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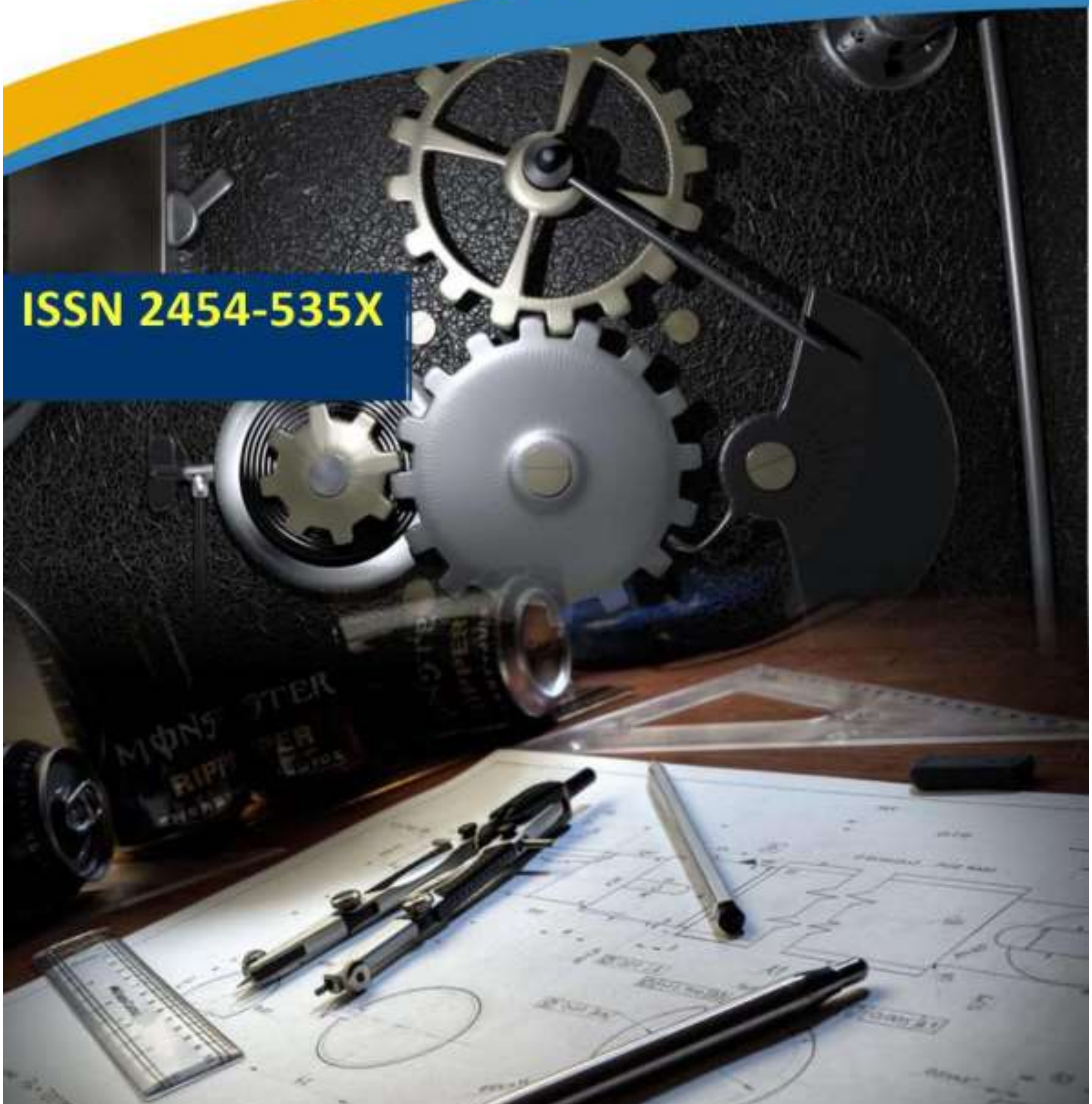

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Flood Hydrograph Estimation Using Lumped and Distributed Models (Kabkian Basin Case Study)

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ABSTRACT: *The mechanisms of rainfall and runoff were studied in the Kabkian basin (846.5 km2) in Kohgilouye and Boyerahad, Iran.Since the hydrologic characteristics may change from one sub-basin to the next, this analysis began by treating the Kabkian basin as a single entity. In this context, lumped models may be referred to as "semi-distributed." HEC-HMS (Hydrologic Engineering Center, Hydrologic Modeling System) and HEC-GeoHMS (Hydrologic Engineering Center, Geospatial Hydrologic Modeling Extension) are hydrologic models. Models of rainfall and runoff were investigated, and in both situations the SCS curve number approach (Soil conservation Service, 1972) was taken into account. Basin data was used to precisely calibrate and verify the model. All flood episodes had determination and agreement coefficients more than 0.9, and the % errors in peak flow and volume were within acceptable limits. The event model was then assessed using a locally based sensitivity analysis. The sensitivity analysis focused on three factors of the event model: curve number, initial abstraction, and lag time.There, in the Kabkian basin. The largest discrepancies between the produced peak hydrographs and the baseline peak hydrograph were due to curve number in both the lumped and distributed model. Semi- dispersed model performed better than Lumped model in capturing peak runoff discharges and overall runoff volume. However, both models' overall performance was respectable.*

Keywords: *Key Terms: Semi-distributed model; Kabkian basin; HEC-HMS; Sensitivity analysis; Rainfall-runoff modeling; HEC-GeoHMS; SCS; kohgilouye; boyerahmad.*

INTRODUCTION

Watershed models now in use may be classified as either being very basic, conceptual lumped models or very advanced, physically based dispersed models. Parameters in conceptual lumped models are described collectively to provide an average value for the basin as a whole. Different sub-basins within a watershed may have distinctively different hydrologic characteristics. In this context, lumped models may be referred to as "semi-distributed." However, since they use artificial means of converting precipitation into runoff, they remain non-physically based. HEC-HMS Version 3.2 was utilized for this analysis. The HEC model represents a basin's hydrologic and hydraulic components as linked systems, simulating the basin's surface runoff response to precipitation. It works particularly well for modeling floods. The basin model in HEC-HMS consists of the loss, the transform, and the base flow; all three are essential processes. Sub-basins are smaller sections of a basin that are modeled separately to account for their own unique precipitation and runoff processes. Surface runoff, a stream, or a reservoir might all be represented by a single element. An element's unique property and the mathematical relations describing its physical processes are each defined by a variable. The hydrographs of the stream flows at the basin outflow are computed as a consequence of the modeling procedure. For many of these issues, it would be ideal to know the exact magnitude and the actual time of occurrence of all stream flow events during the construction period and economic life of the project.

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The design, construction, and operation of many hydraulic projects rely on an understanding of the variation of the basin's runoff. If this data was accessible at the planning and design phases of the project, it might be used to choose the optimal design, construction program, and operational process among the many potential outcomes. Because it is impossible to know the project hydrology in advance, water resources development projects must instead use a hypothetical set of future hydrologic conditions to inform their planning, design, and management. Engineering hydrologists have spent a great deal of time trying to find acceptable simplifications of complicated hydrologic processes and developing sufficient models for the prediction of future hydrologic conditions.

examines the hydraulic and hydrologic reactions of basins to natural and man-made events. These considerations have led to the creation of various hydrologic models for use in flood forecasting and the investigation of rainfall-runoff processes (Yusop and Chan, 2007; Yener and orman,2008; Li and Jia, 2008; Stisen and Jensen, 2008; Khakbaz and et al., 2009; Salerno and Tartari, 2009; Amir and Emad,2010; Jang and Kim, 2010; James and Zhi, 2010;).Similarly, Asadi and porhemat (2012) calibrated and verified the hydrologic parameters in the kabkian basin and the delibajak subbasin. Due to the spatial nature of the factors and precipitation affecting hydrologic processes, GIS (geographic information systems) has been more important in hydrologic research in recent years. In the parameterization of decentralized hydrologic models, GIS plays a crucial role. This is done to counteract the oversimplification that occurs when parameters are grouped together at the river basin scale for depiction. Using a DEM (digital elevation model), GIS applications may extract hydrologic information including flow direction, flow accumulation, watershed borders, and stream networks. In this investigation, GIS was integrated with HEC-HMS to evaluate the model's applicability to the basins under consideration. This study uses rainfall-runoff data from the Kabkian basin gathered by 12 rainfall stations and 1 runoff station between 2008 and 2011 to calibrate basin characteristics (curve number and initial abstraction).

The primary goals of this research are to (1) evaluate the performance of the HEC-HMS hydrologic model using statistical measures, and (2) calibrate, verify, and analyze the sensitivity of the model for the Kabkian basin using both lumped and distributed data.

MATERIALS AND METHODS

The Study Area

Southwest Iran is home to the kabkian basin, which can be found to the west of Yasooj City, kohgilouye, and boyerahmad Province. The basin is located between the longitudes of 51° 05′ and 51° 37′ to the east. There is a total of 846.5 km2 of basin space in the kabkian basin, and the average channel slope is 0.014 meters per kilometer. The basin's elevation varies from 1500 meters at the outflow to 3000 meters at the basin boundary.Over 90% of the year's precipitation falls between November and April, mostly as frontal rains that causes flooding. The average yearly temperature is about 12 c, and the climate is damp and chilly. (Fig 1.)

Data used

Since 2000, the kogilouye and boyerahmad Regional Water Authority has been keeping tabs on the kabkiab basin's streamflow and precipitation. Twelve raingauges in the central and lower regions of the basin were used to gather precipitation data. At one-hour intervals, stream flow measurements were recorded at the basin's outflow (botari hydrometric station). The local climatological station's weather records were accessed. All simulations of hydrologic models are run at an hourly time step.Software used Hec-GeoHMS 5.0

Designed for engineers with little to no background in GIS, this toolkit is a geospatial hydrological resource[USACE-HEC, 2003]. It's an add-on for the popular mapping program ArcMap. In this research, a digital elevation model (DEM) of the basins is utilized with Hec-GeoHMS to generate a river network and divide the basins into subbasins. Kabkian basin streamflow gages are botari in the subbasins delineation procedure.

HEC-HMS 3.3

The Hydrologic Engineering Center of the US Army Corps of Engineers created this program for hydrologic modeling. Included are several of the standard hydrologic approaches used to model river basin rainfall-runoff dynamics. "[USACE-HEC, 2006]"

MODEL APPLICATION AND CALIBRATION

Five flood events that occurred in the Kabkian Basin throughout the course of the study's three-year time frame (2009-2011) were utilized to validate the models. A hydrologic model in HMS is identified by a project name. Before an HMS project can be executed, a basin model, a meteorological model, and control parameters are required. From the data obtained through HEC-GeoHMS for model simulation, the basin model and basin characteristics were constructed in the form of a backdrop map file uploaded to HMS (Figs. 2 and 3). The user gauge weighting technique was utilized to generate the meteorological model from the observed precipitation and discharge data, and the control specification model was then generated. The simulation's temporal structure is set by the control requirements, which include a start date and time, an end date and time, and a computation time step. Basin model data, weather forecast data, and control parameters were all brought together to make this system work. The twelve raingauge stations, one for each sub-, that collected historical data

model was validated using data from a single stream gauge station in the Kabkian Basin and its surrounding region. The time step utilized in the simulation was one hour, which was determined by the time span of the available observed data.

To simulate infiltration loss, the SCS curve number approach was used. To simulate the process by which surplus precipitation is converted into direct surface runoff, the SCS (Soil Conservation Service) unit hydrograph approach was used. To represent baseflow, we used a constant monthly rate. To simulate the stretches, we turned to the Muskingum routing model.

In order to produce the simulated runoff hydrographs, the values of the parameters associated with each technique in HEC-HMS must be provided as input to the model.Stream and basin features may be used to estimate some of the parameters, whereas other parameters cannot be approximated. Model parameters are calibrated when precise estimation of the necessary parameters~~ is not~~ possible; this is done by conducting a systematic search for the parameters that, when combined with data on rainfall and runoff, provide the best match between the observed and calculated runoff. Optimization refers to this kind of methodical searching. Starting with rough estimations of the parameters, optimization refines the model until the simulated flow is as near as feasible to the observed one.

To calibrate the model, a trial-and-error approach was used, whereby the hydrologist would subjectively modify parameter values between simulations to find the minimum values of parameters that produce the best match between the observed and simulated hydrograph. Although the model was calibrated manually, its acceptability and appropriateness for usage in HEC-HMS was verified using the program's in-built automated optimization technique. The need should guide the selection of the goal function. Curve number, starting abstraction, and percent impervious area in the basin are the three factors utilized in the SCS Curve Number approach for dealing with infiltration loss in the subbasins. Since there are no developed areas inside the subbasin, the impervious percentage is set to zero. Consequently, the SCS curve number method's last two parameters (curve number and initial abstraction) were adjusted. For modeling the change from precipitation surplus to direct surface runoff, the SCS unit hydrograph approach incorporates a lag time parameter. We also calibrated this metric.

MODEL PERFORMANCE EVALUATION METHODS:

The models are evaluated based on their ability to forecast the timing and amplitude of hydrograph peaks, as well as the volume of runoff, as well as the degree of agreement between anticipated and observed runoff discharges. Both models' accuracy in performance throughout individual simulation periods and as a whole were measured using the following statistical metrics:

- Percent error in peak flow (*PEPF*). The *PEPF* measure only considers the magnitude of computed peak flow and does not account for total volume or timing of the peak:

$$PEPF = 100 \left| \frac{Q_O(peak) - Q_S(peak)}{Q_Q(peak)} \right|$$

where $Q_O(Q_S)$ is the the observed (simulated) flow.

- Percent error in volume (*PEV*). The *PEV* function only considers the computed volumeand does not account for the magnitude or timing of the peak flow:

$$PEV = 100 \left| \frac{V_O - V_S}{V_O} \right| \quad (2)$$

where $V_O(V_S)$ is the volume of the observed (simulated) hydrograph.

- Coefficient of correlation (R) . The lag-0 cross correlation coefficient was calculated as:

$$R = \frac{\sum_{t=1}^{N}(O_t - \bar{O}) \times (S_t - \bar{S})}{\sqrt{[\sum_{t=1}^{N}(O_t - \bar{O})^2 \times \sum_{t=1}^{N}(S_t - \bar{S})^2]}} \quad (3)$$

Where $O_t\,(S)$ is the observed (simulated) flow at time t, and $\bar{O}(\bar{S})$ is the average observed (simulated) flow during the calibration period.

- The relative root mean squared error, *RRMSE*, were calculated as:

$$RRMSE = 100 \times \sqrt{\frac{1}{N}\sum_{t=1}^{N}\left(\frac{S_t - O_t}{O_t}\right)^2} \quad (4)$$

where N is the number of streamflow ordinates and the meaning of the remaining symbols is the same as inEquation (3).

SENSIVITY ANALYSIS

A sensitivity analysis is a technique for pinpointing the model parameters that have the most significant effect on the final model output. Specifically, it ranks model parameters according to how much they contribute to the total inaccuracy in model predictions. Both regional and worldwide sensitivity analyses exist (Haan, 2002). The event model was assessed using a local sensitivity analysis in this research. The sensitivity analysis focused on three factors of the event model: curve number, initial abstraction, and lag time. The final set of calibrated model parameters was designated as the baseline or nominal set. The model was then ran many times, with each parameter's baseline value incremented by a factor of 0.7, 0.8, 0.9, 1.1, 1.2, and 1.3 while all other parameters were held at their initial levels. After playing about with different parameter values for the model, we compared the generated hydrographs to the original model's output.

RESULTS AND DISCUSSION

Each sub-basin that HEC-HMS considers represents a different part of the basin-wide precipitation-runoff process, as was explained in the introduction. For a component to be represented, it must have a set of parameters that define its unique properties and a set of mathematical relations that characterize its underlying physical processes. The calibrated parameter values for the Lumped and Semi-distributed Kabkian Basin are shown in Tables 1 and 2, respectively. Until a satisfactory match was found between the observed and simulated hydrographs, all of the parameters were calibrated concurrently with the exception of the sub-areas, which are fixed.

Basin's calibration and validation graphs are shown below. The observed and simulated graphs correspond well in Figs. 4 through 7. Additionally, in both the calibration and validation basins, Tables 3 and 4 include both observed and simulated data. Table 5 provides a concise overview of the models' results. As can be seen in the graphs above, the highest time discrepancy between the predicted and actual peak discharges was just one hour, making it suitable for flood forecasting.
The absolute differences between the -30% and 0% situations for each event model parameter are summarized in Figures 8 and 9. The most striking variations in both situations were caused by adjusting the CN parameter, or Curve Number.

CONCLUSIONS

The results above demonstrate that, using the aforementioned historical flood data, the model successfully forecasted the peak discharge. The predictions for the size and timing of the flood were very close. This demonstrates that HEC-HMS is appropriate for the basin under consideration. We may infer that a model's applicability and efficiency are not dependent on its level of structural complexity. HEC-HMS is an effective tool for flood forecasting despite its very simple form. To verify HEC-HMS's usefulness for the iran basins, its wider implementation should be promoted. Semi-distributed model performed better than Lumped model in capturing peak runoff discharges and overall runoff volume. However, both models' overall performance was respectable.In addition, the sensitivity analysis included three event model parameters: curve number, initial abstraction, and lag duration. Both in the semi-distributed basin and the lumped basin, The biggest shifts occurred when the CN (Curve Number) parameter was altered. We also compared the optimized hydrologic parameters, curve number, and first abstraction. The lumped example had a curve number of 62, an initial abstraction of 34mm, and a lag time of 347 minutes. The semi-distributed example has curve numbers between 61 and 66 and starting abstractions between 33 and 40 mm. Basin slope, geologic formations, plant cover, and land use all play a role in this variety.

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