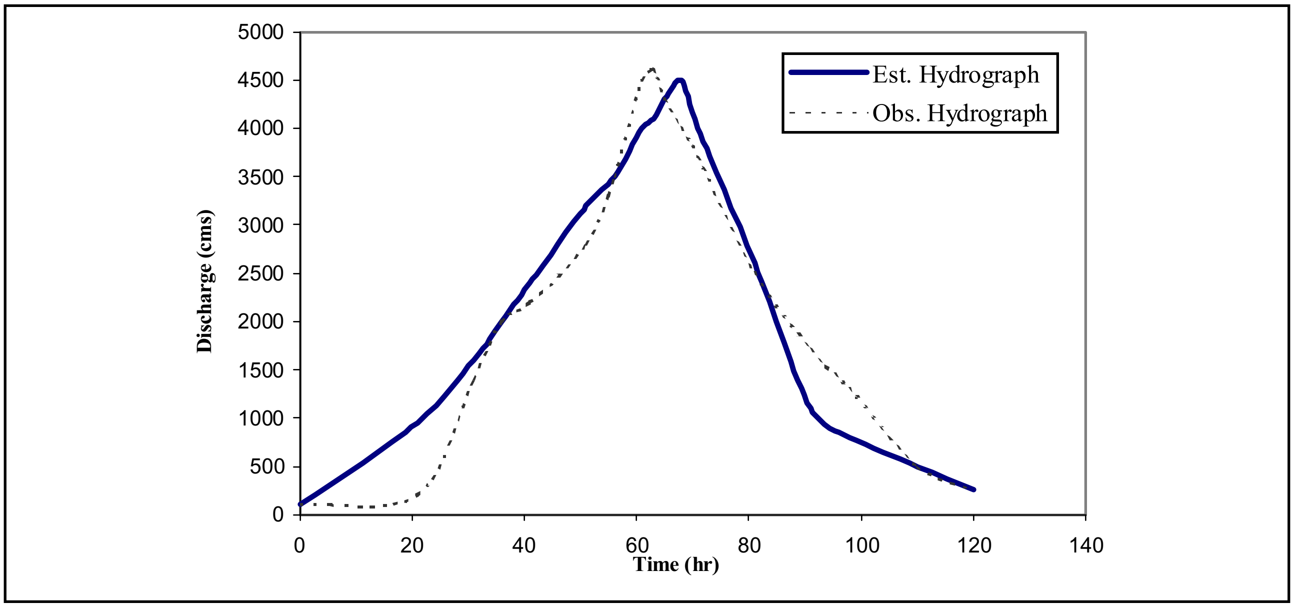

Figure 3. Estimated and observed flood of February, 1992.

It reveals that in rare cases the result could be directly applicable. Because of that, we obtained the range of parameter values from this option. For determining the required parameter values, literature and engineering judgements were applied (Viessman (1986), Maidment (1996)).

Simulation Using the Unit Hydrograph

As mentioned before, for areas under 5000 km^2, this option of HEC-1 was applied, using the parameter calibration results.

Table 2 shows the observed and estimated floods, which occurred between 1986 to 1992 in the different rivers. It reveals that except for two cases (Jamash and Dehshikh rivers at Sarmoghasem and Dehshikh Stations, respectively), the results of simulation are appropriate. To check this matter, station sites and their catchments were revisited and it was found that the recorded quantile of Sarmoghasem Station could not be correct, and there had been some mistakes in the calculation of flow velocity. It is worthwhile to say that for a discharge of 11482 cms in this station the velocity should be 15 m/s with a rainfall depth of 650 mm over a 48 hr period.

Table 1. The Results of Parameter Calibration by HEC-1

River	Station	Date	Obs. Peak (cms)	Est. Peak (cms)	CN	Tp (hr)	Cp
Shamil	Shamil	Mar.1986	718	161	74	1.78	0.18
Shamil	Shamil	Dec.1985	325	216	67	1.73	0.21
Shamil	Shamil	Mar.1986	718	161	74	1.78	0.18
Shamil	Shamil	Jun. 1992	675	378	11	1.74	0.21
Shamil	Shamil	Feb.1992	1620	239	16	1.85	0.18
Mehran	Dejgan	Jun. 1992	239	1620	41	1.83	0.01
Mehran	Dejgan	Feb.1992	4682	4323	82	25	0.41
Jamash	Sarmogh	Dec.1985	460	334	56	4.5	0.79
Jamash	Sarmogh	Jun. 1992	3525	1842	100	4.83	0.83
Jamash	Sikhoran	Feb.1992	684	433	100	3.79	0.6
Hajiabad	Hajiabad	Jun. 1992	118.6	110	32	1.72	0.19
Rassol	Kahor.	Jun. 1992	3100	1759	55	1.8	0.07
Rassol	Kahor.	Feb.1992	4772	4738	56	1.79	0.09
Jalabi	Jalabi	Dec.1985	580	451	84	8.1	0.76
Rendan	Nian	Jun. 1992	320	142	20	1.72	0.19
Rendan	Nian	Jun. 1992	577	198	34	1.52	0.38
Rendan	Nian	Feb.1992	2360	1028	97	0.79	0.50
Mazabi	Mazabi	July 1995	323	207	91	17.6	0.79

For the Dehshikh, investigations showed high transmission losses through the river bed, as a result HEC-1 was not able to simulate the flood for such a catchment.

Flood Routine Using the Kinematic Wave Method

For this option, HEC-1 requires some physiographic information including; main channel length, slope, width, side slope, also overland flow length, slope and the Manning coefficient, as well as rainfall depth and its temporal pattern.

This option of the model was used for the Kol and Minab Rivers with areas of 34000 and 1000 km^2 respectively. For the Kol River, the basin has been divided in to 25 subbasins and for the Minab, it is 4 subbasins.

There is one station located at the pour point of the Kol River, where results of simulations for February 1992 were checked by observed data that are 34345 and 35630 cms respectively. Two of Minab's subbasins have stations at their pour points, one is in the Roodan and another in the Jagin subbasins. The results of simulation at these locations are 4536 and 6024 cms and the observed peaks are 4700 and 5932 cms, respectively.

The result shows the capability of the HEC-1 model to simulate large basins with numerous subbasins.

Temporal Rainfall Pattern

Although the temporal pattern of rainfall has significant effect on hydrographs, by increasing

Table. 2. Comparison of Estimated and Observed Peak Discharges in the Minab Big Basin

River	Station	Date	Obs. Peak (cms)	Est. Peak (cms)	Rainfall (mm)(1)
Jamash	Sikhoran	Jan. 1992	258	246	97
Jamash	Sikhoran	Feb. 1992	682	703	340
Jalabi	Jalabi	Feb. 1986	580	577	74
Barantin(3)	Roodan	Feb. 1992	4536	4700	139
Minab(3)	Barantin	Feb. 1992	6024	5932	132
Gero	Gero	Feb. 1986	227	212	50
Mazabi	Mazabi	Feb.1986	198	322	41
Mazabi	Mazabi	Jan. 1992	244	324	55
Jagin	Jagin	Jan. 1992	1875	1519	60
Jagin	Jagin	Feb.1992	1095	1468	62
Shamil	Nian-Shamil(2)	Feb. 1986	100	1985	74
Shamil	Nian-Shamil	Jan. 1992	995	2481	125
Shamil	Nian-Shamil	Feb. 1986	3520	3511	234
Jamash	Sarmoghasem	Jan.1992	3625	3404	148
Jamash	Sarmoghasem	Feb.1992	11428	5213	319
Mazabi	Mazabi	Feb.1992	1350	1320	170

1) Amount of rainfall has been calculated according to the isohyet map.
2) In peak discharges flow of these two rivers combined together at station locations.
3) The peak has been simulated by the kinematic wave method.

Table 3. Comparison of Estimated and Observed Peak Discharges in the Kol Big Basin

River	Station	Date	Obs. Peak (cms)	Est. Peak (cms)	Rainfall (mm)(1)
Roodbal	Darb Ghaleh	Feb. 1992	494	499	122
Roodbal	Gavarzoon	Feb. 1985	750	745	188
Roodbal	T. Khosoyeh	Jan. 1992	752	1125	95
Roodbal	T. Khosoyeh	Feb. 1992	467	794	78
Daroody(2)	Darashgoft	Feb. 1992	9235	10470	173
Rasool	Kahoorestan	Feb. 1992	4772	4740	245
Mehran	Dejgan	Jan. 1992	1620	1385	77
Dehshikh	Dehshikh	Feb.1992	3437	5630	90
Kol(2)	Ghalat	Feb.1992	34345	35637	210

1) Amount of rainfall has been calculated according to the isohyet map.
2) The peak has been simulated by the kinematic wave method.

basin area, its effectiveness decreases. For this study rainfall patterns were estimated from the recording rainfall gages.

The HEC-1 model is originally designed for single event rainfall and it is assumed that there is no spatial variation in rainfall. This assumption is acceptable for small basins, but for a large basin like the Kol with an area of 34000 km^2, it could not be reasonable. To sort out this problem many solutions were applied and assessed. The final solution is described below:

Suppose the duration of rainfall is 24 hr. We extended this duration to 34 hr. The added 10 hr duration has zero percentage rainfall. For the subbasin, which is closest to rainfall front, this 10 hr was shifted to the end of original 24 hr rainfall, and for the farthest subbasin, to the beginning. For the intermediate subbasins this pattern varies between these two ranges. The actual lags (e.g. 10 hr) estimated by the available graphs of the rainfalls are shown in Figure 4.

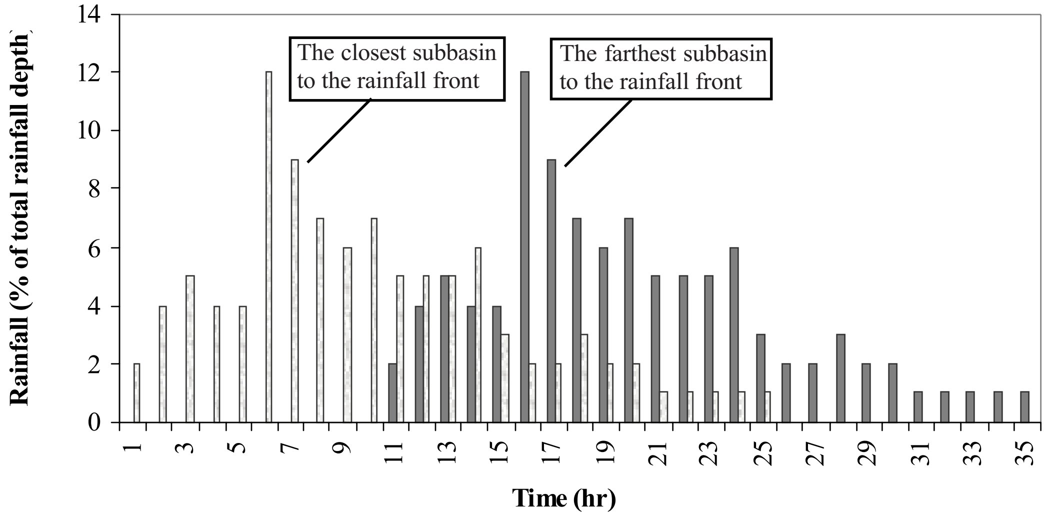

Figure 4. The status of temporal rainfall patterns in different subbasins with respect to their location to rainfall front.

RAINFALL FREQUENCY ANALYSIS

According to the historical flood events in the region, rainfalls with 48 hr duration have created the highest flood peaks, and for this study this duration was used for rainfall frequency analysis. Rainfall frequency was analyzed by annual and partial duration series (FRS, 1975) and the latter was found to give better results.

With the above assumptions, rainfall maps of 50, 100, 1000, and 10000 year return periods were drawn. By planimetry, amounts of rainfall for different frequencies for each of the subbasins were independently calculated. In addition, the Probable Maximum Precipitation (PMP) of each station was calculated by the synoptic method and PMP maps of the province was also drawn (Ghaemi, 1997).

FLOOD FREQUENCY ANALYSIS

After estimation of parameters, calculations of rainfall depths and their temporal patterns were ready as input files for each subbasin, and simulations were done with the HEC-1 model. As we said before, in many stations there were not enough data for frequency analysis with observed annual peaks, but in some of them, like the Minab station, these data were available. This offered a good opportunity to compare results of flood frequency analysis with HEC-1 rainfall-runoff simulation. Table 4 shows the results of the above methods for the Minab Station. As it shows, the HEC-1 simulation of rainfall-runoff is quite good.

CONCLUSIONS

According to the results of widely applying the HEC-1 model, the following conclusions can be drawn:

Table 4. Comparison of Results of Flood Frequency with Statistical Approach and Rainfall-Runoff Simulation Approach (cms)

Selected Method	50yr	100yr	100yr	1000yr	PMF
Log Pierson*	10823	12830	19346	25370	
RRS-PTO	13442	15937	20615	24813	26153
RRS-AM	15148	16977	22945	24762	44518

1. HEC-1 can be used for simulation and forecasting floods in the Hormozgan province

2. For the calibration option of HEC-1, only those hydrographs with normal (bell) shape can lead to good results. Irregular hydrographs give unrealistic parameter values.

3. The HEC-1 model does not take in to account transmission losses and it creates some disturbances in the simulation of rivers with alluvial beds and high infiltration.

4. HEC-1 is able to simulate flood hydrographs of a large basin with numerous subbasins, but for such basins, spatial variation of temporal rainfall patterns should be considered. By applying a lag between rainfalls good result can be obtained.

5. Although HEC-1 is an easy model to implement, it can be difficult to justify and infer the results, without field visits and study of past floods. This is especially true for choosing parameters, where careful consideration should be applied.

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