Hydrological Design of Ashour Watershed by Geographic Information System (GIS) .

التصميم الهيدرولوجي لوادي اشور باستخدام نظم المعلومات الجغرافيه.

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Abstract

In this research, geographic information systems (GIS) were used to analyze the basic features of the catchments in the study area and to calculate the necessary data requirement to design hydraulic structure such as reservoir capacity, culvert or bridge. Ashour-basin in Nineveh province in north region of Iraq is selected as case study.

Hydrological, soil, and climatic data were collected for the study area. Hydrological calculations to estimate the runoff and maximum flood discharge of valleys for different flood return periods are designed. The use of (GIS) has emerged as a significant support tool for managing , analyzing and assembling water resources information. With the Natural Resources Conservation Service (NRCS) method has provided more information and facilitated to suggest the portable, site, size, and type of hydraulic structure to use in the region.

Keywords: *Hydrology design, Curve number, peak flow, GIS.*

ملخص البحث:

في هذا البحث تم استخدام نظم المعلومات الجغرافية (GIS) لتحليل السمات الأساسية لأحواض التصريف في منطقة الدراسة وإنشاء البيانات اللازمة لعملية تصميم المنشأت الهيدروليكيه ك سعه الخزان والعبارات والجسور. تم اختيار حوض وادي اشور في محافظة نينوى شمال العراق كتطبيق للدراسه. تم جمع البيانات الهيدرولوجية والتربه والمناخية لمنطقة الدراسة . وتم إجراء الحسابات الهيدرولوجيه لتقدير التصريف ألفيضاني الأقصى للأودية ولفترات عودة فيضانيه مختلفة . ان استخدام نظام المعلومات الجغرافيه مع التصميم الهيدرولوجي باستخدام طريقه حفظ الموارد الطبيعيه (NRCS) تعتبر طريقه مناسبه وزودت بالكثير من المعلومات والتسهيلات الضروريه والكافيه وبأقل كلفه للتصميم الهيدروليكي لأقتراح حجم وموقع المنشأ الهيدروليكي كالجسور و العبارات الواجب استخدامها في منطقة الدراسة.

1. Introduction

Water resources is one of the most important criteria for societies building and their development, because ancient civilizations were grown at river basins in Iraq. Evaluation, planning and management of water resources are raised to be one of important subjects in the human's life, particularly in arid and semiarid regions since precipitation is extremely limited and spatially distributed, with poorly available ground water supply.

The problem of predicting flood volume (runoff) and peak flow resulted from a known storm of rainfall in catchment has received considerable attention from hydrological engineers.

To estimate the volume of flow and peak flow by hydrological design method needs to know the effective rainfall of the storm, this can be estimated by determining the losses from precipitation such as interception, infiltration, evapotranspiration, and depression storage. Our knowledge of these land phase processes is more limited.To avoid the use of hydraulic structure too much size therefore, an unjustified increase in the cost of structure construction, or use a size less than the required that cause the inability of hydraulic structure to absorb the discharge contained it from storm rain. The destruction of the hydraulic structure causes a big loose material or may be humanity.

The procedure of design hydrulic strecture such as culverts and bridges to external roads in the region of Iraq is facing a lot of difficulties, especially regarding the collection of topographical and hydrological information because the measurements and data available for a few very limited region and the process of making these measurements take a very long time and requires a lot of effort and money.

Therefore, searching for a new way to overcome these difficulties is one of the principal terms of the availability of modern technologies such as remote sensing and geographic information systems (GIS).

Hydrologic analyzes are necessary for designing and evaluating the performance of hydraulic structures such as bridges , culverts and capacity of the reservoiur. Traditionally, geographic (spatially distributed) data needed for such analyzes. Recent advances in computer technology and developments in software led to revolutionize hydrologic modeling. Geographic information systems (GIS) is one of the most software developments, which is a computerized technology for storing, managing, and manipulating spatial data.

GIS is a powerful, simple, reliable and relatively cheap tool and integration it with hydrologic modeling is expected to replace, to a large extent, the traditional modes of data manipulation in hydrologic analyzes shortly

[1] led hydrologists to design approaches using a complex watershed model and to predict many data such as areas drainage basins, waterway length, the slope of the main waterway, main points of intersection, main flow with the road, runoff, and others.

The researchers **[2]** used GIS to facilitate the design with the process under the highway where the use of geographic information systems reduced the time of analysis and good accuracy analysis by improving the accuracy of the representation of drainage basins specifications to increase the maximum discharge calculation accuracy and account high of catharsis in area of studying.

[3] used GIS to extract data from satellite images to be used in the construction of hydrological models that can be relied upon for the design of facilities, such as highway roads and bridges.

[4] presented a study applied for an aquarium in northern Iraq. He used GIS technique for extracting topographic and morphometric information. The processing and analysis of digital altars by Digital Elevation Model (DEM) which includes an integrated database in the X, Y, Z coordinates. He extracted properties of Basin, Network discharge efficiency. GIS faster way compared to the ways of traditional handway.

[5] studied the morphometric characteristics of the basin Jbab Valley. They studied the aspects of spatial and morphological characteristics of the water drainage network, the hydrology situation including a limited account of water that income of it during the rainy season. Therefore, Remote Sensing and GIS are better techniques to select the appropriate position for the construction of dams and reservoirs for use in water harvesting.

[6] employ techniques of Remote Sensing and GIS software to create topographic maps of the Alkaarh Dam, which is located in the western region of Iraq as well as the definition of geometrical characteristics of the basin water dam and through which hydrological information account designed a dam such as storage capacity and runoff maximum design liquefied water to fill.It was found that the use of data remote sensing techniques provides voltage and the cost and time when compared to traditional means in addition to that accuracy in line with the precision required in the quantities account.

The aim of this research is to estimate the lag time ,concentration time and maximum discharge flood for different period's promises to a group of valleys in Ashur basins. Analysis, processing and creation of hydrological design data by geographic information systems (GIS) and suggest the appropriate structure to the passage of this safe runoff using the hydraulic design. The importance of the study will look at the use of GIS management and analysis tools to build a spatial hydrological model to improve hydraulic and hydrologic design tools available for use by engineers and consultants.The selection that uses engineering analysis and interactive graphics is expected to reduce production times for design and improve quality control. Besides, The worst hydrological design led to the collapse of massive material losses in many of the roads in Iraq, such as wet road Rotba - Akkashat and other as shown in fig.(1).

Fig.(1): Failure of hydrological design.

2. Watersheds studied descriptions

The Ashour wadi basin is located in the Eastern part of the province of Nineveh in the north of Iraq. The watershed lies between (36^{O} 0' 0") to (36^{O} 40' 0") N latitude and (43^{O} 10' 0") to (44^{O} 0' 0") E longitude . It extends to the Ain al-sufera of the north, to the River Khazar of the east, and to the Nimrod of the south as shown in fig.(2).The total area of it is about (281 .85) km^2. This area is located topographically in a depression surrounded by hilly lands from the east slopping toward Tigris River. This characteristic brought this area to deliver big quantities of surface runoff during rainfall, flowing through number of main wadies to Tigris River.

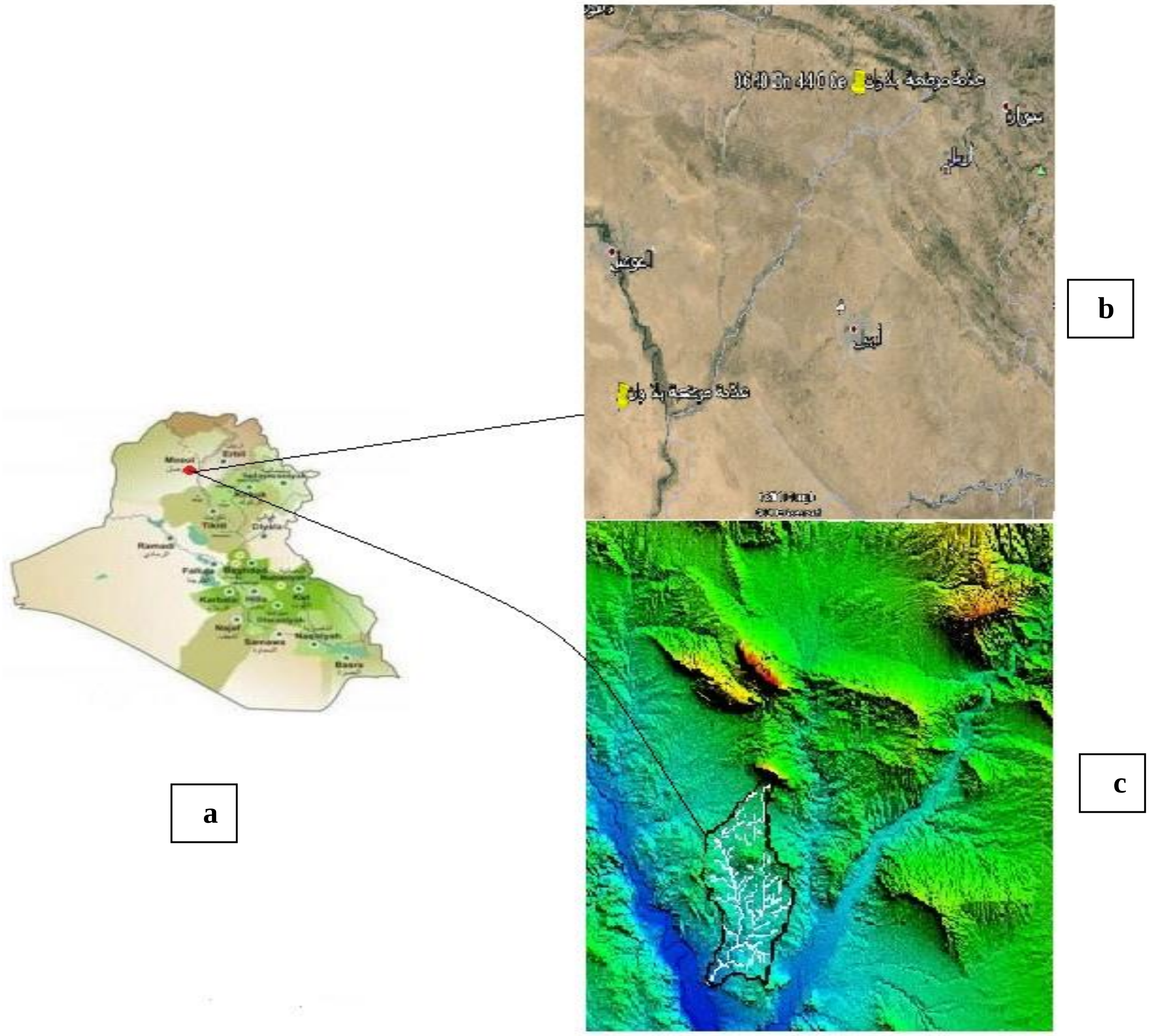

Fig.(2): The location of Ashour Wadi a:Iraq mab. b: Location of Ashour Wadi from GPS.
C: The Ashour Wadi are derived from satellite images

3. Methodology

In this research, A GIS has been developed to assist the design of hydraulic structure facilities by utilizing hydrologic spatial data (location, climate, soil)to calculate the input parameters for hydrological design information such as watershed parameters, peak discharge for different return period and runoff curve number. . Due to the lack of adequate studies about flow income to the different valleys of studying area ,therefore use of geographic information system to derive necessary data to calculate lag time, time of concentration ,the maximum discharge passes through the various valleys during the design age of hydraulic structure , as follows:

3.1 Climate and Land Cover

Ashour wadi basin is characterized by the Mediterranean climate. It is hot in Summer which starts in May and ends at the end of September. The temperature varies a lot and it may approach 50 °C. This is one of the reasons to rise a little above sea level which does not exceed 220 m , while low temperatures to below zero in winter which starts in December and ends at the end of February. The average annual evapotranspiration is about 91 mm. The average annual rainfall is about 375 mm **[7],** and all the precipitation occurs in winter and spring month. Heavy rain that leads to the flooding of the streets of the city. This flood took place in 1982. **[7].**Land cover is extremely variable due to differences in morphology and land use. Most of these areas are composed of gypsum, limestone, and marl **[8]**, which is very tough , highly jointed and fractured. Thus cannot be used for agricultural practices. Percentage of vegetation cover is very poor. Main crops are wheat, barley **[9].**

3.2 Soil Analysis

The analysis of soil texture has an important role to know the amount of surface runoff and this will be taken into account in the design of the hydrological basin. Six disturbed specimens were taken from selected sites along the study area in 2005 year [10]. The specimen's selection covering the whole area as possible as it could be done. The specimens were taken at 100-150 cm depth. Grain size analysis and hydrometer test for soil specimens were done according to the ASTM D422-63 (ASTM, 1983). The lab analysis results as shown in Table (1). That the clay, silt, and sand fraction ranged between (44 -60 %), (21-35 %) and (15– 27%), respectively. Owing to the Unified Soil Classification (USC) system, the texture of the studied soils could be classified as silt clay with gypsum. The natural gypsum Contents of Ashour basin ranges between 35- 65%, with an average value of 49.1%.

Table (1): Sieve and chemical analysis of the soil at depth (100-50 cm).[10]

Sample Location.	Specific gravity	Sand %	Silt %	Clay %	U.S.C Type	Gypsum %
Ain Talawi	2.34	17	26	48	Silt clay	46
Al-Mizraa	2.32	19	21	60	Clay silt	43
Adaii	2.41	27	30	53	Silt clay	52
Mahalabia	2.34	22	34	44	Silt clay	54
Ain Mahabia	2.33	15	35	47	Silt clay	65
Al-Musaad	2.3	18	35	48	Silt clay	35

3.3. Building a database for Ashour watershed by (GIS)

Due to the lack of adequate studies about flow income to the studying area. Therefore use of A geographic information system (GIS) software to derive necessary database to calculate the maximum discharge passes through the various valleys during the design age of hydraulic structure.

(GIS) is a computer system designed to allow users to collect, store, manipulate, analyze spatial information , manage, and present all types of spatial data entry in maps and visualization functions **[11].** A GIS is comprised of several map layers. Each map layer is a collection of spatial features (lines, points, or areas) linked to database tables which describe the attributes of those features.

[4] Extracted data base including topographic and spatial characteristics of the Ashour wadi by selecting space model of the study area format HGT which stored in astronomer location N365043 HGT in the website www.nasa.gov .The valley basin was converted to a digital model (DEM).

Fig. (3) represent the surveying and morphological properties which special important in design water resource project especially in semi-arid region and are summarized in table (2).

The GIS program was used to determine the boundaries of drainage basins in the study area in addition to identify some of the properties and other essential to calculate the drainage basins such as(drainage basin area, length, perimeter, slop, shape coefficient, sinuosity coefficient, and other specifications). Fig. (3) Shows the drainage basins in the work area are derived from satellite images by GIS software which were identified four drainage basin of varying sizes.

The value of the area shape coefficient indicate the basin is close to the rectangle shape and thus indicates the increase the velocity of flow this mean the runoff reach to peak after fall rainfall.

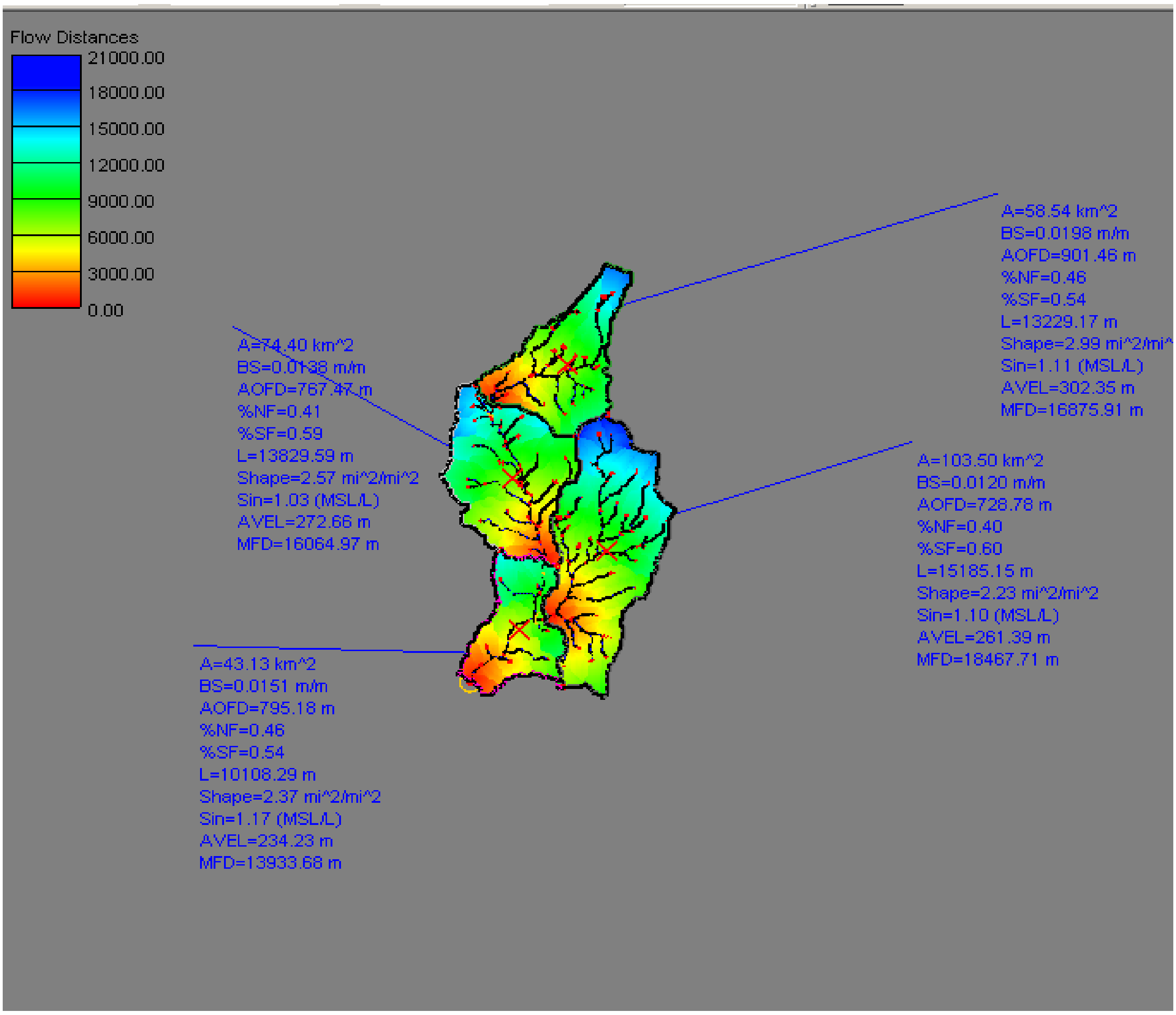

Fig. (3): Morphometric parameters of the four sub-catchments of Ashour basins derived from GIS [4].

The largest drainage basin have a symbol (basin 2), which represents with total area (103 km^2) and borders along the main valley (64.11 Km), and the smallest drainage basin symbol (basin 1), reaching an area (43 km^2) and the length of the main valley (10.1 Km). The elevation within the study area range between (234.2 m) at the (basin 1) and (302.34 m) in the north (basin 4) .The average slope Distributed over the whole area is 1.4%, There is low slop and poorly drained. These characteristics in turn may be entered into the Natural Resources Conservation Service's (NRCS) graphical method to determine the peak flows for a desired return period.

Table (2):Morphometric characteristics of watershed under study[4].

Properties	Ashour Basin	Basin 1	Basin 2	Basin 3	Basin 4
Area (Km^2)	282	43	103	74	59
Perimeter(Km)	115.64	43.5	64.11	49.67	48.58
Length(Km)	32.95	10.1	15.18	13.83	13.22
Slop	0.014	0.015	.0012	0.013	0.02
Shape Coff.	.42	.43	.44	.39	.33
Sinuosity Coff.	1.25	1.17	1.1	1.03	1.11
Elvation(m) (a.s.l)	268	234.2	261.38	272.65	302.34
Longevity Coff.	.84	.98	.98	.95	.98
Drainage Density	3.1	3.19	3.36	3.25	3.18

4. Results and Discussions

4.1 Estimation of Runoff

The purpose of this analysis is to provide the tools for estimating peak flow rates and necessary data for designing hydraulic structure. Soil Conservation Service(SCS) method was used. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area , to estimate the total volume of runoff that may come from a watershed during a design flood long return period and to predict the total annual runoff volume for mean monthly rainfall. It is used for drainage basins with area of more than (2.5 Km2) **.** .Mosul and Sinjar stations record data for the interval during a period of (2000 – 2013) years **[9].** The SCS runoff equation is **[12]:**

$Q = (P- 0.2 S)^2 / (P +0.8 S)$ for $P > 0.2S$ --------------------(1)

$Q = 0$ for $P < 0.2S$ ------------------------ (2)

Where Q = runoff (mm); P = rainfall (mm); S = potential maximum retention after runoff begins (mm).

The parameter S is related to soil and cover conditions of the watershed through the Curve Number (CN):

$S = (25400/ (CN - 254)$ ------------------------- (3)

Where CN = Curve Number ranges between (1-100)

Runoff volume of the catchment has been calculated using the following formula:

$Q_v = 10 * Q * A$ ---------------------------- (4)

Where Qv = runoff volume (m^3); Q = runoff depth (mm); A = catchment area (ha)

4.2. Estimation of Runoff Curve Number

The runoff Curve number (or simply **CN**) is an empirical parameter used in hydrology for predicting direct runoff or infiltration from rainfall excesses. Field data, laboratory analysis have been used to estimate the CN. To select the appropriate CN the following factors cover type, hydrologic condition, hydrologic soil group, and impervious area have been considered. The Curve Number is inversely proportional with water retention potential by land surface **[13].** The moisture conditions are grouped in three types: low humidity; medium humidity; high humidity. In this research, CN values were considered for medium humidity. Table (3) is used to estimate CN according cover type and hydrologic condition.

Table (3): Curve Number values of Ashour basin .

Land use	Soil group	CNi	Area(Km^2)	CNi*Area
Built areas	D	95	28.2	2679
Pastures	D	84	112.8	9475.2
Degraded area	D	91	84.6	7698.6
Irrigated agriculture	D	89	31.1	2767.9
Rain fed agriculture	D	84	25.3	2125.2

The U.S. Soil Conservation Service prepare a special schedule includes soil classification according to soil textures into four categories (A) Deep sand;, (B) sandy loam, (C) Clay loams,(D) Soils that swell significantly when wet; heavy plastic clays; certain saline soils **[14]**. Table (3) shows the way to obtain a curve number of (CN) for different types of land use **[15]**. Depending on the results of 6 samples of soil test in the study area, the soil of drainage basins that (silt clay) texture was represented by the type (D), and through the preview field of land use in the study area shows that the drainage basins located in a sime arid area tapped for agriculture and so it was of each basin unit have been estimated (84-95) on approximately (40% to 10%) of the study area. Lower numbers indicate low runoff potential and more permeable the soil while larger numbers are for increasing runoff potential. In order to calculate the weighted Curve Number value (CN_{avg}) the following formula, proposed by **[16],** was used:

$$CNavg = \frac{\sum_{i=1}^{n} CNi*Ai}{\sum_{i=1}^{n} Ai} \text{ -- (5)}$$

Where: $\mathbf{CN_{avg}}$ = average Curve Number within the catchment area;
CNi = the curve number for each land use-soil group polygon
Ai =the area for each land use-soil group polygon;
n = the number of land use-soil polygons in each drainage basin
By applying the formula (5), the weighted Curve Number was obtained (88).

4.3 Estimation of peak Runoff

Lag time is the time difference between the center of the unit rainfall event and the runoff peak .In order to calculate the lag time for the Ashour basin, the Soil Conservation Service formula, adopted by **[17],** was used:

$$T_{\text{lag}} = \frac{(L*3.28*1000)0.8*\left(\frac{1000}{CNavg}-9\right).7}{14104\ CNavg^{0.7}Y^{0.5}} \text{ ---------------------- (6)}$$

Where: T_{lag}= Lag time in hours; **L**= Hydraulic length of the catchment in km;
; **Y**=average catchment slope in%
Time of concentration is the longest travel time to reach a discharge point in a watershed **[18].**

$$Tc = T_{lag} / .6 \text{ ------------------------- (7)}$$

By using the morphological properties that have been obtained using GIS information is calculated to reach the peak time (tP), the period of time from the farthest part of the basin to the downstream point can be measured by the equation following **[19]:-**

$$t_P = \frac{t_r}{2} + T_{\text{lag}} \text{ ------------------------- (8)}$$

$$T_b = 2.67\ t_p \text{ ------------------------------- (9)}$$

$$Q_P = \frac{2.08\,A}{t_p} \qquad \text{-------------------------------- (10)}$$

Where:
T_p = Base time for standard hydrograph, tr = Time of rain fall., t_p = time to peak
Q_p = Max. Flow (M^3 /s), A= Area of basin (Km^2).
By using frequency rain of (25) years **[20]** to calculate the design intensity rain based on the value of the rain fall time (tr) taken from the value of lag time (T_{lag}) to calculate the peak flow to the valleys for using in design of hydraulic structure . In this research were used intensity - sustainability - Frequency curves Mosul and Sinjar for the interval 2000 - 2008 station. Table (4) shows the hydrological calculations of the study area, which has to extract the time of rainfall Tr, time of concentration Tc, Lag time T_{lag} , time of beak t_p , Intensity for 25 year frequency and peak flow passes through the valley in the study area of the drainage basin symbol (basin 1) to the basin (basin 4).

Table (4): Hydrological Design for Ashour basin

Catchment Symbol	Intersection coordinate (UTM)		Time of Rainfall T_r (hr)	Time Of Concentration.	time lag t_L (hr)	time to peak tp (hr)	Intensity for 25 year frequency (mm/hr)	Q_{max} for Intensity of 25 year frequency (m3/s)
	Easting	Northing		Tc(hr)				
Basin1	440071.76	3618054.83	0.46	3.53	2.12	2.35	15.00	41.94
Basin2	431514.19	3617460.74	0.74	5.65	3.39	3.76	11.00	64.16
Basin3	430048.78	3616866.66	1.9	14.33	8.6	9.55	9.00	39.25
Basin4	438559.62	3615060.65	2.5	18.66	11.2	12.45	10	34.62

5. Conclusions

1. The use of (GIS) technology has provided us with a lot of effort, time and cost in variety of hydrologic design .The cost can be significant, especially when the cost of data collection and manipulation is considered. It is the best method when the data base can be used for several purposes and identifies topographic properties for many of the drainage basins of the valleys such as flood forecasting.
2. The use of SCS CN method based on GIS model will be helpful to the design engineering for the design of water resources structure in watersheds. This method makes the runoff estimation more accurate and fast to calculate the peak flow passing through the valleys cutting of the road and gave a clear vision for the size and type of the necessary dams, bridges, culverts, and flood control structures.to passage of this under roads safely.
3- The low values of water time lag (Tlag) and time of concentration (Tc) which computed in this study demonstrate that, in case of torrential rainfall, accelerated flow and water concentration within basin at the slope base would cause a rapid conveyance of the flood wave from uphill to downstream and an exponential growth of the discharge in a short time.

6. Recommendations

1. Suring on the importance of conducting hydrological studies for roads before the construction process in order to avoid future problems of immersion and the failure of the hydraulic structure.
2. There is a good chance to harvest water in Ashour basin therefore; the dams projects and other water harvesting water must be achieved in basin because a good average rainfall with a low losses.
3. Tlag and Tc values are used for the calibration of several rain-flow hydrological models, like Hec-HMS model or SWIM model to obtain the flash-flood hydrograph. This software's are the most popular programs for computing flash-flood hydrographs

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