Gomaspan Dam Catchment Area Runoff Volume Evaluation by SCS Method

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doi: 10.23918/iec2017.07

ABSTRACT

This research presents a method for computing daily, monthly and annual runoff volume (annual inflow) for Gamesman dam catchment area on Bastora stream in Erbil Governorate.The procedure is developed by the U.S. Soil Conservation Service (SCS) which depends on physical parameters of the catchment area and daily rainfall depth data in Shaqlawa Meteorological station within the catchment area.The advantage of this method is being straightforward to apply, and the physical parameters are easily determined. The runoff depth and volume was computed upon collecting and determining physical parameters (such as drainage area, land uses, soil type and soil infiltration rate) for the catchment area.The results were compared with estimated depth and volume of runoff suggested by (Sogreah) empirical equation used in the design planning report for Gomspan dam prepared by the Project's Consultancy team. The results of the comparison revealed the fact that the depth and volume of runoff was over estimated in the planning report.

Keywords: Runoff, SCS, RCN, SRO.

1. INTRODUCTION

The Gomaspan dam site is located at about 30 km from Erbil city at the foot of the northwest-southeast trending Pirmum Mountain Range within Gomaspan gorge where the Bastora River crosses this mountain structure in perpendicular direction. The Dam site is found very satisfactory from morphological and geological conditions.

The Bastora stream is a tributary of the Greater Zab on the west bank; it is located to the south of Rawanduz; and it is approximately 70 km long. The basin at the dam site is 132.5km^{2}as shown in figure (1),while figure (2) shows the satellite image of dam's catchment area[1]. The basin lies from East to West and almost wholly (approximately 90%) belongs to the cretaceous which is made up of marl and clay[1].The estimated average discharge (base flow) of the stream is approximately about 0.5 m^3/s for eight rainy months in the year, for the rest of four months,the stream is almost dry.Many small valleys fall in the study area in various places that are drained towards the main valley. In winter season, rainfall runoff takes place in the valley while there are no flow measurement records for the main stream of the catchment area.

Bastora reservoir area is located in the semi-arid zone, with hot summer and cold winter. The maximum daily temperature has been recorded as high as 45 C^o on July and August and minimum daily temperature recorded as low as 0 C^{o}on January and February. The rainfallsusually betweenOctober to May with some meteorological records are available for the area. The nearest meteorological station to the reservoir is Shaqlawastation. The average annual pan evaporation in Shaqlawa metrological station for the period (2002 -2010) is 1725.9 mm, and the average minimum and maximum air humidity for the period (2002 -2010)are32.4% in July and 68.2% in January respectively[2].

Gomaspan dam reservoir receives surface runoff from a catchment area about 132.5 km^2;this catchment has different elevations, starting from 800 m.a.s.l.at the dam site up to about 1900 m.a.s.l. at the higher regions at the north. The dam site lies within (300-400) mm isohyets, while the upper part of the dam's catchment area receives about 1000mm in average of rainfall annually.The average monthly and annual rainfall depth for 15 years counted from (1991-1992) to (2010-2011) is 795.7mm for Gomaspan Dam'scatchment areain the Shaqlawa station, as shown in table (3).

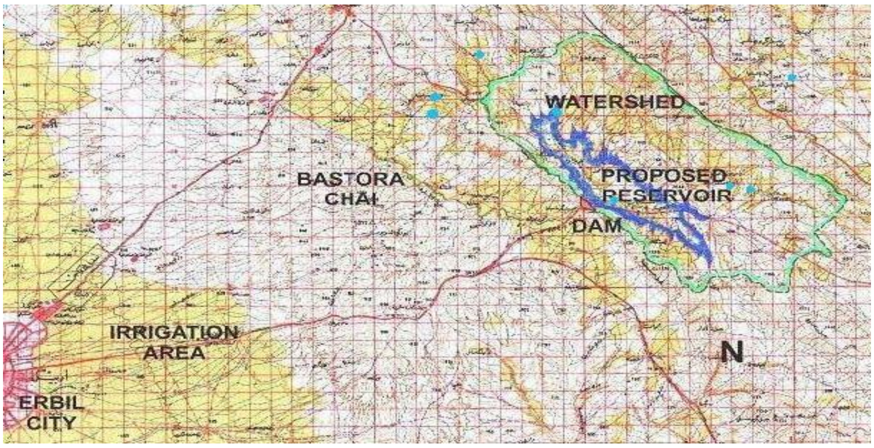

FIGURE 1. Gomaspan dam location and catchment area

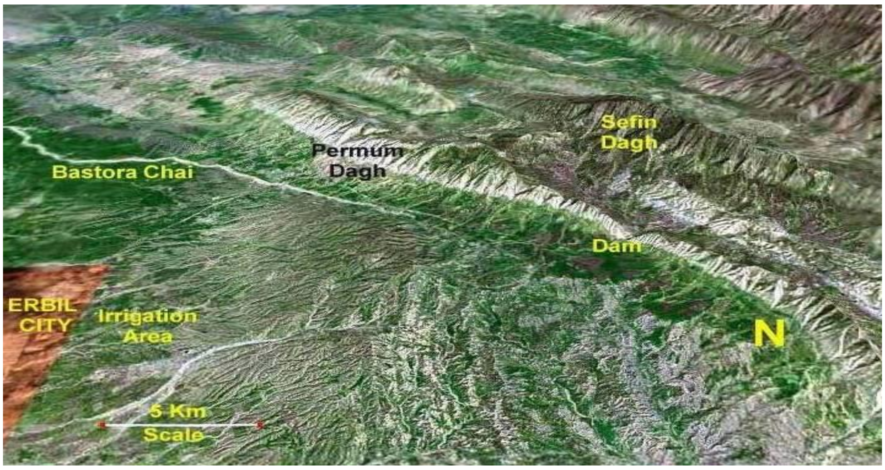

FIGURE 2. Gomaspan catchment area Satellite Image

In 2007 a planning study reportand design of the Gomaspan Dam and Irrigation project was performed by (El Concorde/ MWH Consultants)[1]. In the planning report (hydrological analysis part), and due to insufficient data for stream flow measurements being available,the following approximate empirical formula wassuggested for Gomaspan dam's catchment area by above-mentioned Consultants based on "Upper Adhaim dam-Planning Report" which was prepared previously by The French Company "Sogreah Consulting Engineering"(1983) [3]:

$L_{annual} = 0.56\ (P_{annual} - 6.00)$ (1)

Where:

L_{annual} is average annual depth of runoff at Gomaspan dam catchment area in mm;

$P_{annual}$is annual mean rainfall at Gomaspan dam catchment area (from Shaqlawa gauge station) in mm.

As what has been mentioned earlier, the average annual precipitation of Bastora stream at Gomaspan dam for the period 1991-2011 (P_{annual} = 795.7 mm) and from equation (1):

$L_{annual} = 0.56\ (795.7 - 6.00) = 442.232$ mm

Average runoff volume = 442.232x 132.5 x 10^{-3} = 58.595MCM = 1.858 m^3/sec
The Specific discharge at Gomaspan dam = 1.858 x 10^3 /132.5 = 14.023 l/sec/km^2

The present study (The evaluation of Runoff Volume for the Gomaspan Dam Project) was conducted at the request of General Directorate of Damsin Kurdistan region to check the runoff volume calculated in above planning report toensure that there is enough inflow to fill the designed reservoir volume. In other words, because insufficient data for stream flow measurements are available, this type of streams are called ungauged stream.

In order to estimate the volume of runoff for any ungauged stream, one may use several rainfalls - runoff models, depending on land use and daily rainfall data. One of the methods is the rational equation. This method is most reliable for small catchment areaswith adequate information about rainfall intensity are available. The other method is SCS model (Soil Conservation Service), which depends on the available daily rainfall data and catchment area characteristics (Soil infiltration rate and land use). The SCS method can be considered as most suitable methodfor suchcases, being flexible and it could be implemented for any size of catchment areaswithdaily rainfall depth data being available.

2. METHODOLOGY, AND DATA COLLECTION, FOR CALCULATION OF THE RUNOFF VOLUME BY SCS METHOD

SCS (Soil Conservation Services)[4]method is used for calculating the daily runoff for ungauged streams by using daily recorded rainfall data for the dam site and catchment area characteristics.

SCS derived the following equation for calculating surface runoff depth in (mm):

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

Where:

P is daily rainfall depth in (mm), and

S is a potential maximum retention in (mm), that can be calculated from the following equation:

$$S = \frac{25400}{RCN} - 254 \qquad (3)$$

RCN: is runoff coefficient called runoff curve number, which depends on (soil type, land use and infiltration rate).

2.1 RUNOFF CURVE NUMBER (RCN), CALCULATING THE CATCHMENT AREA UNDER STUDY

In 1954 [5], the SCS developed a unique procedure for estimating surface runoff from rainfall. This procedure, the Runoff Curve Number (RCN) technique, has proven to be a very useful tool for evaluating effects of changes in land use and treatment on surface runoff. It is the procedure most frequently used withinthe SCS and by hydrologists worldwide to estimate surface runoff from ungauged watersheds. The infiltration rate, is the rate at which water enters the soil at the surface and which is controlled by surface conditions. The hydrologic soil groups, as defined by SCS soil scientists according to infiltration rate, are:A type Soils having high infiltration rates (greater than 0.76 cm/hr), B type Soils having moderate infiltration rates (between 0.38 – 0.76 cm/hr), C type Soils having slow infiltration rates (between 0.13 – 0.38 cm/hr), and D type Soils having very slow infiltration rates (less than 0.13 cm/hr).SCS gives RCN corresponding to above soil groups in tables.

In the SCS method of runoff estimation, the effects of the surface conditions of a watershed are evaluated by means of land use and treatment classes. Land use is the watershed cover and it includes every type of vegetation. The following is a brief description of various land uses suggested by SCS [5].

- Pasture or range: Is grassed land that is used for grazing animals. The hydrologic condition is characterized by the degree of grazing and plant cover. Poor condition is that which is heavily grazed that has plant cover on less than half of the area. Fair condition has a moderate amount of grazing with plant cover on ½ to ¾ of the area. Good condition refers to light grazing with plant cover on more than ¾ of the area.
- Meadow:Is a field on which grass is continuously grown, protected from grazing, and generally mowed for hay. They plantations are generallyalfalfa and sweet clover crops.
- Woods or forests: Poor condition refers to those woods which are either heavily grazed and/or regularly burned. Woods in fair condition may still be grazed but have not been burned. In a good condition, the woods are protected from grazing and litter.
- Fallow: Is the agricultural land use and treated with the highest potential for runoff. The land is kept as bare as possible to conserve moisture for use by a succeeding crop.
- Row crop: Is any field crop (corn, soybeans, and sugar beets).
- Small grain: Are wheat, oats, and barley crops.

SCS gives RCN corresponding to the above land uses in table (1)[3]. The tabulated RCN values are for normal soil moisture conditions which are referred to as Antecedent Moisture Condition II (AMC-II). AMC-I, has the lowest runoff potential and the watershed soils are dry. AMC-III has the highest runoff potential as the watershed is practically saturated from antecedent rainfall. The following equations shall compute RCN for AMC-I or AMC-III:

$$\mathrm{RCN(I)} = \frac{4.2\ \mathrm{RCN(II)}}{10 - 0.058\ \mathrm{RCN(II)}} \qquad (4)$$

$$\mathrm{RCN(III)} = \frac{23\ \mathrm{RCN(II)}}{10 + 0.13\ \mathrm{RCN(II)}} \qquad (5)$$

A typical watershed is comprised of many different combinations of soil types and land uses. The most practical way to determine RCN (as used in this study) is to tabulate each of the four hydrologic groups as a percentage of the total drainage area. Land uses should then be tabulated as a percentage within each specific group along with the appropriate RCN. Multiplying the RCN by the percentages and summing over all the different soil-cover complexes, yields the average RCN. Table (2) shows calculations of RCN for dam catchment area under study using SCS tables after considering the following points:

TABLE 1.
SCS Table for RCN for Hydrologic soil cover complex AMCII conditions

Land Use	Treatment or Practice	Hydrologic Condition	Hydrologic Soil Group			
			A	B	C	D
Fallow	Straight row	....	77	86	91	94
Row crops	Straight row	Poor	72	81	88	91
	Straight row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
	Terraced	Poor	66	74	80	82
	Terraced	Good	62	71	78	81
Small grain	Straight row	Poor	65	76	84	88
	Straight row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
	Terraced	Poor	61	72	79	82
	Terraced	Good	59	70	78	81
Close-seeded legumes or rotation meadow	Straight row	Poor	66	77	85	89
	Straight row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
	Terraced	Poor	63	73	80	83
	Terraced	Good	51	67	76	80
Pasture or range	Straight row	Poor	68	79	86	89
	Straight row	Fair	49	69	79	84
	Straight row	Good	39	61	74	80
	Contoured	Poor	47	67	81	88
	Contoured	Fair	25	59	75	83
	Contoured	Good	6	35	70	79
Meadow	....	....	30	58	71	78
Woods	....	Poor	45	66	77	83
	....	Fair	36	60	73	79
	....	Good	25	55	70	77

a. The catchment area was divided into hydrologic soil parts (A, B, C, and D) according to the infiltration rate with help of (arc GIS) software using the satellite image of the dam catchment area.The infiltration rates for different soil types in the dam catchment area were estimated according to the classification given insoil survey of Northern Iraq conducted by Nikolav in 1983 [6].Table (2) shows the percentage (%) of each soil group and summaries as: Type A soil covers (11.3%),type B soil covers (22.6%), type C soil covers (37.7%) and type D soil covers (28.3%) of the catchment area respectively.
b. The land use of the catchment area was surveyed from satellite image for the Gomaspan dam catchment area and consisted of: Fallow which represents (51.7%) of total area,Close- Seeded legumes which represents (3.8%) of total area, small grain which represents (16.2%) of total area.The common crops are wheat and chickpea which are grown on gentler slopes and at the bottom of the valleys. The Grass Land Pasture or range, which represents (20.7%) of total area and grass species found in this zone are mainly annual under heavy grazing by local livestock herds and nomadic herds. Finally,woods (Forests),and represents (7.6%) of total area.

c. Months October and November are regarded as (AMCI) because the land is at its lowest moisture content, period of starting rainfall, the duration between two rainfalls are almost long then the probability of runoff is low.Months December, January and February are as (AMCII), because the soil moisture increases, the duration between two successive rainfalls is short, the probability of runoff increases. Months March, April and May, considered as (AMCIII), because the soil is almost saturated and the possibility of runoff is great.

d. Based on above steps, runoff curve number was found for dam catchment area from SCS table per hydrologic soil groups and the nature of the antecedent moisture condition for AMCII group (weighted mean) and was equal to 84as shown in table (2).For AMCI and AMCIII groups, RCN calculated by equations (4) and (5) and equal to 68.8 and 92.4 respectively.

TABLE 2.
RCN Calculations Details for Gomaspan Dam Catchment Area

Hydrologic Soil Group	Area (km^2)	Measured infiltration rate range (cm/hr)	Measured infiltration rate type	Land Use and Cover	Hydrologic Condition	Partial Area (km^2)	% Area	CN from SCS tables for AMCII	CN x %Area for AMCII	Weighted average CN		
										AMCII	AMCI (from eq.)	AMCIII (from eq)
Type A	15	(0.86 - 6.68)	High	Fallow		10.00	0.075	77	5.81	84.0	68.8	92.4
				Close- Seeded lagumes	Terraced (Poor)	5.00	0.038	63	2.38			
Type B	30	(0.45 - 0.73)	Modrate	Fallow		18.00	0.136	86	11.68			
				Small Grain	Contoured (Poor)	7.00	0.053	74	3.91			
				Grass land Pasture or range	Contoured (Poor)	5.00	0.038	67	2.53			
Type C	50	(0.21 - 0.36)	low	Fallow		20.50	0.155	91	14.08			
				Woods	Poor	5.00	0.038	77	2.91			
				Small Grain	Contoured (Poor)	14.50	0.109	82	8.97			
				Grass land Pasture or range	Contoured (Poor)	10.00	0.075	81	6.11			
Type D	37.5	(0.075 - 0.11)	Very Low	Fallow		20.00	0.151	94	14.19			
				Woods	Poor	5.00	0.038	83	3.13			
				Grass land Pasture or range	Contoured (Poor)	12.50	0.094	88	8.30			
Sum	132.5					132.50	1		84.0	84.0	68.80	92.40

2.2 RUNOFF DEPTH AND VOLUME CALCULATION

Using daily rainfall data for the years from (1991-1992) to (2010-2011), and equations (2)and (3), the daily, monthly, and annual runoff depth in mm for each daily rainfall data were calculated.The results of runoff depth and average annual inflow volume calculations of Gomaspandam catchment area on Bastora stream are shown in table (3) below.

TABLE 3.

Results of Average Monthly, and Annual Surface Runoff Calculation for Gomaspan Dam Catchment Area by SCS Method

Month	Oct.		Nov.		Dec.		Jan.		Feb.		march		April		May		Total depth					
Year	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Rainfall (P) (mm)	Runoff (R) (mm)	Base flow depth (mm)	(Runoff + Base flow) (mm)	Volume of Runoff (m^3)	Avg.Runoff (R) depth (mm)
1991-1992	17.00	0.00	186.00	60.75	152.50	21.84	191.00	70.57	170.00	36.63	54.80	30.96	104.80	39.88	3.00	0.00	879.10	260.63	79.22	339.85	45,030,385	42.48
1992-1993	0.00	0.00	0.00	0.00	161.00	18.03	91.50	17.13	212.00	49.71	169.00	90.14	173.00	85.66	0.00	0.00	806.50	260.66	79.22	339.88	45,034,230	42.49
1993-1994	78.00	9.17	48.50	4.61	65.00	3.80	120.00	25.37	181.50	22.77	150.00	64.83	160.00	115.93	14.00	0.16	817.00	246.65	79.22	325.87	43,177,218	40.73
1997-1998	43.00	0.00	65.00	0.00	319.00	121.55	100.00	8.47	154.00	22.53	64.00	8.35	77.00	18.24	17.00	0.59	839.00	179.72	79.22	258.94	34,310,081	32.37
2000-2001	12.90	0.00	16.40	0.00	192.20	32.88	36.20	0.84	160.80	46.21	127.40	73.59	40.40	9.61	30.00	2.91	616.30	166.03	79.22	245.25	32,495,897	30.66
2001-2002	10.20	0.00	63.20	1.31	135.50	12.14	200.50	27.77	121.50	31.04	148.30	52.12	180.50	68.88	21.00	1.61	880.70	194.88	79.22	274.10	36,318,761	34.26
2002-2003	33.80	0.00	37.80	0.20	292.00	134.16	140.00	18.31	195.00	24.31	238.00	95.52	94.00	29.27	14.70	0.46	1045.30	302.22	79.22	381.44	50,541,250	47.68
2003-2004	41.50	0.00	110.00	2.34	173.00	32.93	303.00	84.40	169.00	34.87	20.50	4.74	171.00	111.19	22.00	6.72	1010.00	277.19	79.22	356.41	47,224,881	44.55
2004-2005	4.00	0.00	248.00	7.04	40.00	3.80	208.50	36.32	145.00	20.75	101.50	46.66	32.00	3.78	33.50	3.73	812.50	122.08	79.22	201.30	26,672,253	25.16
2005-2006	7.50	0.00	36.50	0.03	70.00	12.15	173.50	29.93	366.50	132.03	48.00	23.75	148.50	63.28	24.00	2.26	874.50	263.43	79.22	342.65	45,400,835	42.83
2006-2007	163.00	3.02	82.00	0.01	54.50	21.18	116.50	17.46	233.50	75.90	100.50	28.03	131.50	39.06	37.50	10.83	919.00	195.49	79.22	274.71	36,399,287	34.34
2007-2008	1.00	0.00	16.00	0.00	21.00	0.00	84.00	6.84	100.50	5.66	115.50	63.40	1.50	0.00	4.00	0.00	343.50	75.90	79.22	155.12	20,553,029	19.39
2008-2009	91.00	3.97	44.00	0.00	106.50	12.41	7.00	0.00	69.70	3.46	192.20	87.19	72.30	21.07	4.00	0.00	586.70	128.11	79.22	207.33	27,471,675	25.92
2009-2010	65.50	0.00	14.00	0.00	238.00	66.33	113.50	15.65	165.00	44.74	120.50	54.64	85.00	18.12	33.00	4.31	834.50	203.78	79.22	283.00	37,497,770	35.38
2010-2011	6.00	0.00	0.00	0.00	85.50	13.04	168.50	47.11	118.50	21.75	69.50	24.01	155.50	57.58	68.00	28.00	671.50	191.50	79.22	270.72	35,870,521	33.84
Total	574.40	16.16	967.40	76.29	2105.70	506.24	2053.70	406.19	2562.50	572.35	1719.70	747.94	1627.00	681.55	325.70	61.58	11936.10	3068.29		4256.59	563,998,071	
Average	38.29	1.08	64.49	5.09	140.38	33.75	136.91	27.08	170.83	38.16	114.65	49.86	108.47	45.44	21.71	4.11	795.7	204.55		283.77	37,599,871	

3. RESULTS AND DISCUSSIONS

From table (3) the following are in order: -

a. The annual runoff volume vary between 20.553 MCM and 50.641 MCM with an average value at the Gomaspan catchment area during the period from 1991-2011 of 37.599 MCM (1.192m^3/sec).
b. The Specific discharge of Bastora stream at Gomaspan dam = 1.192 x 10^3/132.5 = 8.998 l/sec/km^2
c. The maximum runoff was in December 2002 at 17.776 MCM (0.563 m^3/sec).
d. The most abundant months are December to April where it varies between 13.23% and 24.37% of annual mean. At times, the least abundant months are June to October, when the runoff varies from 0.0% to 0.527% of the annual mean.
e. The annual runoff with a 0.90 probability of being exceeded is 28.19 MCM, and 48.73 MCM with a 0.10 probability. The estimated annual runoffs for different return periods are shown in Table (4).

TABLE 4.

Estimated Annual runoff for different return periods

T (year)	1.02	1.11	1.25	2	3	5	10	20	50	100	500	1000
Probability	0.98	0.90	0.80	0.50	0.33	0.20	0.10	0.05	0.02	0.01	0.002	0.001
Runoff in MCM	24.6	28.2	30.6	36.2	39.8	43.7	48.7	53.5	59.7	64.35	75.08	79.69

Table (5), shows the comparison between the calculated annual runoff depth and volume for period (1991-2001) for Gomaspan dam catchment area by SCS method with that calculated by the Consultants (El Concorde/MWH Team) in the planning report.

TABLE 5.
Comparison of Calculated Annual Runoff Depth and Volume

For period (1991-2001)	In this study By SCS method	In planning report By consultants (El Concorde / MWH Team)
Average annual depth of runoff (mm)	283.77	442.232
Average runoff volume (MCM)	37.599	58.59
Average runoff volume (m^3/sec)	1.192	1.858
Specific discharge is (l/sec/km^2)	8.998	14.023

From table (5), we note that the calculated depth and volume of the runoff by SCS method is less than the estimated one in the design planning report and the percentage differenceis about 36%.This is because the estimation of runoff volume in the design planning report was based on an empirical equation (Sogreah,1983) which was derived for another catchment area (Adhim river catchment area) and has different characteristics from Bastora river catchment area. Also, the equation depends on annual rainfall depth which not gives accurate runoff depth and volume.On the other hand, SCS method gives more accurate results because it depends on detailed catchment area characteristics (Soil type,soil infiltration rate and land use).Also, the SCS equation uses daily rainfall depth which means the daily runoff depth is calculated for each particular daily rainfall depth then accumulated to find monthly and annual depth and volume of runoff. From above, its clear that the calculated runoff depth and volume in the design planning report for Gomaspan dam is overestimated.

4. CONCLUSION

(1) The catchment area of Gomaspan dam on Bastora River was studied for calculating the depth and volume of runoff by SCS method. According to the results of soil survey, thecatchment area was divided into four soil groups: Type A, Type B, Type C and Type D.
(2) The land use survey of Gomaspan dam catchment area, are Fallow which represents (51.7%) of total area,Close-Seeded legumes which represents (3.8%) of total area, small grain which represents (16.2%) of total area, Grass land Pasture or range which represents (20.7%) of total area, and finally woods, which represents (7.6 %) of total area.
(3) RCN for Gomaspan dam catchment area was calculated from SCS tables for AMCI condition (RCN=84), for AMCII condition (RCN=68.8), and for AMCIII condition (RCN=92.4).
(4) The daily, monthly and annual runoff depth and volume from SCS equation was calculated for Gomaspan dam catchment area using daily rainfall depth recorded in Shaqlawa rainfall gauging station and the average annual depth and volume of runoff for period (1991-2001) is calculated, andthe annual runoffs volume vary between 20.553 MCM and 50.641 MCM with an

average value of 37.599 MCM (1.192m^3/sec).The Specific discharge was equal to 8.998 l/sec/km^2.

(5) The results of this study were compared with calculated annual runoff depth and volume for period (1991-2001) by the Consultants (El Concorde/MWH Team) in the Gomaspan dam design planning report.The comparison revealed that the average annual depth and volume of Gomaspan dam catchment area runoff is less than the estimated one in the design planning report and the percentage difference is about 36%.This isdue to the fact that the equation used for annual runoff volume calculation in the design planning report was an empirical equation derived for another catchment area (Adhim River) and depends on average annual rainfall depth only whichresults in inaccurate and overestimated figures.

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