Case Study

MODELING OF FLOODS IN GÜVENÇ BASIN, ANKARA USING HEC-HMS

Ankara Güvenç Havzası'nda Taşkınların HEC-HMS ile Modellenmesi

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Abstract

The presented paper detaily described the flood modeling for Güvenç Basin in Ankara, Turkey through the use of the Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS). In flood modeling studies, the HEC-HMS model is a widely used hydrological model in combination with the Geospatial Hydrologic Modeling Extension (HEC-GeoHMS) that works with GIS softwares. It was applied to the basin whose drainage area is totally about 15.3 km^2. Firstly, the basin physical and climatic characteristics were determined by using Hec-GeoHms and then simulations were created with using the HEC-HMS model. Data sets obtaining from five meterological stations located in the basin area and one streamflow observation station at the outlet of the basin were used for the study. Within the scope of the study, both of peak flood flows simulated with the HEC-HMS model and peak flood flows observed at specific times of 1992, 1993, 1996, 2000, 2002 and 2005 were used in calibration and validation studies. The flood modeling was evaluated by comparing the observed data of those stations with the hydrologic model results for the selected flood events. Its calibration was carried out by using the trial-error method. Validation process was applied in selected years after determining calibration parameters. As a result of the calibration and validation processes, the compatibility between the observed and simulated flood hydrographs showed us that the flood modeling for Güvenç Basin was convenient for evaluating flood risks in this area.

Keywords: *Hydrological modeling, HEC-GeoHMS, calibration and validation, Güvenç Basin*

Öz

Makalede Ankara ilinde bulunan Güvenç Havzası için Hidrolojik Mühendislik Merkezi-Hidrolojik Modelleme Sistemi (HEC-HMS) kullanılarak oluşturulan taşkın modellemesi ayrıntılarıyla verilmiştir. Taşkın modelleme çalışmalarında HEC-HMS modeli, CBS yazılımlarıyla çalışan Hec-GeoHms uzantısı ile birlikte yaygın bir şekilde kullanılan bir hidrolojik modeldir. Drenaj alanı yaklaşık 15.3 km^2 olan havzada, bu model uygulanmıştır. İlk olarak, havzanın fiziksel ve iklimsel karakteristik özellikleri modelin HecGeo-Hms uzantısı kullanılarak belirlenmiş daha sonra HEC-HMS modeli kullanılarak simülasyonlar üretilmiştir. Çalışmada, havzanın yağış alanı içerisinde bulunan beş adet meteroloji gözlem istasyonu ve havzanın çıkışında yer alan bir adet akım gözlem istasyonundan elde edilen veri setleri kullanılmıştır. Çalışma kapsamında, 1992, 1993, 1996, 2000, 2002 ve 2005 yıllarının belirli zamanlarında gözlemlenmiş pik taşkın debileri ile HEC-HMS modeli ile simüle edilen pik taşkın debileri, kalibrasyon ve validasyon çalışmalarında kullanılmıştır. Havza için oluşturulan taşkın modeli, istasyonlardan elde edilen veriler ile model tarafından simule edilen sonuçları, seçilen taşkın olayları için karşılaştırılmıştır. Model kalibrasyonu, deneme-yanılma metodu kullanılarak gerçekleştirilmiştir. Deneme yanılma metodu ile kalibrasyon parametreleri öncelikli olarak belirlendikten sonra modelin performansını değerlendirmek için validasyon işlemi uygulanmıştır. Kalibrasyon ve validasyon işlemleri süreçlerinde, model tarafından simüle edilmiş ve gözlemlenmiş taşkın hidrografları arasındaki uyum, Güvenç Havzası için oluşturulan taşkın modelin bu alandaki taşkın riskini değerlendirmek için kullanılabilir olduğunu göstermiştir.

Anahtar kelimeler: *Hidrolojik modelleme, HEC-GeoHMS, kalibrasyon ve validasyon, Güvenç Havzası*

Introduction

Accurate estimates of the peak floods and flood hydrographs are important elements of the design of hydraulic structures. Flood predictions are important in basin planning and management studies, as saving human lives and protecting properties have priority (Olivera and Maidment, 2000). Hydrologic models are the tools that represent the actual hydrologic systems of a basin by using simplified mathematical functions. Additionally, hydrologic models used in the predicition of the hydrologic response of various watersheds management practices and provides a better understanding of the impacts of these practices (Verma et al., 2010).

The HEC-HMS model (HEC, 2001) has common usage in modeling of flood processes. Gül et al. (2010) used the HEC-HMS model to evaluate the efficiency of structural flood control measures in Bostanlı Basin, Turkey. Yusop et al. (2011) use the HEC-HMS model for modeling storm flow hydrographs in an oil palm catchment in the Skudai River in Johor. Verma et al. (2010) evaluate HEC-HMS and WEPP for simulating watershed runoff using remote sensing and geographical information system. Du et al. (2012) analyse the urbanization effects on annual runoff and flood events using HEC-HMS in the Qinhuai River basin, China. Yener et al. (2011) compare flood peaks obtained using both HEC-HMS and General Directorate of State Hydraulic Works (DSI) Synthetic Method in Yuvacık Basin. Derdour et al. (2017) simulate rainfall-runoff in the semi-arid region of Ain Sefra watershed through the employing of HEC-HMS model. In the study, the frequency storm is used for the meteorological model, Soil Conservation Service (SCS) curve number is selected to calculate the loss rate and SCS unit hydrograph method have been applied to simulate the runoff rate. After calibration and validation studies, we determine that the simulated peak discharges are very close with the observed values. Mishra et al. (2018) investigate the future flood inundations under climate and land use change scenarios in Ciliwung River Basin. They utilize the HEC-HMS model to simulate the river discharge and analyse climate change impact on the basin. They find the increasing flood inundation areas and depts as 6% to 31% for different Global Climate Models (GCMs). Gumindoga et al. (2017) analyse runoff simulation in upper manyame catchment using the HEC-HMS model. The study demonstrates the suitability of the HEC-HMS for continuous runoff simulation in a complex watershed with numerous subcatchments and channel reaches.

In the study, the flood modeling for Güvenç Basin is developed with using the HEC-HMS model. For this purpose, simultaneous measurements of both rainfall and runoff are used. The model is firstly calibarated and then validated.

Study Area

Güvenç Basin is located between the coordinates of 42°08'10" N and 32°45'15"E in the city of Ankara in the mid of Turkey (Figure 1). The basin area is totally about 15.3 km^2, and the overall region is mostly covered with agricultural areas. Outlet of the basin is located at 1053 meters above sea level.

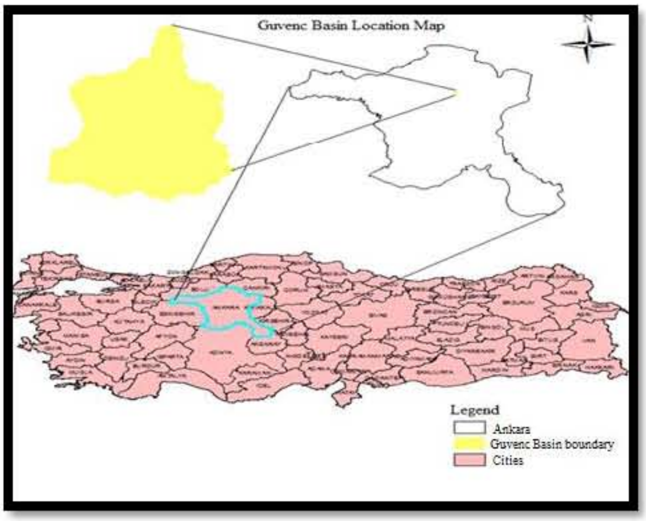

Figure 1. Güvenç Basin location map.

Method

The Hydrologic Modeling System (HEC, 2005) was developed by US Army Corps of Engineers to simulate the complete hydrologic processes of watersheds. The model combines hydrologic analysis procedures such as infiltration, unit hydrographs, and hydrologic routing. The HEC-HMS is also capable of conducting continuous simulation which requires evapotranspiration, snowmelt, and soil moisture accounting. Gridded runoff simulation using the linear quasi-distributed runoff transform (ModClark) is also possible by using the HEC-HMS. It also enables model optimization, forecasting streamflow, depth-area reduction, assessing model uncertainty, erosion and sediment transport, and water quality features. The HEC-HMS uses, together with other inputs, the design storm hyetograph and the unit hydrographs to simulate the rainfall-runoff response of a watershed by representing the entire watershed as an interconnected system of hydrologic and hydraulic components, and was designed to work with various Geographic Information Systems (GIS) data and to facilitate the use of GIS technology in hydraulic engineering. In the HEC-HMS model, precipitation can be identified by using either historical data or the generated data for design storms in order to evaluate the different parts for hydraulic structures. A userspecified unit hydrograph, can then be used in the model to obtain runoff. The HEC-GeoHMS, is an extension of ArcGIS software which was developed to serve as an assistant for deriving geospatial data (HEC, 2000). By using the HEC-Geo-HMS, it is possible to perform spatial analysis, delineate subbasins and streams, construct inputs to hydrologic models, prepare reports, and generate background map files, raster parameter files, and lumped or distributed basin models that can be directly transferred into the HEC-HMS model (HEC, 2000; Bedient and Huber, 2002).

Major data required in this study are land use information, Digital Elevation Model (DEM), observed rainfall and runoff data, and characteristics of the hydraulic structure in the basin. Corine Land Cover maps for the years of 1990 and 2012 were used for the study. The required characteristics of the Güvenç pond were obtained from the Soil Fertilizer and Water Resources Central Research Institute and DEM with 30 m resolution was obtained from U.S Geological Survey (USGS) website in digital format.

Five meteorological stations (R24, R25, R26, R27, and R28) and one flow observation station were simultaneously operated by the Ankara Research Institute of the General Directorate of Rural Services (GDRS) between the years of 1984 and 2010 (Figure 2).

Temperature, runoff and precipitation in Güvenç Basin are given in Table 1. These data were obtained from the Institute.

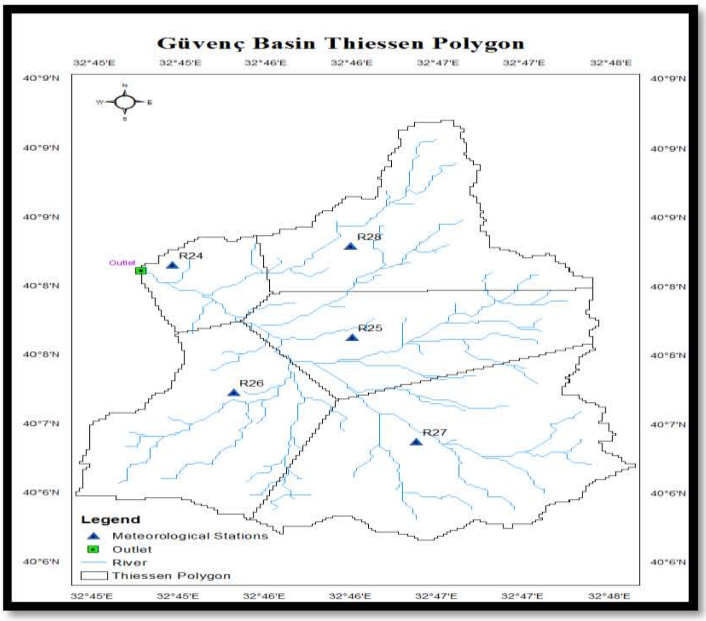

Figure 2. Güvenç Basin thiessen polygon.

Table 1

Temperature, Runoff and Precipitation Values in Güvenç Basin

26 Years Mean (1984-2010)	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Yearly
Total Precipitation (mm)	37.1	49.4	62.8	40.1	37.3	50.7	56.9	51.1	35.6	20	13.3	18.9	473.3
Total runoff (l/s)	2.96	13.27	38.58	48.49	76.41	120.4	134.6	83.07	39.98	14.62	2.3	0.73	575.1
Surface runoff (l/s)	1.82	7.62	16.91	11.18	23.35	24.38	31.15	16.21	8.26	3.73	0.72	0.39	145.68
Subsurface runoff (l/s)	0.35	3.08	5.98	7.32	9.38	19.44	14.44	7.09	3.31	1.324	0.199	0.035	71.99
Temperature (Mean) (°C)	12.8	6.7	2.3	0.4	1.3	5.6	10.7	15.1	19.2	22.6	22.2	18.2	11.4

Application

In the presented study, the first step was determination of physical and climatic characteristics of the basin such as river slope, basin centroid, longest flow path, centroidal longest flow path, and watershed drainage area by using HEC-GeoHMS (Figure 3). The HEC-GeoHMS model extension initially uses DEM. The characteristics of the basin were considered individually. As a result of HEC-GeoHMS operations, which are operated by ArcGIS program, the schematic of the basin was formed (Figure 4). With the HEC-HMS model study, the hydrological cycle of the basin was discussed extensively. Flow estimation was generated by correlating the methods used for the model and the meteorological parameter. The results were compared with actual observations and then the performance of the model was determined. Figure 4 shows basin schematic generated with HEC-GeoHMS.

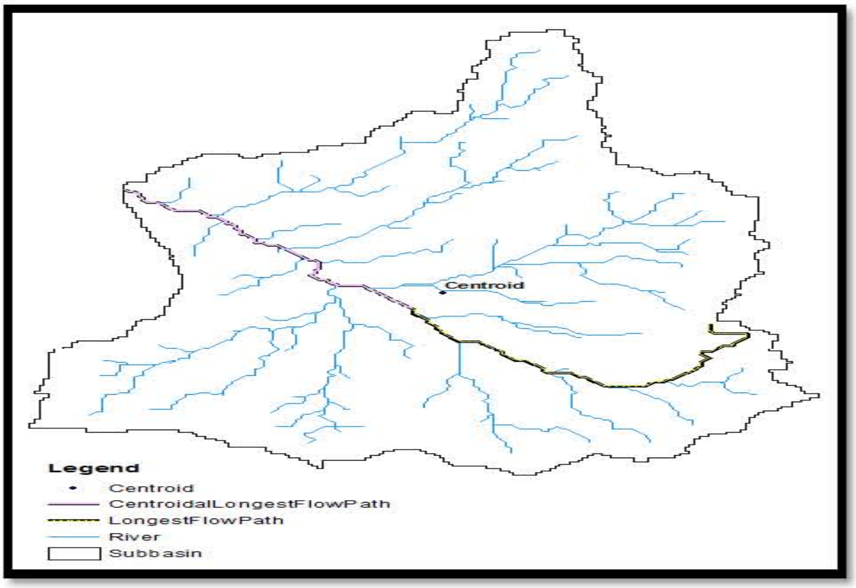

Figure 3. Güvenç Basin physical characteristics generated with HEC-GeoHMS.

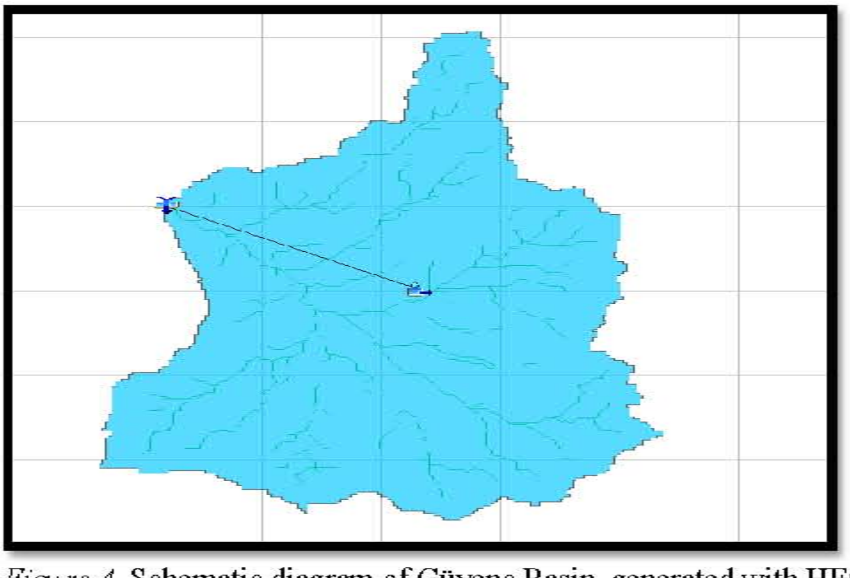

Figure 4. Schematic diagram of Güvenç Basin, generated with HEC-GeoHMS.

The Soil Conservation Service Curve Number (SCS CN) Method was selected to determine the loss rates in the basin. SCS CN method is efficient method for determining the approximate amount of runoff from rainfall. The method requires rainfall amount and CN. The curve number is based on research area's hydrologic soil group and land use. Land cover characteristics of the basin are given in Table 2. Representative CN values for the related years for the basin was obtained by using areal CN averages and then assigned to the basin for the hydrologic modeling set up. In this process, Corine maps were considered for the land cover of the basin. Table 2 also shows the CN calculation process for the year of 2012. CN value for 1990 was also calculated as 81.67 by using the same procedure.

SCS CN Model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture, using the following equation:

$$P_e = \frac{(P - I_a)^2}{P - I_a + S}$$

From analysis of results from small experimental watersheds, the SCS developed an empirical relationship of I_a and S:

$$I_a = 0.2S$$

The cumulative excess at time t is:

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

The maximum retention, S, and watershed characteristics are related through an intermediate parameter, the curve number as:

$$S = \frac{100 - 10CN}{CN}$$

CN values range from 100 (for water bodies) to approximately 30 for permeable soils with high infiltration rates (HEC, 2005).

Table 2

Soil Conservation Service Curve Number Value for Güvenç Basin (1990 & 2012)

Land Cover	SCS CN Value	Percent	Areal CN Value
Sparse vegetation	78	29.44	23
Rock area	100	3.212	3
Plant cover	84	49.4	42
Meadows	70	9.189	6
Non-irrigated mixed farming	82	0.855	1
Non-irrigated cultivated land	81	7.88	6
Total	-	-	**81**

Unit hydrographs obtained by using observed hydrographs were used for rainfall-runoff transformation. In order to determine meteorological characteristics of the basin, the average amount of precipitation over the basin was computed with the observed data from the five meterological stations using the Thiessen Polygons Method (Figure 2).

In the study, runoff and rainfall data of Güvenç Basin obtained from the precipitation and flow characteristics project in Güvenç Basin (Tekeli and Demirkıran, 2010). In the project, short term maximum rainfall data for unit hydrograph analysis were analyzed and unit hydrographs were formed in 10 different time periods between 1984 and 2010. In the HEC-HMS model, the maximum rainfall data, influenced by the observed unit hydrographs and the formation of these currents in the years of 1992, 1993, 1998, 2000, 2002 and 2005, was recorded in meteorological stations at the same time scale. The model compared to the observed flow data at the same time period using the “SCS CN” Method and meteorological data at the observed time interval.

Last step for generating of the flood modeling was that the calibration of some of the HEC-HMS parameters including CN, and the validation of the simulation outputs using the best parameter estimates were conducted for the Güvenç Basin. The calibration and validation processes were carried out by splitting the observation periods. For calibration, the years of 1992, 1993 and 1998; for validation, the years of 2000, 2002 and 2005 were chosen. Applied methods, input and output parameters in HEC-HMS Model for Güvenç Basin are given as follows:

1. Loss method: SCS Curve Number
2. Transform method: SCS Unit Hydrograph
3. Baseflow method: Recession

Input parameters:

- Rainfall
- Observed runoff
- Unit hydrograph values
- Curve number
- Calibration parameters (ratio, recession, impervious)

Output parameters:

- Observed runoff
- Simulated runoff
- Hyetograph

Results

Figures 5-7, showed the simulated (marked with blue line) and observed (marked with black line) hydrographs for calibration. The flood modeling was simulated by using curve number with the values of the basin characteristics (Table 3). The calibrations parameters were determined by comparing the observed flood values with the simulated results (Table 4). The figures were generated with the HEC-HMS Model.

Table 3
Values of Güvenç Basin Characteristics

Drainage Area (km^2)	**Longestflowpath (m)**	**Centroidal Longestflowpath (m)**	**Average height (m)**	**Basin slope (%)**	**Basin Perimeter (m)**
15.3	5896	2610	1235	0-40	19000

Table 4
Calibrated Model Parameters

Years	Curve Number	Initial Abstraction (mm)	Ratio	Recession	Impervious
1992	81	1.2	0.02	1	1
1993	81	3.8	0.01	1	0.8
1998	81	13	0.01	1	1.2

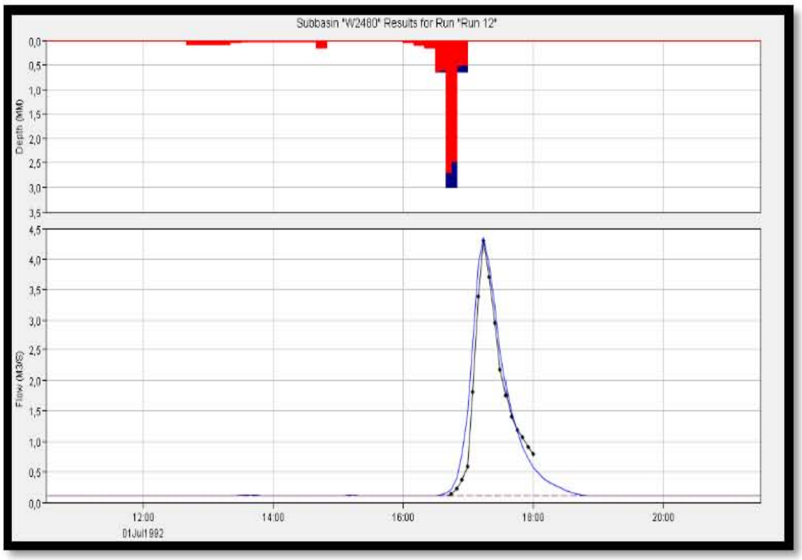

Figure 5. Observed and simulated hydrographs in 1992.

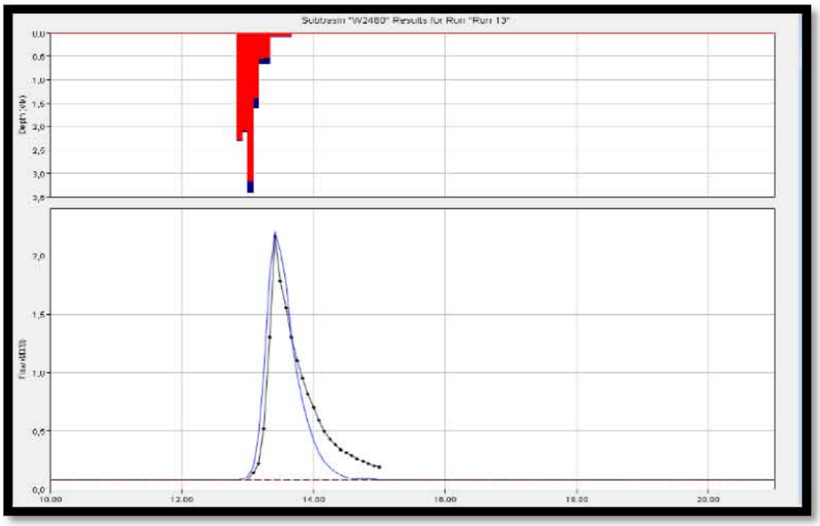

Figure 6. Observed and simulated hydrographs in 1993.

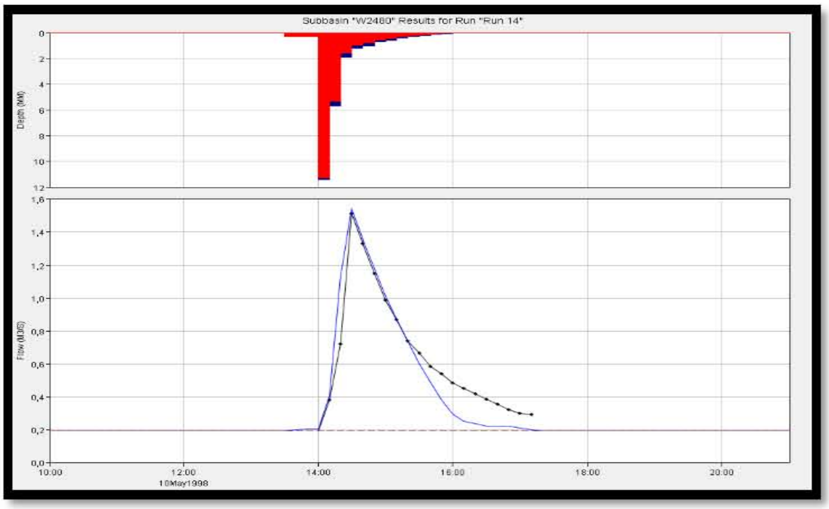

Figure 7. Observed and simulated hydrographs in 1998.

Calibrated model parameters which include CN (related to land cover), initial abstraction (soil water availability), ratio (depends on sediment), recession (base flow) and impervious (depend on urbanization) were given in Table 4.

For validation; CN, ratio, recession, and impervious parameters were chosen as 81, 0.01, 1.0, and 1.2 respectively. After determining the calibration parameters, the model performance was evaluated by validation process. As a result of the validation process, the observed and simulated flood values were shown in Table 5 and Table 6.

Figures 8-10 showed the simulated (marked with blue line) and observed (marked with black line) hydrographs for validation.

Table 5

Observed Values of Flood Hydrograph in Validation Process

Date	**Peak flow (m^3/s)**	**Initial Discharge (m^3/s)**	**Time of concentration curve (hour)**	**Time of recession curve (hour)**
02.06.2000	1.271	0.089	1	2
01.05.2002	1.18	0.233	1	3.5
26.05.2005	2.52	0.039	1	8

Table 6

Simulated Values of Flood Hydrograph in Validation Process

Date	**Peak flow (m^3/s)**	**Time of concentration curve (hour)**	**Time of recession curve (hour)**
02.06.2000	1.225	1	4
01.05.2002	1.16	1	2.5
26.05.2005	2.60	1	3

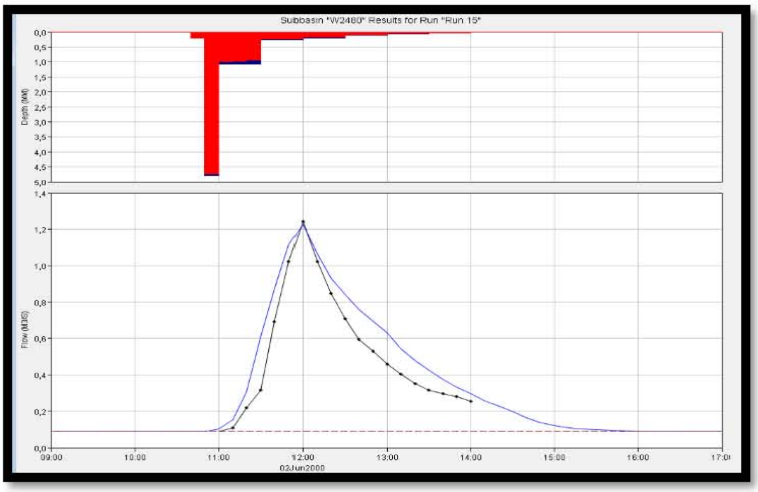

Figure 8. Observed and simulated hydrographs in 2000.

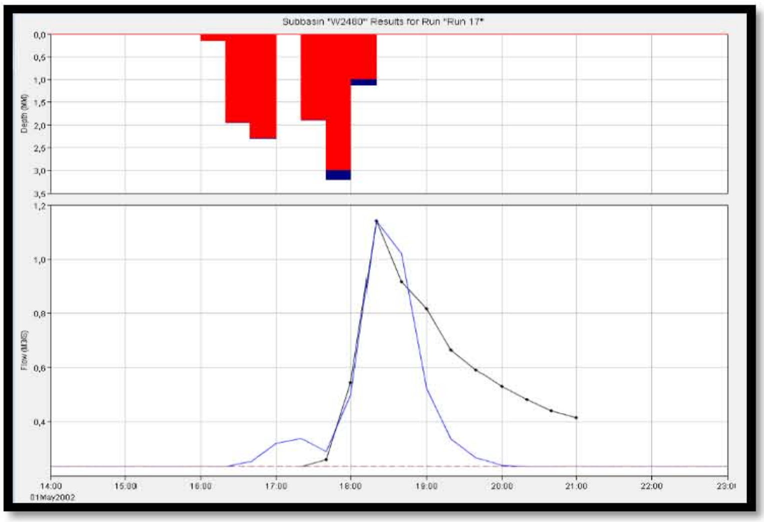

Figure 9. Observed and simulated hydrographs in 2002.

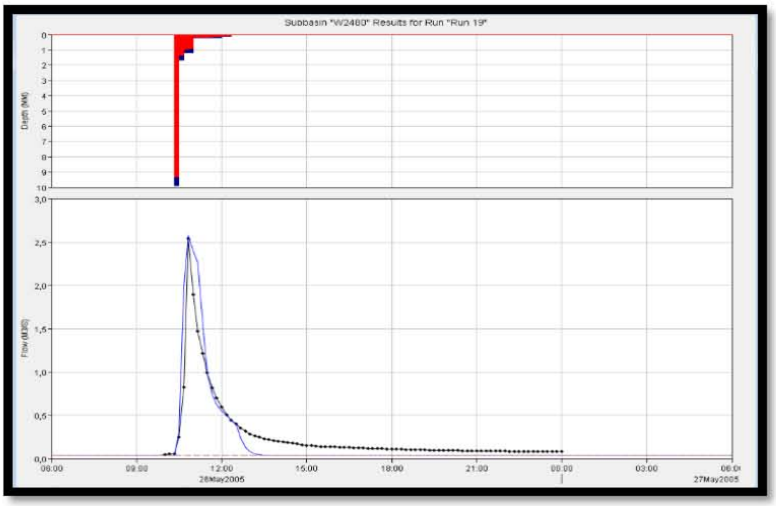

Figure 10. Observed and simulated hydrographs in 2005.

Initial abstraction values were again determined for validation simulations as 3.98 mm, 5.75 mm and 6 mm for the years of 2000, 2002 and 2005, respectively. Initial abstraction values were different for each year for both calibration and validation processes because of the different soil conditions in the basin.

For calibration work; in 1992, 1993 and 1998, hourly precipitation values were simulated using the HEC-HMS Model. In calibration process, initial abstraction, impervious, recession, ratio calibration parameters were calculated by comparing simulated and observed peak discharges optimum values. For verification work; the values of the 2000, 2002 and 2005 were evaluated. Lastly, the results of the model which was simulated with the observed peak flow rates, were found very close to each other. Observed peak values were found 1.271, 1.18, 2.52 m^3/s respectively in 2000, 2002, 2005 years. On the other hand, simulated peak flow were found as 1.225, 1.16, 2.60 m^3/s respectively for these years.

Discussion and Conclusion

The climate change has impacted the rainfall pattern, and it is resulted in flood events due to the deterioration of land structures. Flash floods often causes serious loss of life and property. In order to minimize the impacts of this situation, it is need to predict truthfully floods in any area. The short-term precipitation is a warning to any region for modeling flood phenomena that can be predicted. Therefore, in order to evaluate the flood risk using precipitation data, the relation between the observed results and the model simulations should be investigated by performing precipitation-flow modeling of the regions. In this study, the relation between the floods occurring in the Güvenç Basin and the HEC-HMS flow simulations was investigated.

The performance of the flood modeling has been evaluated by comparing observations and model simulations for the selected flood events. Model calibration parameters (impervious, recession, ratio, initial abstraction) were estimated in calibration process and by using these parameters, validation of the model was conducted for flood events. Model simulated flood datas were found to be compatible with the observed data.

The high performance of the model is not an important intervention on the water potential of the basin and it is an essential factor for the basin to be untouched. The selected periods (1992, 1993, 1998, 2000, 2000, 2002, and 2005) for the calibration and validation processes are periods that heavy precipitation occurs sufficiently to form a unit hydrograph. The presence of long term data in short time intervals is another factor that ensures high performance of the model.

As a result, the hydrological model has high performance in Güvenç Basin. The hydrologic model created for Güvenç Basin can be used for the other flood management and flood early warning studies.

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Extended Turkish Abstract
(Genişletilmiş Türkçe Özet)

Ankara Güvenç Havzası'nda Taşkınların HEC-HMS ile Modellenmesi

Sanayi devrimiyle birlikte ekosistem üzerindeki antropojenik etkilerin artması sonucunda tüm dünya, küresel iklim değişikliği sorunuyla karşı karşıya gelmiştir. Küresel iklim değişikliğinin olumsuz etkileri neticesinde atmosfer tabakası kararsızlaşmıştır. Bu durum, son yıllarda, yağış trendlerinde değişikliğe ve ekstrem yağışlarla beraber taşkınlara sebep olmaktadır. Çevre felaketlerine ve can kaybına neden olan taşkınların zararlarını ve boyutlarını analiz etmek amacıyla bilim insanlarınca çeşitli metotlar geliştirilmiş ve çalışmalar yürütülmüştür. Taşkın frekans analizi, su kaynakları projelerinin ekonomik ve hidrolojik olarak değerlendirilmesinde oldukça önemli bir yöntemdir. Bu yöntem olası taşkın büyüklüğü veya belirli büyüklükteki bir taşkının frekansının tahmin edilmesini, hidrolik yapıların uygun tasarım kriterlerinin saptanmasına ve proje maliyetinin düşürülmesine olanak sağlar. İstatistiksel frekans analizi uygulanarak belirlenen olasılık dağılımlarıyla taşkın tahminleri yapılmaktadır fakat iklim değişikliği ve artan şehirleşmenin etkisiden dolayı parametrik yöntemler ile taşkın riskinin belirlenmesi tek başına yeterli değildir. Dolayısıyla, günümüz şartları gözönüne alınarak taşkın risk değerlendirmesi çalışmalarında, parametrik olmayan metotlar veya hidrolojik modellerin iklim değişikliği senaryoları ile birlikte kullanılmasıyla risk yönetimi açısından daha sağlıklı sonuçlar elde edilir.

Bu çalışmada, Tarımsal Araştırmalar ve Politikalar Genel Müdürlüğü'ne bağlı, Toprak Gübre ve Su Kaynakları Enstitüsü tarafından yürütülen "Güvenç Havzasının Yağış ve Akış Karakteristiklerinin Belirlenmesi" araştırma projesi kapsamında, gözlemlenmiş yağış ve akış değerleri, HEC-HMS modeli kullanılarak modelin performansı analiz edilmiştir. Örnek çalışma kapsamında, 1992, 1993, 1996, 2000, 2002 ve 2005 yıllarının belirli zamanlarında gözlemlenmiş pik taşkın debileri ile HEC-HMS modeli ile simüle edilen değerler, kalibrasyon ve validasyon çalışmalarında kullanılmıştır. Pik taşkın debilerinin hesaplanmasında ve model performansının ölçülmesinde kullanılan yöntem (SCS Curve Number) için gerekli olan akış eğri numarası (CN), arazi örtüsü haritaları (CORINE 1990, CORINE 2012) analiz edilerek belirlenmiştir. Sayısal Yükseklik Haritası (DEM), "usgs" web adresinden temin edilmiştir. 30 metre çözünürlükteki sayısal yükseklik haritası tiff formatında, CBS işlemlerinde kullanılmıştır. CBS tabanlı HecGeo – HMS model uzantısı ile havzanın karakteristik özellikleri (akım yönü belirleme, kümülatif akım hesaplama, nehir tanımlama, nehir bölümleme, su toplama alanı oluşturma, su toplama alanı poligonlama, drenaj çizgilerini belirleme, bitişik su toplama alanı belirleme, en uzun akarsu boyu, akarsu eğimi, akarsuya bağlı havza orta noktasının merkeze (aksa) olan uzaklığı, drenaj alanı, havzanın eğimi, ortalama kot) belirlenmiştir. Havzanın karakteristik özellikleri analiz edildikten sonra HEC-HMS model içerisinde, havza karakteristik değerleri, gözlemlenmiş meteorolojik ve hidrolojik veriler kullanılmış olup simülasyon sonucuna göre gözlemlenmiş değerler karşılaştırılarak en uygun kalibrasyon parametreleri belirlenmiştir. Doğrulama (validasyon) işlemleri ile modelin sonuç performansı değerlendirilmiştir.

Havza, 40 08 00 N enlemi ve 32 45 15 E boylamı arasında yer almaktadır. Karakteristik özellikleri değerlendirildiğinde, drenaj alanı 15.3 km², çevre uzunluğu 19 km, en düşük kotu 1053 m, en yüksek kotu 1453 m, ortalama yüksekliği 1235 m, akış eğri numarası (CN) 81, en uzun akarsu boyu 5896 m, Havzanın orta noktasının aks yerine olan en uzun akarsu boyu 2610 m, Havzanın eğimi % 0-40 arasında değişmekte olup Havzanın ortalama eğimi ise %21'dir. Modelde kalibrasyon ve validasyon işlemleri uygulanarak elde edilen gözlemlenmiş ve simüle edilmiş taşkın hidrografları birbirine çok yakın sonuçlar vermiştir. Doğrulama işlemlerinin yürütüldüğü 2000 yılında, gözlemlenmiş pik debi 1.271 m³/s, simüle edilmiş pik debi 1.225 m³/s olarak hesaplanmış ve hidrografın yükselme eğrisi her iki durum içinde 1 saat, çekilme eğrisi ise gözlemlenmiş değerlerde 2 saat, model simülasyonunda 4 saat sürmüştür. 2002 yılının doğrulama çalışması incelendiğinde, gözlemlenmiş pik debi 1.18 m³/s, simüle edilmiş pik debi 1.16 m³/s'dir. Hidrografın yükselme eğrisi, gözlemlenmiş ve simüle edilmiş sonuçlarda 1 saat sürmüş olup çekilme eğrisi ise gözlemlenmiş sonuçlarda 3.5 saat simüle edilmiş sonuçlarda 2.5 saat sürmüştür. Bir diğer doğrulama işlemi 2005 yılı için araştırılmıştır. 2005 yılında gözlemlenmiş pik debi 2.52 m³/s, simüle edilmiş pik debi ise 2.60 m³/s olarak hesaplanmıştır. Hidrografın çekilme eğrisi gözlemlenmiş sonuçlarda 8 saat, simüle edilmiş sonuçlarda 3 saat sürmüştür. Yükselme eğrisi, her iki durum için de 1 saat sürmüştür. Gözlemlenmiş ve simüle edilmiş taşkın hidrograf sonuçları değerlendirildiğinde, taşkının oluşma süresi ve şiddetinin birbirine oldukça yakın bulunmuş olup Havzada değerlendirilen HEC-HMS modelinin performansı oldukça yüksek bulunmuştur. Bu duruma etki eden en önemli husus ise havzadaki akış değerlerinin doğal olması, dereler üzerinde herhangi bir müdahale olmaması yani havzanın bakir olmasıdır. Ayrıca, havza içerisinde istatistiksel olarak anlamlı bir şekilde veri sağlayan istasyonlar değerlendirilmiş olup veriler saatlik üretilmektedir. Dolayısıyla, ani maksimum yağışların pik debileri istatistiksel yaklaşımlardan ziyade gözlemlenmiş veriler kullanılarak hesaplanmıştır. Çalışmada, ani maksimum yağışlara bağlı oluşturulan birim hidrograf değerlerinin tümü model içerisinde kullanılmıştır. Havzanın bakir olması, meteoroloji ve akım gözlem istasyonlarının havza içerisindeki uygun konumu, üretilen veri setinin sürekli ve kesintisiz olması model performansını olumlu yönde etkileyen faktörler arasındadır.

Güvenç Havzasında hidrolojik model kullanımı ile yağış akış ilişkisi analiz edilerek çalışma alanında uygulanan modelin kullanılabilirliği test edilmiştir. Model performansının yüksek olması ile çalışılan bölgede taşkın tasarım ebatlarındaki risk yönetimi çalışmaları ve taşkın erken uyarı sistemleri geliştirilebilir.

Hidrolojik model seçiminde, araştırma alanının karakteristik özelliklerini belirleyen ve Coğrafi Bilgi Sistemleri (CBS) tabanlı programlara entegre edilebilen modellerin kullanılması, havza karakteristik özelliklerini daha iyi temsil edebileceğinden dolayı diğer modellere göre avantaj sağlamaktadır. Bu sebeple, HEC-HMS ve Toprak ve Su Değerlendirme Aracı (SWAT) gibi CBS tabanlı programlarla birlikte kullanılan hidrolojik modeller araştırma çalışmalarında yaygın bir şekilde kullanılmaktadır. Bu gibi modeller kendi web siteleri üzerinden kullanıcı yorumlarına açık olduğundan kullanıcıya teknik destek sağlanabilmekte, modeller sürekli güncellenebilmektedir. Model performansında ise önemli olan araştırma sahasının karakteristik özellikleri ve mevcut veri varlığının en iyi şekilde modele tanıtılmasıdır. Araştırma bölgesindeki meteoroloji ve akım gözlem istasyonlardaki saatlik hatta dakikalık ölçümler, yeraltı suyu seviyesi, toprak haritası, arazi örtüsü, toprak katmanları, taban suyu, toprak nemi, toprak iletkenliği, kar örtüsü, kar-su eşdeğeri, referans evapotranspirasyon, gerçek evapotranspirasyon verilerinin tümü ya da bir kısmı ile simülasyonlar üretilebilir. Model performansına etki eden husus ise doğal ya da doğallaştırılmış veri varlığı ve sağlıklı ölçümlerdir.