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URBAN WATERSHED MODELLING - A COMPARATIVE STUDY

(A CASE STUDY OF NAZAFGARH DRAINAGE BASIN)

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PREFACE

India has witnessed rapid urbanization since independence. At present the percentage share of population in urban areas is of the order of 23.71 percent as per 1981 census. With the increasing urbanization and rapid development of cities, the problem of urban drainage has become more complex. Modifications of the land surface due to urbanization produce changes in the magnitude of runoff volume. The major factor which affects the runoff process is that part of the area of the catchment which is rendered impervious. The infiltration capacity of these area is lowered to almost zero and many areas that remain under soil cover are trampled to an almost impervious state so that volume and rate of overland flow have increased. Due to the inadequate drainage facilities in urban areas the rain water gets accumulated in low lying areas causing problems in transportation as well as to inhabitants. Most of the big cities are situated near the river banks. During the high flood period, the river may not be capable of accommodating the drain water. Under this circumstances even if drainage system is adequate, it may not be able to drain the flood water to the river due to back water effect of river.

The present practices of urban storm runoff estimation in India are empirical in nature. Recently some attention has been made to use already developed mathematical model for the estimation of urban storm runoff. The primary component in designing urban drainage system is the design storm i.e. rainfall value of specified duration and return period. Extreme value of rainfall of various short durations (1 hr to 24 hrs) are required for design of urban drainage system. In this study Soil

Conservation Service (SCS) model is used for determination of required drainage capacity at the outlet of Nazafgarh drainage basin. This report is prepared by Sri M. K. Shukla, Scientist B, drainage division of the Institute. The relevent data has been collected by Sri Hukam Singh, R.A. of drainage division of the institute. This report is prepared under the specific work program of drainage division for year 1993-94.

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ABSTRACT

The movement of people from rural to urban centers or cities is called urbanisation. Urbanisation has been taking place at a vary fast rate since early eighteenth century after the industrial revolution. In India also the urbanisation in major urban centers is progressing vary fast. The present study area, the Nazafgarh drainage basin in the city of Delhi, the national capital is also experiencing urbanisation at a vary fast rate. It is found during study from the published literature that the population of Delhi has gone up from almost 40 lakh to nearly 90 lakh during 1971 to 1991. With this massive increase in population a large part of fertile land has turned impervious for various uses such as residential buildings, roads, railway lines, airport etc. This changed land use practice has changed the hydrological scenario of the Delhi. In this study the land use pattern for year 1972 has been found using the topographic map of Delhi. The land use for 1989 was found out using the spot photograph and IRS imagery. The increase in runoff depth has been found using SCS model, the runoff peak and time to peak are found using SCS synthetic hydrograph and S hydrogaph method. The possible depth of runoff, peak discharge and time to peak to be handled in year 2000 have also been found out in this study taking certain assumptions.

1.0 INTRODUCTION

Water is the most vital requirement for survival and inheritance of mankind. With the ever growing population the need for water is also increasing manifold. With the industrial revolution of 1800 the population of cities had started increasing at a vary fast rate because of the huge migration of people from rural surrounding th the urban areas. This movement of people from village to cities is termed as urbanisation (Shukla & Soni, 1992).

1.1 Issues related to urban hydrology

The major issues which urban hydrology needs to deal with, are water supply for urban settlement, urban water pollution and water quality, and urban storm-water runoff disposal.

History indicates that most cities and major urban centers have developed near natural lakes and rivers (Shukla & Soni, 1993). As urban areas continue to expand, new sources of water are required to be found. The maintenance of urban water quality standards is a second major issue. Main sources of urban water pollution are 'Point-source pollution', such as out fall of storm-water drain, overflow from a combined sewerage system or effluent from a sewage treatment plant, industrial effluent to lake or river. 'Non-point source pollution', such as turbidity from erosion prone urban watersheds, agro-based chemical pollutants from agricultural crop lands draining into lake or river.

The third major issue, which urban hydrology needs tc address, is the urban storm-water runoff disposal system. In some flat urban topography, urban life suffers from the nuisance of drainage congestion resulting in damage to public utility installations, hindrance to traffic, property destruction and annoying inconvenience. This situation increases, as more areas turn from pervious surface to impervious surface (Chakraborti, 1989).

1.2 Indian scenario

India had an urban population of around 160 million out of the total population of 685 million in 1981. This population was distributed over 3301 towns of which nearly 1,014 have a population above 20,000 and 318 above 1,00,000.

Major metropolitan cities, viz., Calcutta and Bombay were reported to reel under urban flood water every year during monsoon spell. Towns like Patna, Silchar, Cuttack and even Delhi (1977 flood) are threatened with perennial problem of river flooding and /or drainage congestion. City of Madras faces chronic shortage of potable water supply. Hyderabad, Bangalore, Bhopal have their sources of water supply, dependent on man-made reservoirs. Problems of water management and urban storm disposal of many cities and towns in India need to be seriously looked into (Chakraborti, 1989).

The present practices of urban storm runoff estimation in India are empirical in nature. Recently some attention has been made to use already developed mathematical model for the estimation of urban storm runoff. The primary component in designing urban drainage system is the design storm i.e. rainfall value of specified duration and return period. Extreme value of rainfall of various short durations (1 hr to 24 hrs) are required for design of urban drainage system.

1.3 Urbanisation of Delhi

It is generally believed that, there were nine cities of Delhi which were built from time to time during ancient and medieval periods. These cities are given in the following table :

Table 1: Ancient & New Cities of Delhi

	Cities of Delhi	Built by	Period (A.D)
1.	Indraprastha	Pandavas	
2.	Lalkot	Anangpal	1052
3.	Qila Rai Pithora	Prithviraj Chauhan	1180
4.	Siri or Qila Alai	Allauddin Khilji	1304
5.	Tughlaquabad	Tughlaqshah	1321
6.	Adilabad	Mohammed Tughlak	1325
7.	Jahan Panah	Mohammed Tughlak	1325
8.	Firojabad	Firozshah Tughlak	1354
9.	Shahjahanabad	Shah Jahan	1638-1658

From 1910 to 1947, Delhi was the capital of India under British rule. However, the post-independence era has seen tremendous growth of urbanisation of Delhi. The total population and its density for Delhi for year 1971, 1981 and 2000 is given in the following table (Begda, Vide Chakraborti 1989).

Tab 1 : Population growth of Delhi

Sl No.	Year	Population	Population Growth (%)	Density (per sq.km)
1.	1971	4065649		2742
2.	1981	6220442	53	4194

3	1991	9370475	50.46	6319
3.	2000	14115684	50.64 *	9519*

*- assumed

1.4 Location, Climate and Rainfall of study area

The area of study, is situated between latitude 28°25' to 28°53'N and longitudes 76°15' to 77°15' E (Fig. 1). The region is represented by parts of the topo-sheet Nos. 53H/2, 53H/1, 53D/13, and 53D/14 etc. Study area is about 35 km in length from North to South and 25 km from East to West with an approximate area of 856 sq.km. The area has semi-arid climate. The mean annual temperature at Delhi is about 24.8°C. About 85 percent of the annual rainfall in the Delhi region occurs during the monsoon period i.e. June to September. The rainfall varies considerably from year to year and uncertain in intensity (Chaturvedi, 1993).

1.5 Physiography

The elevation in the study area as ginev in topographic map ranges from 260m to 198 m. The study area in general slopes from West to East. The river Yamuna enters from North at an elevation of 216 m and leaves the region at 198 m, above Mean Sea Level, in the South. To the East of the ridge the drainage passes into the river Yamuna, and to the West it enters the natural depression of the Najafgarh Jhil near the western periphery of the region. The Najafgarh drain flowing from West to East meets river Yamuna near Wazirabad. The meandering course of river Yamuna within Delhi region has a length of about 128 kms.

1.6 Drainage system of Delhi

Delhi represents a part of the alluvial plains of Yamuna

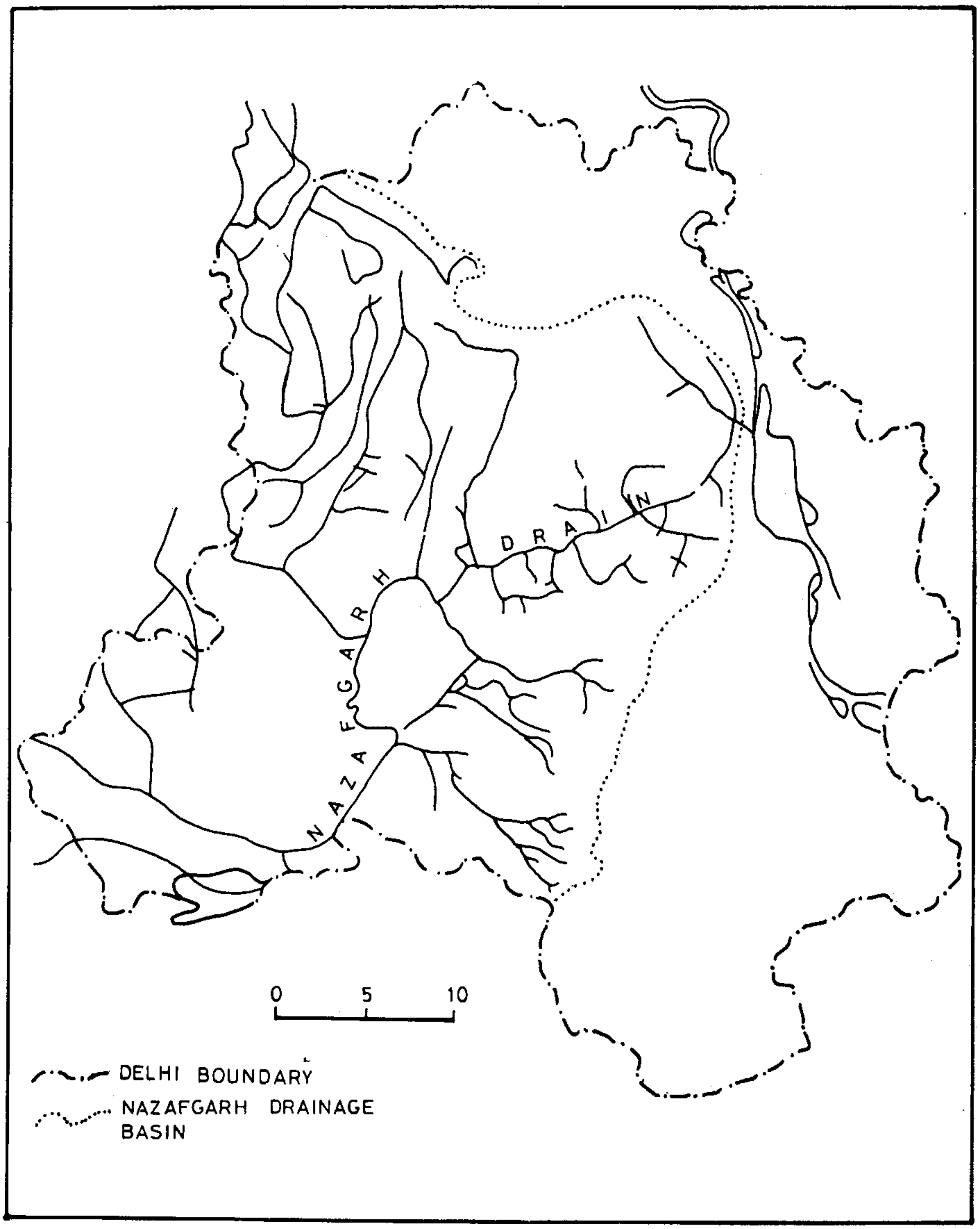

Fig.1. Drainage map of Nazafgarh Basin

river. General topography slopes towards west to east draining to Yamuna river. Nazafgarh drain the main drainage artery, passes through Delhi metropolitan complex from south-east to north-west and out falls into Yamuna river. The drainage basin map of the Delhi (Fig. 1) shows that most of the link drains join main Najafgarh drain both from north and south almost in parallel type. This drain pattern leads to the view that Najafgarh drain was a natural drainage system of Delhi which might have been subsequently renovated to take load of the increased flood discharge as the urbanisation progressed in Delhi.

Najafgarh drain receives the upland discharge from Sahibi river at Dhansa Bund bordering Haryana State and Delhi Union Territory. Watershed of Sahibi river is about 6900 sq.km. originating from the hills near Bairath and Shahpura in Jaipur district of Rajasthan State. The river remains largely ephemeral but it had contributed on few occasions flash floods during monsoon season. For a major part in the plains of Haryana State, the river does not have a well-defined course and after silting the original shallow bed, it has been shifting within its wide sandy bed.

2.0 METHODS

2.1 Current design criteria for drainage design

The design of rural drains, or drains in rural parts of urban areas, are often approached empirically in India. In general, in drainage design practice in India, following empirical drainage indices (Table 2) are adopted for the drainage system design, with adequate factor of safety.

Table 2: Current Design Criteria for Drainage Design

Landuse Cover	Design Index		
	Rainfall		Runoff
	Rate	Frequency	
Urban	Hourly maximum	Once in 2 years	0.5 cusecs/acres
Rural	3 days maximum	Once in 5 years	- 10 cusecs/sq. mile (revised) - 5 cusecs/sq. mile (pre-revised)

This current design practice shows that several factors which have strong bearing on peak and time to peak of drainage discharge are not taken into consideration, some of these are degree of development in the drainage basin at different time span and details of landusé-cover and soil types, wetness and infiltration conditions, depression storage factors etc. These factors may result in under-design or over design of the systems and consequent urban drainage problem in the long run.

2.2 SCS Method of Runoff Estimation

The soil conservation service, procedure (SCS), which came into common use in the year 1954, is the product of more than 20 years of studies of rainfall-runoff relationships for small rural watershed areas. The procedure which is basically empirical was developed to provide a rational basis for estimating the effects of land treatment and land use changes upon runoff resulting from storm rainfall. Because of its simplicity, however, its use has spread through the spectrum of hydrolytic applications by Agriculturists, hydrologists and by soil conservation engineers (Shukla and Singh, 1993).

The SCS method is the most widely used method to estimate runoff amounts from agricultural watersheds. It is also the basis of the hydrologic component of several models used for agricultural lands, for example CREAMS model,USDAHL-74 model etc. This method is widely used because (i) it is a reliable procedure that has been used for many years in different parts of the world, (ii) it is computationally efficient, (iii) it relates runoff to soil type, land use and management practices.

The volume of runoff depends on both meteorologic and watershed characteristics. The precipitation volume is the single most important meteorological characteristics in estimating the runoff. The soil type, land use and the hydrologic condition of the cover are the watershed factors that will have significant effect on the volume of runoff.

The factors affecting infiltration are: hydrologic soil group, type of land cover, hydrologic condition, antecedent moisture condition, and cropping practice in the case of cultivated agriculture land. Each of these factors is subdivided into many classes. Hydrologically, soils are assigned four groups on the basis of intake of water on bare soil when thoroughly wetted, as shown below. With urbanization the soil profile is disturbed considerably. The group classification can be based on the texture of disturbed soil (Tab 3).

Tab 3: Hydrological Group of soil based upon texture

Group	Minimum Infiltration Rate (in/hr)	Texture
A	0.3 - 0.45	Sandy, loamy sand,or sandy loam
B	0.15-0.30	Silt loam or loam
C	0.05-0.15	Sandy clay loam
D	0-0.05	Clay loam, silty clay loam, sandy clay, silty clay, or clay

Type of land cover, such as bare soil, vegetation, impervious surface, and so on, establishes runoff production potential. Important cover types for urban areas, cultivated agriculture lands, other agriculture lands, and arid range lands are given in Table 4. Cultivated agricultural lands are further subdivided by treatment or cropping practice, such as straight row, contoured, and contoured and terraced. The hydrologic conditions reflect the level of land management (Tab 5). Hydrologically poor conditions represent a state of land use that will provide higher runoff as compared to the good condition. The antecedent moisture condition (AMC) is the index of the soil condition with respect to runoff potential before a storm event. It has three categories:

Category	Condition
I	Dry soil but not to the wilting point
II	Average conditions
III	Saturated soils; heavy rainfall or light rainfall with low temperatures haveoccurred in the last 5 days

Table 4 Curve Numbers for Antecedent Moisture Condition II

Use	Cover Type	Treatment	Hydrologic Condition	Hydrologic soil group A	B	C	D
Urban	Fully developed		Poor(cover<50%)	68	79	86	89
	Open space(lawns,parks)		Fair	49	69	79	84
			Good(grass cover> 75%	39	61	74	80
	Impervious areas(paved parking,roofs,driveways, paved roads)			98	98	98	98
	Dirt roads			72	82	87	89
	Urban districts						
	Commercial and business			89	92	94	95
	Industrial			81	88	91	93
	Developing areas			77	86	91	94
Cultivated agriculture lands	Fallow	Bare soil		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
		Contoured and terraced	Poor	66	74	80	82
		Contoured and 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
		Contoured and terraced	Poor	61	72	79	82
		Contoured and 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
		Contorued	Poor	64	75	83	85
		Contoured	Good	55	69	78	83
		Contoured and terraced	Poor	63	73	80	83
		Contoured and terraced	Good	51	67	76	80
	Agriculture lands	Pature or range	Poor	68	79	86	89
			Fair	49	69	79	84
			Good	39	61	74	80
		Meadow		30	58	71	78
		Woods	Poor	45	66	77	83
			Fair	36	60	73	79
			Good	30	55	70	77
		Farmsteads (building, lanes, driveways)		59	74	82	86

Arid	Herbaceous (mixture of					
	grass ,weeds, and	Poor		80	87	93
and	low-growing brush)	Fair		71	81	89
semiarid		Good		62	74	85
rangelands	Oak-aspen (mountain	Poor		66	74	79
	brush mixture)	Fair		48	57	63
		Good		30	41	48
		Poor		75	85	89
	Pinyon-juniper	Good		41	61	71
		Poor		67	80	85
	Sagebrush with grass	Good		35	47	55
	understory	Poor	63	77	85	88
	Desert shrub	Fair	55	72	81	86
		Good	49	68	79	84

The SCS has evolved a system of curve numbers. A distinct curve number (CN) is assigned on the basis of the combination of each of factors above. Table 4 gives curve numbers (CN) for antecedent moisture condition II. For an area with many different sub areas, the composite CN is determined by adding the product of CN and respective area and dividing by the total area.

The curve number (CN) represent the combined hydrologic effect of soil, land use, agricultural land treatment class, hydrologic condition and antecedent soil moisture. As antecedent moisture condition of soil changes, the corresponding curve number also changes. AMC conditions are identified based on the previous 5 day of rainfall preceding the designed rainfall. Once the AMC condition is known, based on soil type and cropping pattern of the area the runoff from agricultural watershed can be estimated.

Table 5 Antecedent Soil Moisture Condition

AMC group	Total of 5 day Antecedent Rainfall: Dormant Season (inches)	Growing Season (inches)
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	over 1.1	over 2.1

The SCS runoff equation is

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \qquad \text{............(1)}$$

where,

Q = accumulated runoff, mm depth over the drainage area;
P = accumulated rainfall depth, mm;
S = potential maximum retention of water by the soil, mm (this is mostly the infiltration. The term is distinct from the surface retention, which does not include the infiltration);
Ia = initial abstraction in mm.

The potential maximum retention, S in mm, is related to the curve number, CN, by the following relation:

$$CN = \frac{25400}{254 + S} \qquad (2)$$

The analysis of experimental watershed data resulted in the following recommendations by Central unit for soil conservation, Ministry of Agriculture, Govt. of India (vide Chakraborti, 1989).

Region in India	AMC Class	Ia
Black soils region	II and III	0.1S
Black soils regions	I	0.3S
All other regions		0.3S

Since the study watershed does not belong to black soil regions of the country (Fig 2)

Ia = 0.3S, Putting the value of Ia in equation (1)

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \qquad \text{........(3)}$$

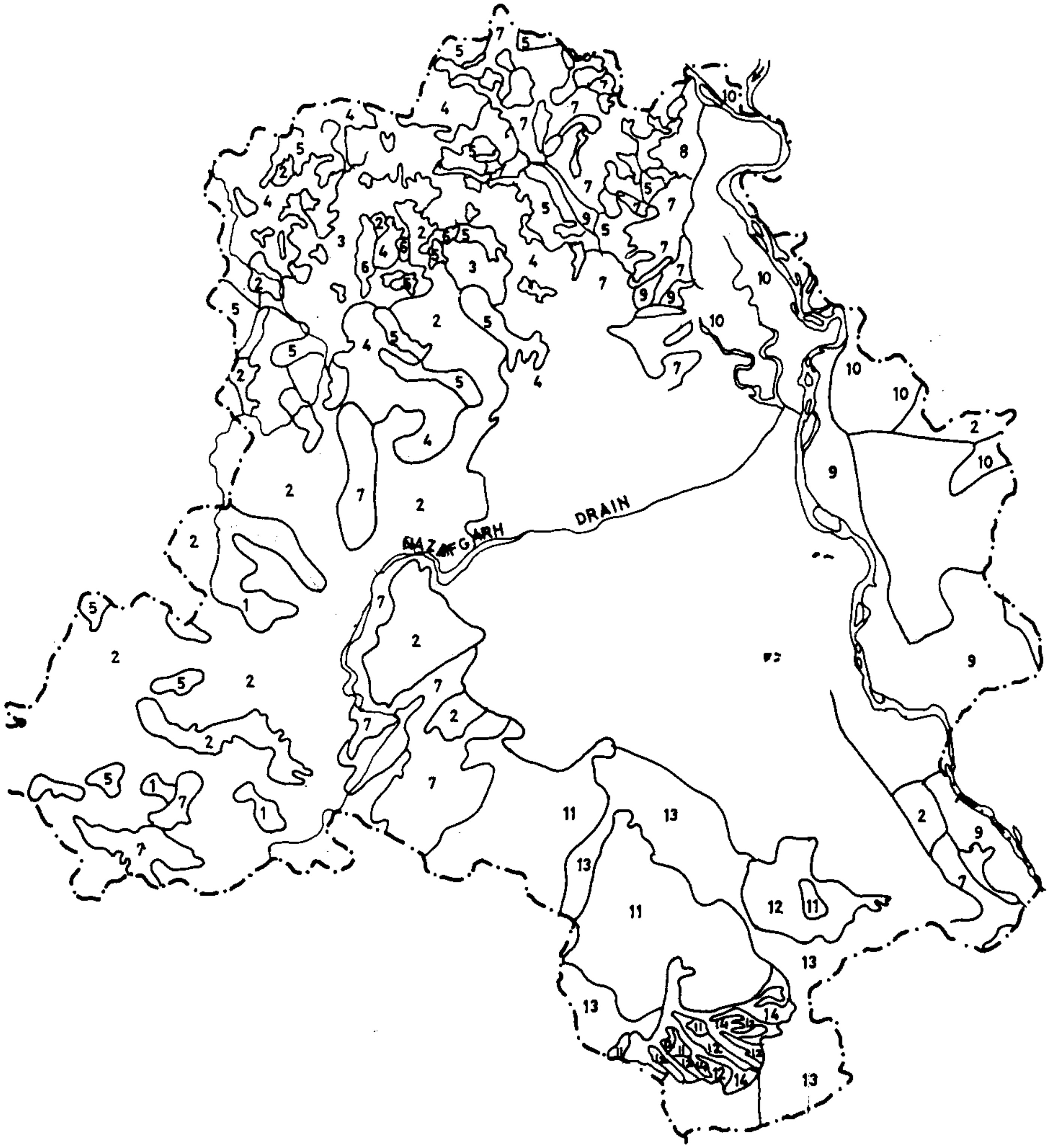

FIG.2-SOIL MAP OF DELHI TERRITORY

REFERENCE

State Boundary

Soil Boundary

Thus, once a curve number is ascertained from Tables 4 for the known conditions, the direct runoff can be computed from eqs. (2) and (3).

2.3 SCS Synthetic Unit Hydrograph

The SCS synthetic unit hydrograph is the dimensionless unit hydrograph developed by Victor Mockus in 1950 (USDA, 1985). The SCS method uses a constant ratio of actual time base to time to peak, $T_b / T_p = 5$. In addition it uses a dimensionless hydrograph function to provide a standard unit hydrograph shape. The catchment lag, t_l, is found by the following equation using the curve number method.

$$t_1 = \frac{L^{0.8} (2540 - 22.86 * CN)^{0.7}}{14104 * CN^{0.7} * Y^{0.5}} \qquad \ldots\ldots(4)$$

where L = hydraulic length (m);
CN = curve number;
Y = average catchment slope.

The other relationship used in the SCS method for computing unit hydrograph duration (t_r), time to peak (t_p), peak (Q_p) and base length (T_b) are calculated by following formulae.

$$t_r = \frac{2}{9} t_l \qquad \ldots\ldots(5)$$

$$t_p = \frac{10}{9} t_l \qquad \ldots\ldots(6)$$

$$Q_p = \frac{2.08 * A}{t_p} \qquad \ldots\ldots(7)$$

$$T_b = 5\ T_p \qquad \ldots\ldots(8)$$

Where, t_l, t_r, t_p, and t_b are in hours and Q_p in cumec, A is the catchment area in sq. km.

3.0 RESULT AND DISCUSSION

3.1 Design Rainfall

The daily rainfall data of last 27 years of Delhi was supplied by India Meteorological department, Delhi. The rainfall observations were recorded at Palam. The daily rainfall data for last 27 years was analysed and daily maximum rainfall for each year was found out. This daily maximum data was then arranged in descending order as given in tab 6. The design rainfall was selected as daily maximum rainfall of 10 year recurrence period.

Tab 6 Daily Rainfall of N.Delhi (Palam) from 1967 to 1993

Sl No.	Year	Rainfall mm	Rank	Sl No.	Year	Rainfall mm	Rank
1.	1981	215.6		15.	1976	76.2	
2.	1967	183.6		16.	1972	75.4	
3.	1978	144		17.	1990	70.2	
4.	1971	125		18.	1970	68.0	
5.	1983	124.3		19.	1975	66.4	
6.	1980	110.8		20.	1982	65.9	
7.	1991	105		21.	1974	60.7	
8.	1968	101		22.	1992	59.1	
9.	1969	96		23.	1980	48.8	
10.	1977	85.3		24.	1989	47.8	
11.	1973	85.0		25.	1979	47.6	
12.	1993	84.3		26.	1986	29.6	
13.	1987	80.3		27.	1984	11.8	
14.	1985	79					

From the above table the design rainfall is calculated as below

Total number of daily maximum rainfall records = 27= 27

Return Period (RI) = 10 years

Therefore,

Design rainfall = Y/RI = 27/10 = 2.7 = 2nd severest rainstorm

In the above table the second severe most storm is of 183.6 mm of rainfall occurred on 6th August of 1967. Therefore, the design rainfall for the study is 183.6 mm.

3.2 Antecedent Moisture Condition

The daily maximum rainfall selected as design rainfall was 183.6 mm. This rainfall has occurred on 6th August 1969. The five day total rainfall prior to 6th August i.e. total rainfall of 1st, 2nd, 3rd, 4th and 5th August 1969 was 23.9 mm. The total 5 day antecedent rainfall which is more than 0.5 inches or 12.7 mm or less than 1.1 inches or 27.9 mm (table 5) represents the AMC class of II. Since, 23.9 mm of rainfall falls within this limit, the AMC II condition is prevailing in the study area for the selected design rainfall.

3.3 Land Use Classification Of Study Area

3.3.1 Land Use Classification for year 1972

The land use pattern of the area was found from the toposheets of Delhi area. The land use pattern of Nazafgarh drainage basin for year 1972 was found using toposheets no. 53H/1, 53H/2, 53D/13, and 53D/14 (Fig 3). The land use classes selected were as highly dense urban area, urban planned area with vegetation or grass, urban planned /unplanned with no vegetation or grass, forest area including agriculture, Horticulture, park

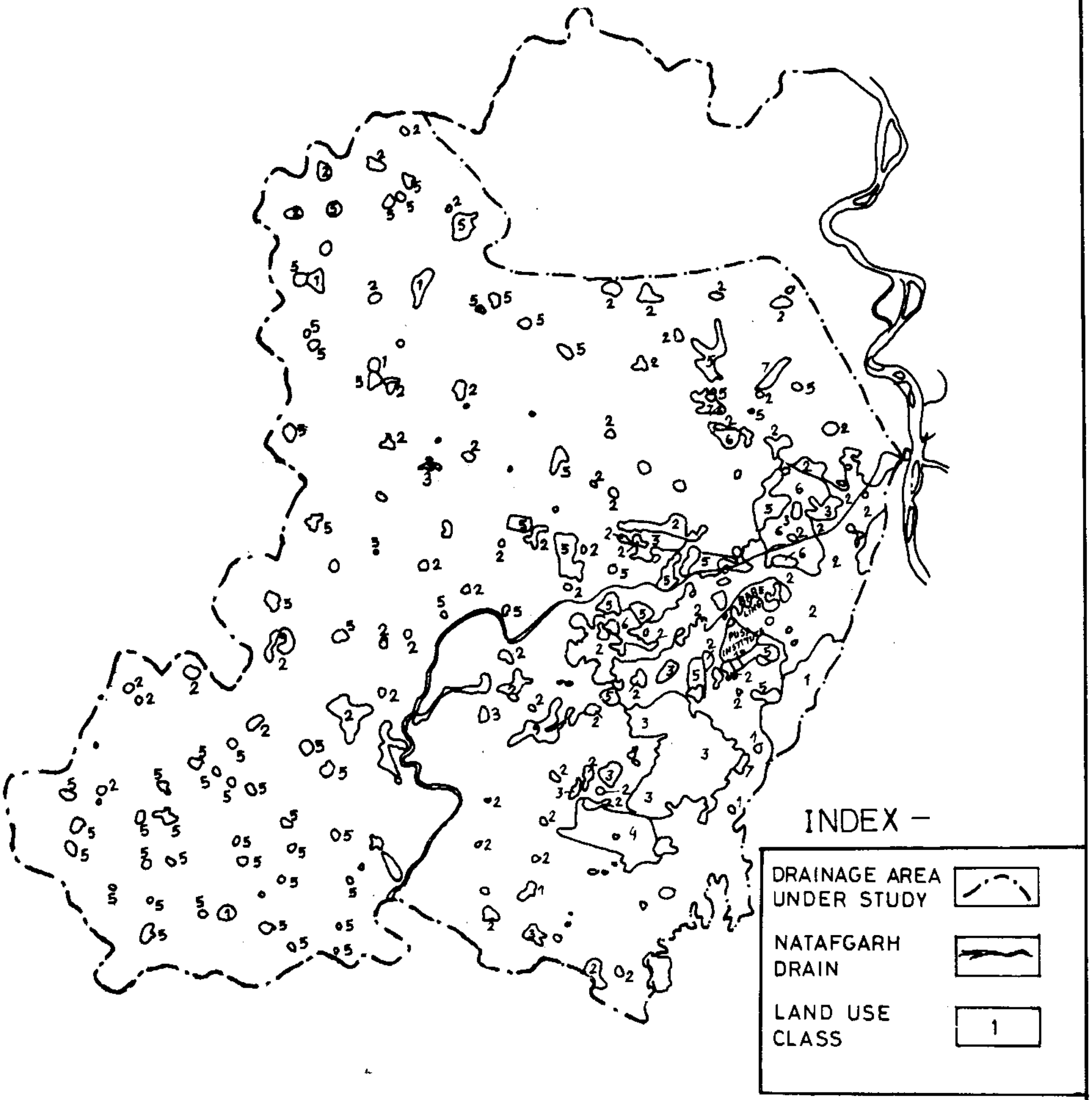

Fig.3. Land use map for year 1972 (from toposheets)

and lawns, cultivated fields, barren saline alkaline land and airport (Tab 9).

Tab 7: Land use classification of Nazafgarh drainage basin for year 1972

S.No.	Type of land use 1972- 73	Area in km^2
1.	Highly dense Urban area	51.6
2.	Organised Residential area with vegetation or grass	31.2
3.	Urban planned / Unplanned with no vegetation	10.31
4.	Forest agril/ Horticulture/ Park/ Lawn etc	20.19
5.	Cultivated fields	713.9
6.	Barren, Saline, Alkaline land	12.8
7.	Airport	16.81

3.3.2 Land Use Classification for year 1988-89

The spot photograph of National Remote Sensing Agency (NRSA) was provided by Indian Remote Sensing Agency, Water Resources Division, Dehradun. The spot photograph used for mapping the land use classification was SPOT1,HRV1, MLA, BAND Bib 2 R 3 of 30th May 1988. This spot photograph covered almost 80% of the Nazafgarh drainage basin and almost 100% of the Highly dense urban area. For the classification of remaining 20% of the area located on the western and north - western part of study area the FCC of 9th March 1989 of path and row 29-47 A2B2 was used. The resolution of spot data used was 20 m and the resolution of IRS data, Liss II imagery was 36.25 m. This IRS Liss II imagery was available at Remote Sensing Laboratory of the Institute. The analysis of IRS Liss II data was done for only the remaining 20% portion because the resolution of spot data was better than the IRS Liss II imagery. Also, there may not be much visible difference between IRS Liss II data of March 1989 and Spot data of May 1988, as the time gap is only of 10 month. The land use classification was carried out as given in 3.3.1 (Fig 4). From the analysis following land use pattern was obtained.

Tab 8: Land use classification of Nazafgarh drainage basin for year 1989

S.No.	Type of land use 1988 - 89	Area in km^2
1.	Highly dense Urban area	233.13
2.	Organised Residential area with vegetation or grass	85
3.	Urban planned / Unplanned with no vegetation	13.63
4.	Forest agril/ Horticulture/ Park/ Lawn etc	23.94
5.	Cultivated fields	452.25
6.	Barren, Saline, Alkaline land	31.25
7.	Airport	16.81

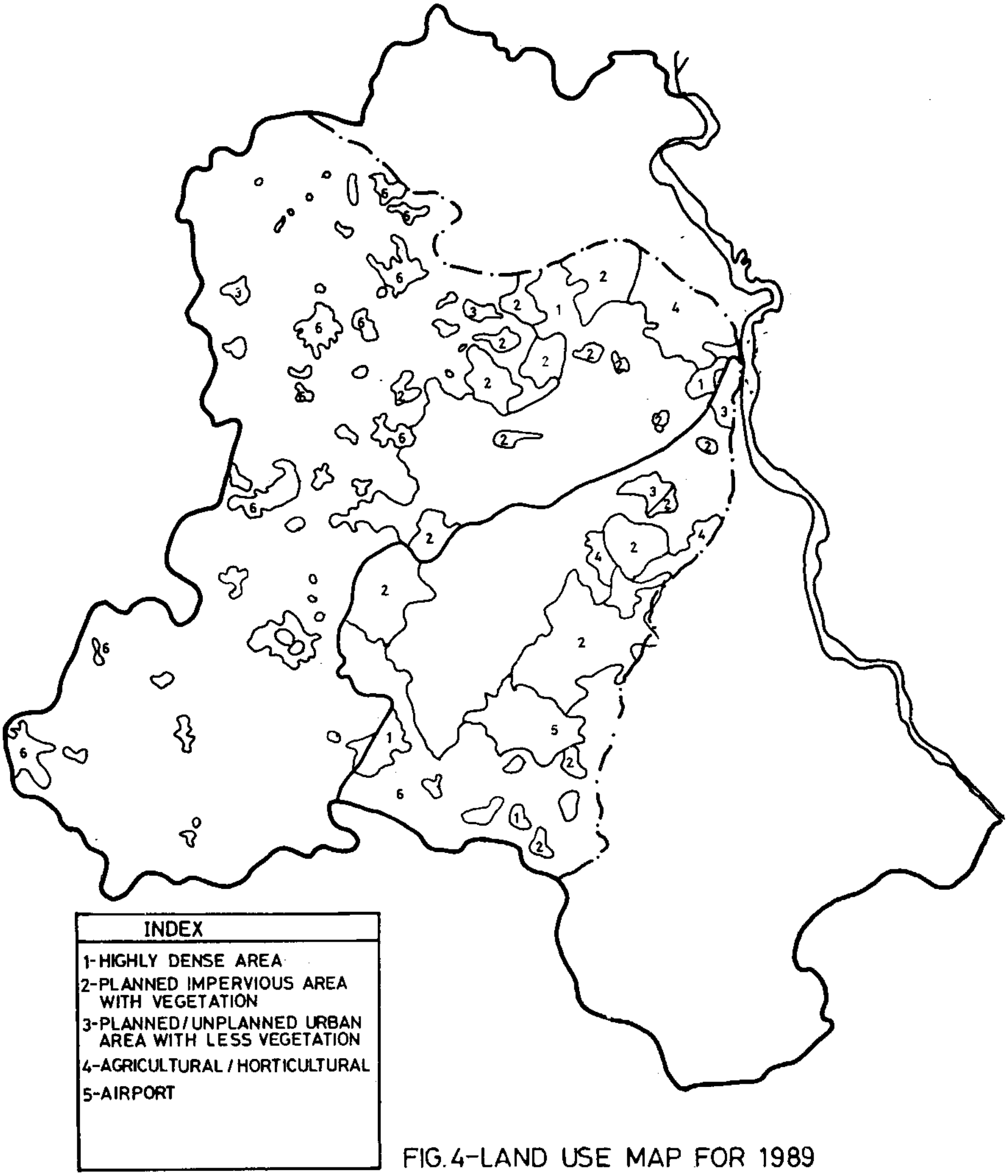

FIG. 4-LAND USE MAP FOR 1989

3.4 CURVE NUMBER FOR THE STUDY AREA

3.4.1 Soil Map of Study Area

The soil map of Delhi was provided by National Bureau of Soil Survey and Land Use Planning, Indian Agriculture Research Institute (IARI), Regional Center, New Delhi. The soil map is given in figure 2 . The soil map has given all together 14 classes. For the present analysis several classes were suitably merged and the hydrologic soil group of the soil of the area was made based upon the infiltration capacity of soil (Tab 3).

3.4.2 Curve Number for year 1972

The land use classification obtained from the toposheet of Delhi for year 1972 is given in table 9. The soil hydrological group was obtained from the soil map of Delhi for the various land use classes listed in tab 3 . Based upon the existing land use in the study area and the corresponding hydrological soil class, the Curve Number was obtained for year 1972 and is given in Table below.

Tab 9: Curve Number for Delhi for year 1972

S.No.	Type of land use 1972- 73	Area in km^2	Hydrologic soil group	CN
1.	Highly dense Urban area	51.6	D	95
2.	Organised Residential area with vegetation or grass	31.2	C	79
3.	Urban planned / Unplanned with no vegetation	10.31	E	86

4.	Forest agril/ Horticulture/ Park/ Lawn etc	14.13 6.06	A B	39 61
5.	Cultivated fields	499.73 214.17	A B	67 78
6.	Barren, Saline, Alkaline land	12.8	C	91
7.	Airport	16	C	74

3.4.3 Curve Number for year 1989

The land use classification obtained from the Spot data of 1988 and FCC of 1989 of is given in table 10 .The soil hydrological group was obtained from the soil map of Delhi for the various land use classes as listed in tab 3 . Based upon the existing land use in the study area and the corresponding hydrological soil class, the Curve Number was obtained for year 1988 - 89 and is given in Table below.

Tab 10: Curve Number for Delhi for year 1989

S.No.	Type of land use 1988 - 89	Area in km^2	Hydrologic soil group	CN
1.	Highly dense Urban area	233.13	D	95
2.	Organised Residential area with vegetation or grass	85	C	79
3.	Urban planned / Unplanned with no vegetation	13.63	B	86
4.	Forest agril/ Horticulture/ Park/ Lawn etc	16.76 7.18	A B	39 61
5.	Cultivated fields	316.58 135.67	A B	67 78
6.	Barren, Saline, Alkaline land	31.25	C	91

7.	Airport	16.81	C	74

3.4.4 Curve number for Delhi in year 2000

Delhi has experienced very rapid rate of urbanisation in the last several years. This is quite evident from the land use tables of year 1972 and year 1989. The percentage rate of change in the land use pattern of the study area in a time span of 14 years is given in the table below. If it is assumed that the present trend of urbanisation will continue in the future at the same rate as during 1981-91. The possible percentage rate of change in the land use pattern of study area taking year 1972 as datum will be as given in the table below.

Tab 11: Rate of change in Land Use of Study area

S. No.	Type of land use	Area in sq.km 1972	1989	% Change in Land use 72-89	72-2000
1.	Highly dense Urban area	51.6	233.13	+351.8	+580.5
2.	Organised Residential area with vegetation or grass	31.2	85	+172.4	+284.5
3.	Urban planned / Unplanned with no vegetation	10.31	13.63	+32.2	+53.1
4.	Forest agril/ Horticulture/ Park/ Lawn etc	20.19	23.94	+18.6	+30.7
5.	Cultivated fields	713.9	452.25	-36.7	-60.6
6.	Barren, Saline,Alkaline Land	12.8	31.25	144.1	+237.8
7.	Airport	16.81	16.81	Nil	Nil

(+) increase (-) decrease

From the above table it is found that there is an increase in the highly dense urban area, organised residential area with vegetation, urban planned/ unplanned area without vegetation, forest/ lawns/ parks etc, and barren land. There is a corresponding decrease in the cultivated area in the drainage basin under study. However, no change in the airport area is assumed. For the land use classification of the drainage basin for year 2000 two assumptions are made, they are : (1) the Hydrlogic soil group for a particular land use class is assumed to be the same as for the corresponding land use class for the year 1989; and (2) the urbanisation will take place first in those portion of the cultivated area which have poor hydrological condition than the area having better hydrologic condition i. e. the portion of cultivated area having hydrological soil group as B will be urbanised early than the area having hydrologic soil group A. Based upon table number 11 and above assumptions following land use pattern and the corresponding curve numbers have been obtained and are given in table below.

Tab 12: Curve Number for Delhi for year 2000

S.No.	Type of land use 2000	Area in km^2	Hydrologic soil group	CN
1.	Highly dense Urban area	351.14	D	95
2.	Organised Residential area with vegetation or grass	120.0	C	79
3.	Urban planned / Unplanned with no vegetation	15.80	B	86
4.	Forest agril/ Horticulture/ Park/ Lawn etc	19.22 7.18	A B	39 61
5.	Cultivated fields	282.65	A	67

6.	Barren, Saline, Alkaline land	43.2	C	91
7.	Airport	16.81	C	74

3.4.5 Composite Curve Number for existing AMC Condition

From the table 9, 10 and 12 the composite curve numbers for the AMC II condition for year 1972, 1989 and 2000 were obtained as 72, 79 and 87 respectively (Tab 13).

3.5 Effective Rainfall

The Curve Numbers for AMC II condition were obtained for the year 1972, 1989 and 2000. Using equation number (2) the potential maximum retention (S) was calculated for these curve numbers. The total runoff depth (effective rainfall) resulting from the design rainfall of 183.6 mm for the study area was calculated using equation number (3) for year 1972, 1989 and 2000 respectively and is given in table below.

Tab 13: SCS Runoff (Effective rainfall in mm)

Sl No.	Year	CN	S mm	Q mm
1	1972	72	96.08	93.79
2	1989	79	67.52	115.57
3	2000	87	37.95	141.12

3.6 Computation of Design flood Hydrograph based on unit hydrograph approach

The SCS synthetic unit hydrograph was derived for the

Nazafgarh basin. For this purpose the hydraulic length of the drain and the average land slope were obtained from the topographic map on Delhi. The total hydraulic length and total elevation difference of the land was obtained as 57.7 m and 10 m respectively. The catchment lag (t_l), unit hydrograph duration (t_r), unit hydrograph time to peak (t_p), Unit hydrograph peak (Q_p) and the unit hydrograph time base (T_b) are calculated by using equation no. (4), (5), (6), (7) and (8) respectively for year 1972, 1989 and 2000 and are listed in Tab 14.

Tab 14 : Parameters for SCS synthetic unit hydrograph

sl. no.	Year	Hydraulic length (m)	t_l (hr)	t_r (hr)	t_p (hr)	Q_p (cu.m/sec)	T_b (hr)
1	1972	57.7	202.3	45	224.8	7.92	1124
2	1989	57.7	165.89	37	184.32	9.66	921.6
3	2000	57.7	126.3	28	140.3	12.69	701.5

Using SCS non-dimensional unit hydrograph of table 15 (column 1 and 2 of table 15) the ordinates of unit hydrograph of 45 hr were computed for year 1972 (column 3 & 4). The S hydrograph of 45 hour duration was obtained (column 5). The ordinates of S hydrograph of 45 hr duration was read for a time interval of 24 hr (column 7). This is done because the drainage system of the area was to be designed on daily basis. The S hydrograph of column 7 was lagged by 24 hr (column 8) (Fig 5). The ordinates in the column 7 and 8 were subtracted (column 9). The unit hydrograph of 24 hr duration was obtained by multiplying the ordinates of column 9 with 45/24 (column 10). The ordinates of 24 hr unit hydrographs were then multiplied by the effective rainfall of 9.38 cm and the designed flood hydrograph for year 1972 was obtained (Fig 8).

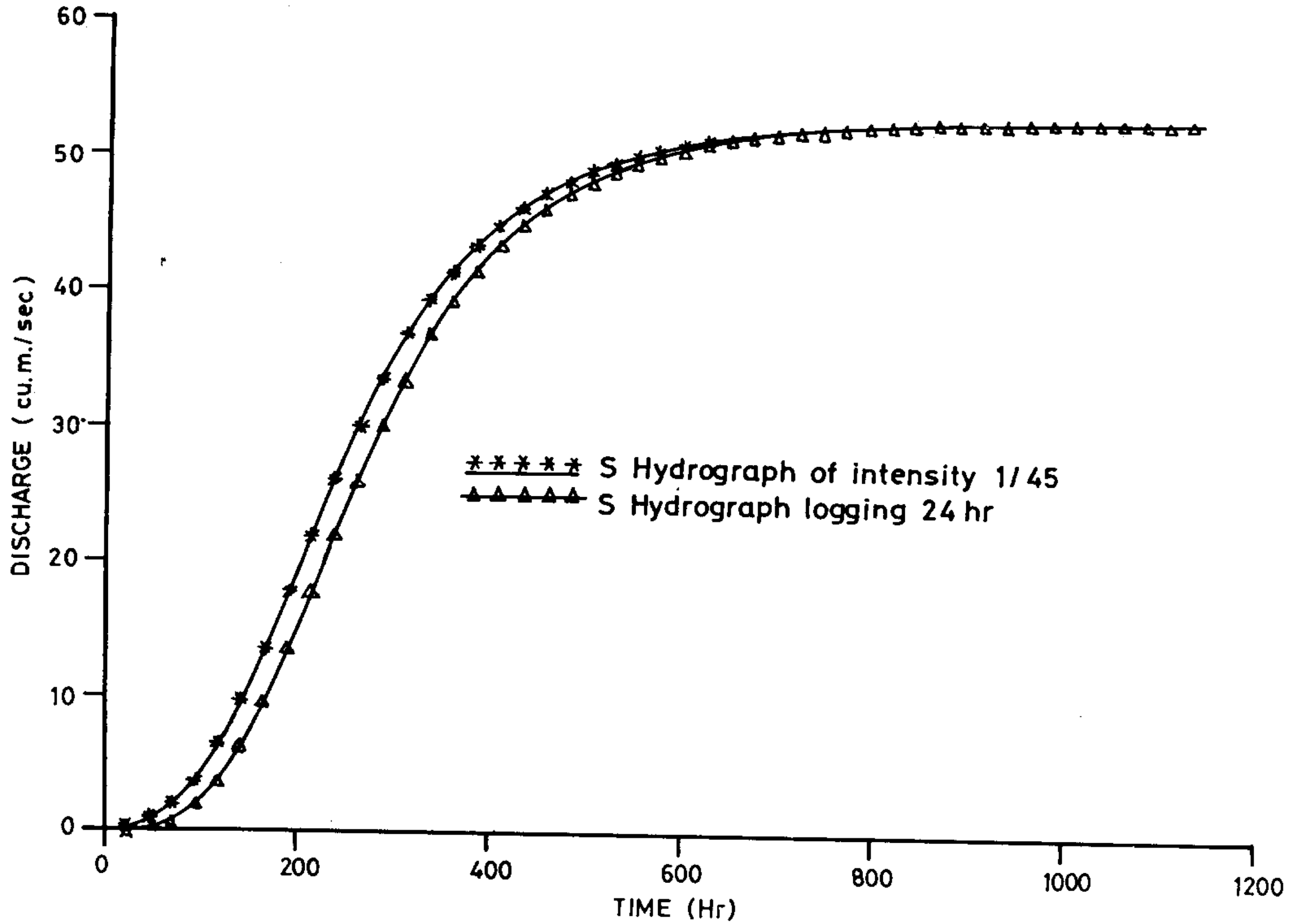

FIG. 5—S HYDROGRAPH FOR YEAR 1972

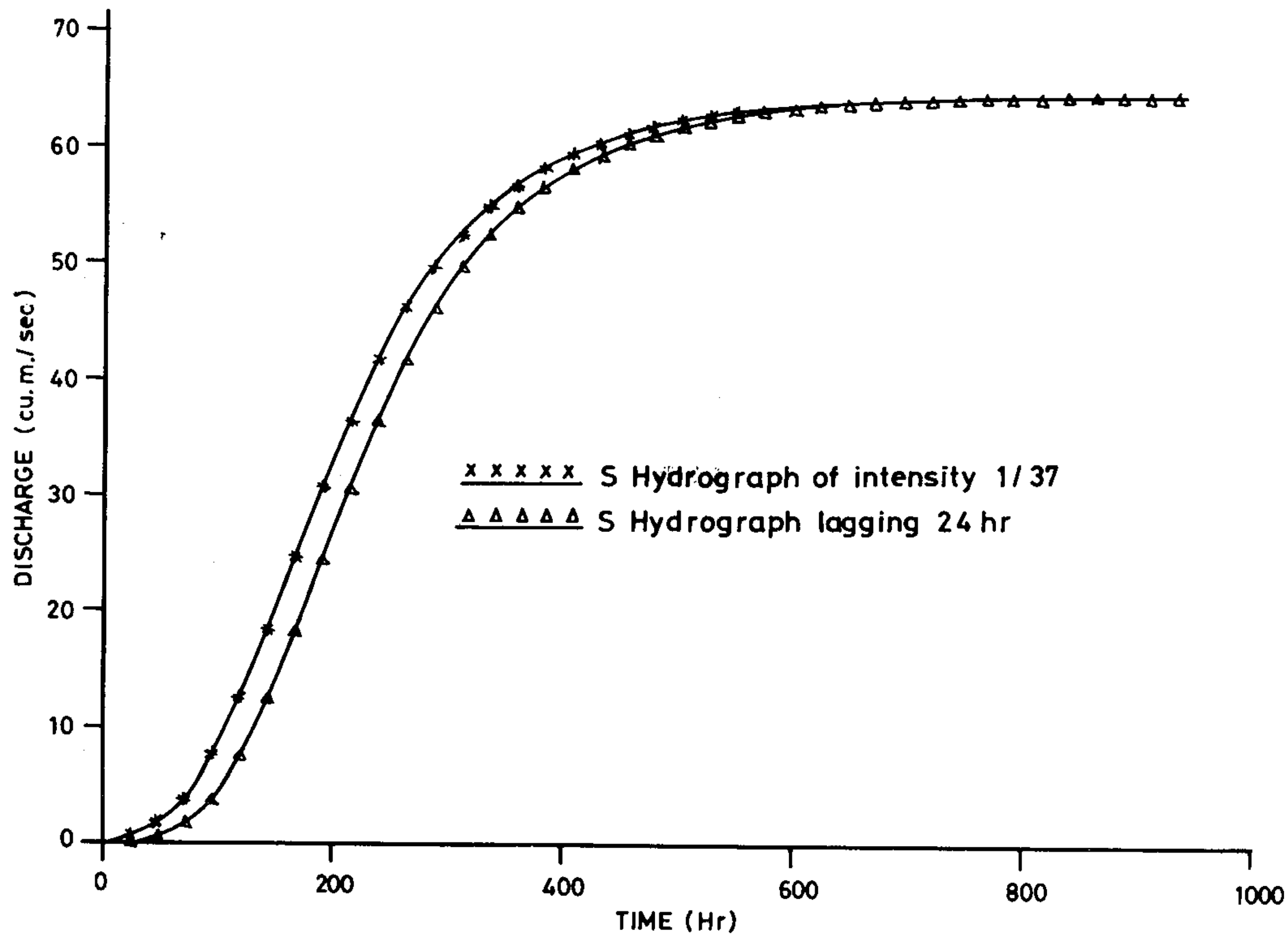

FIG. 6—S HYDROGRAPHS FOR YEAR 1989

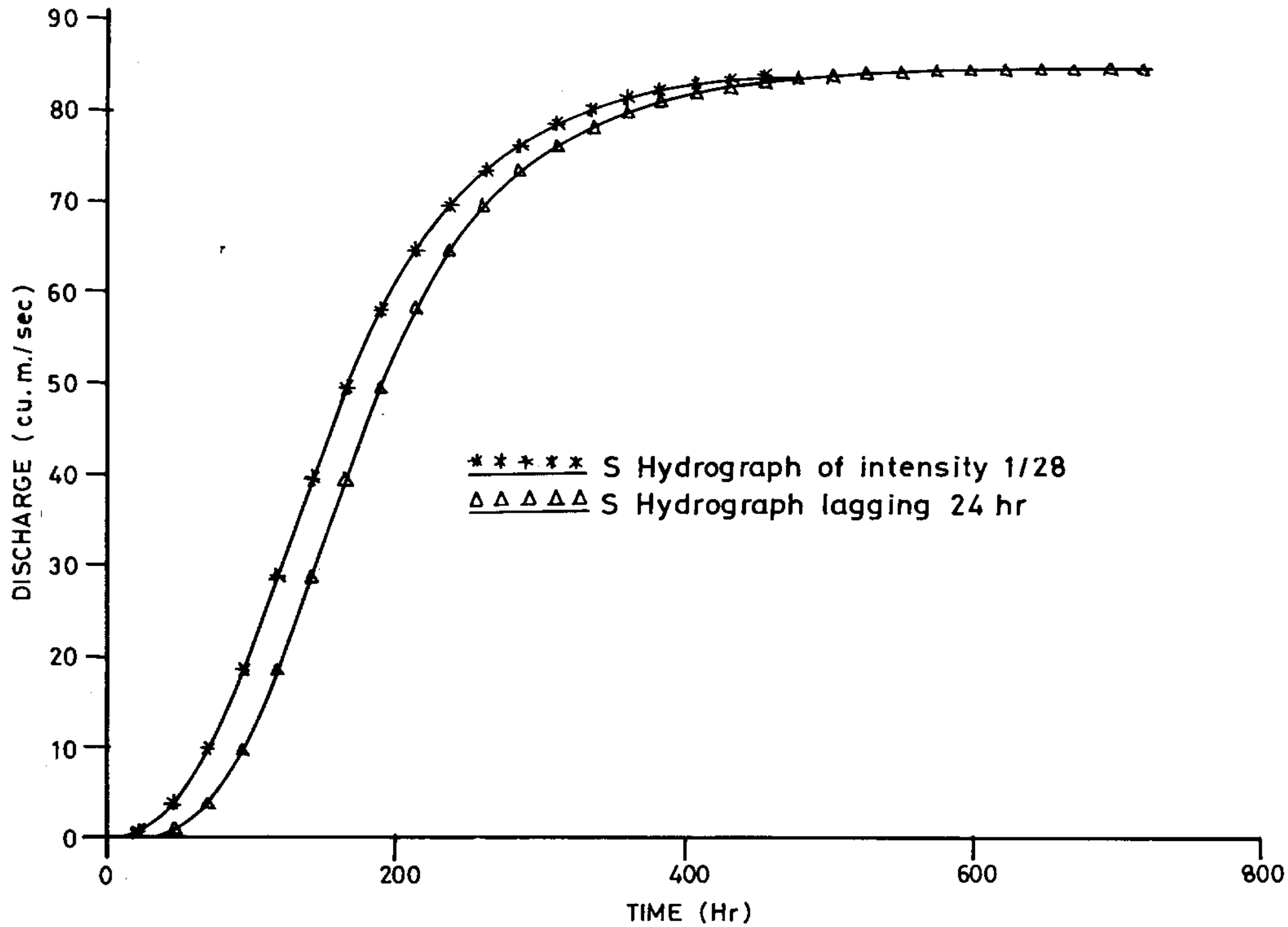

FIG.7 S HYDROGRAPHS FOR YEAR 2000

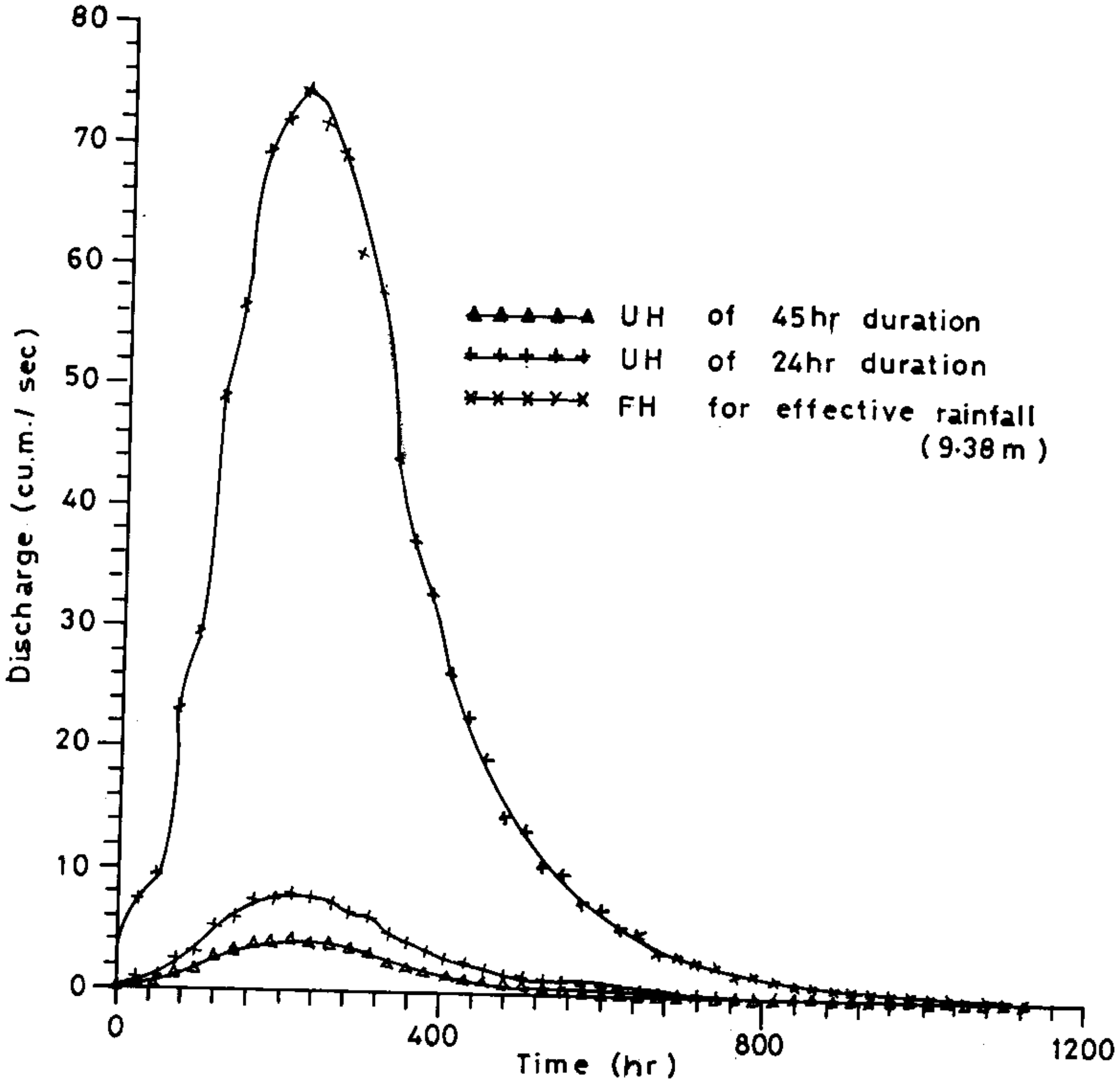

Fig.8. Unit hydrograph of 45 hr 24 hr and Flood hydrograph for year 1972

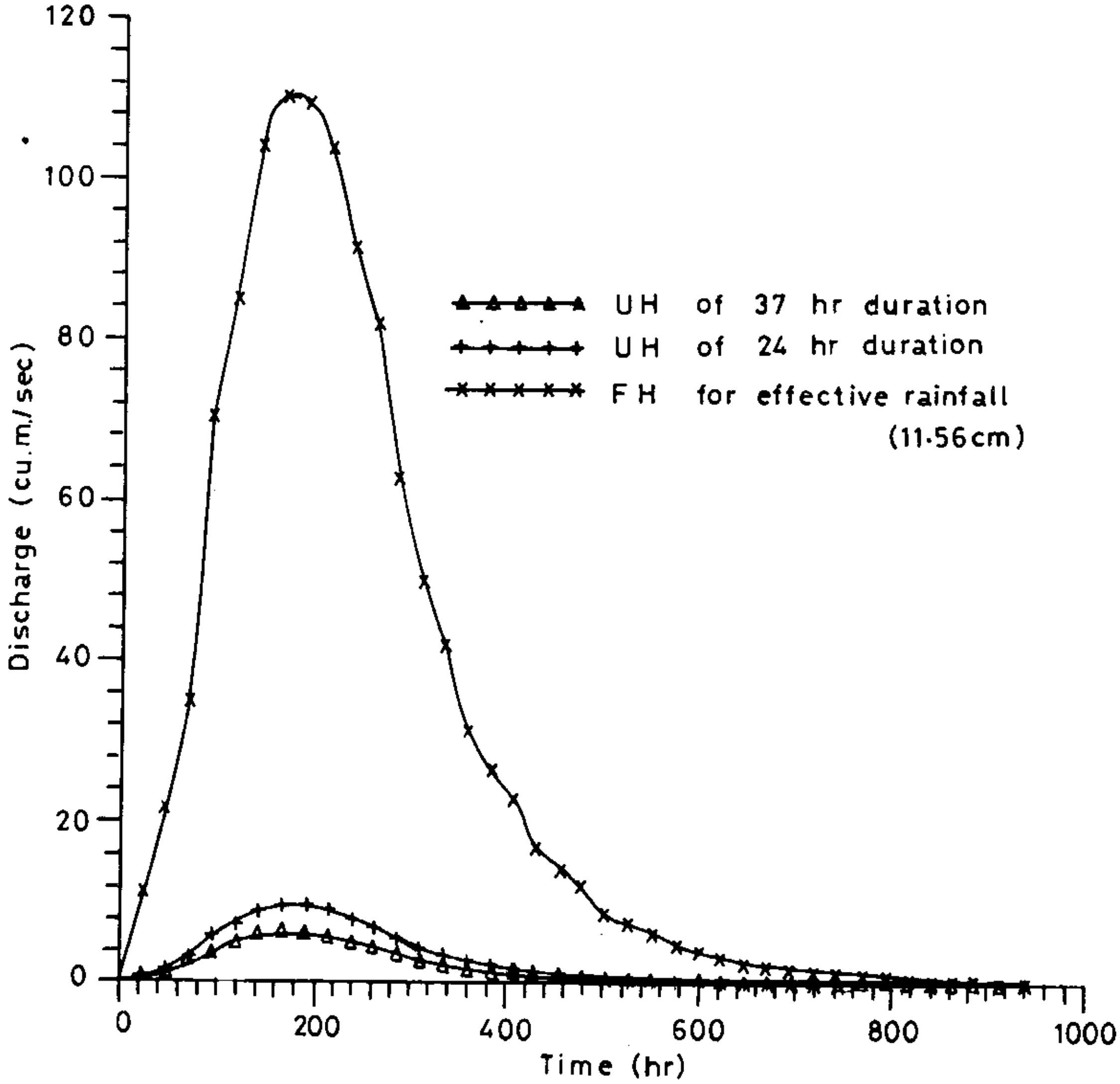

Fig.9. Unit hydrographs of 37 hr 24hr and Flood hydrograph for year 1989

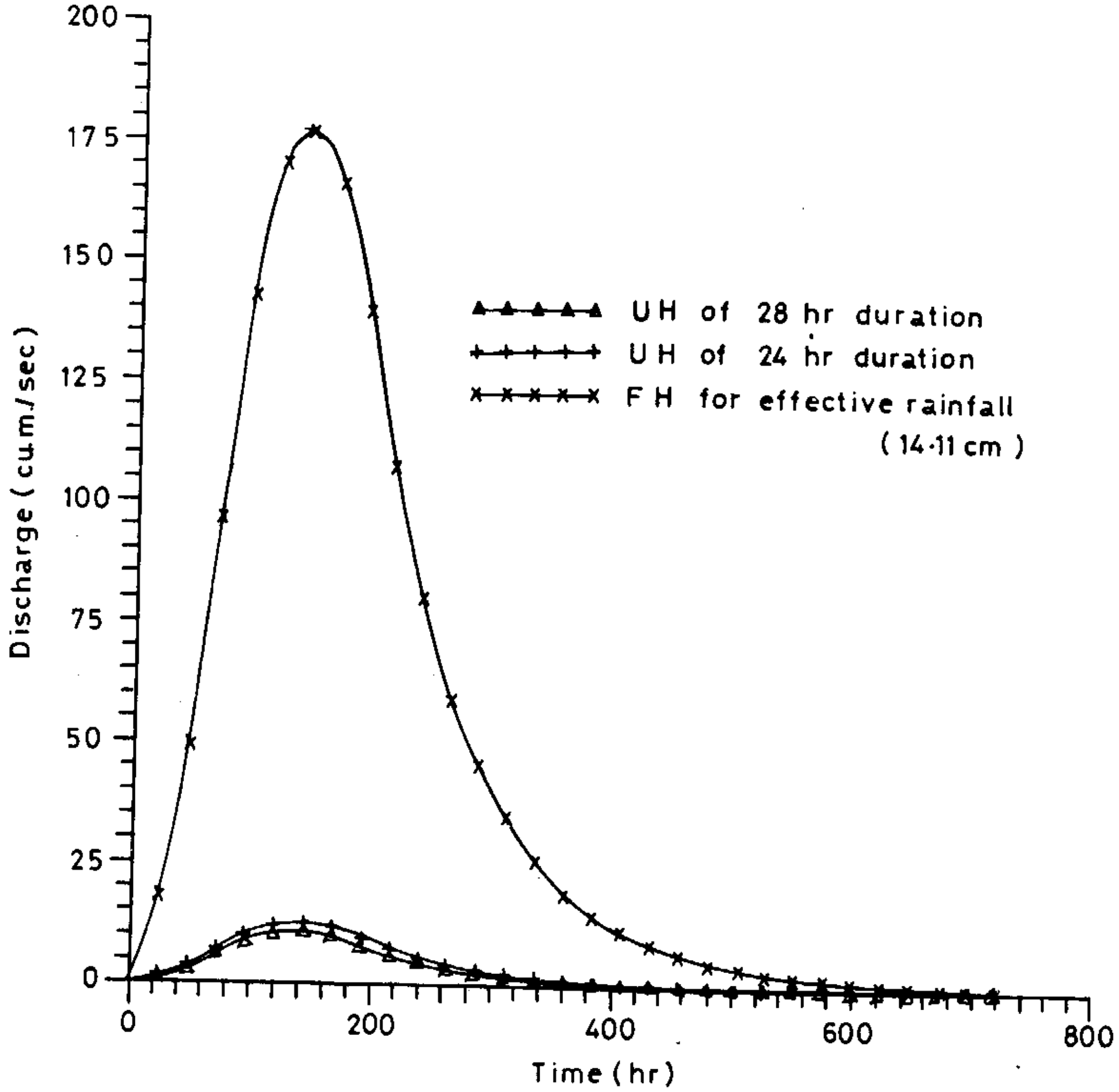

Fig. 10. Unit hydrographs of 28 hr 24 hr and Flood hydrograph for year 2000

Tab 15 : SCS Synthetic hydrograph and Flood hydrograph values for 1972

t/tp (1)	Q/Qp (2)	t hr (3)	Q cumec (4)	S cumec (5)	t hr (6)	S cumec (7)	L24 cumec (8)	UH cumec (9)	(9)* 45/24 cumec (10)	(10)* 9.38 cumec (11)
0	0	0	0	0	0	0	0	0	0	0
0.2	0.1	45	0.8	0.8	24	0.43	0	0.43	0.81	7.56
0.4	0.31	90	2.46	3.26	48	0.96	0.43	0.53	1.0	9.38
0.6	0.66	135	5.23	8.49	72	2.28	0.96	1.32	2.48	23.22
0.8	0.93	180	7.37	15.86	96	3.96	2.28	1.68	3.15	29.55
1.0	1	225	7.92	23.78	120	6.75	3.96	2.79	5.23	49.01
1.2	0.93	270	7.37	31.15	144	9.96	6.75	3.21	6.02	56.46
1.4	0.78	315	6.18	37.33	168	13.90	9.96	3.94	7.39	69.3
1.6	0.56	360	4.44	41.77	192	17.97	13.90	4.07	7.63	71.58
1.8	0.39	405	3.09	44.86	216	22.2	17.97	4.23	7.93	74.4
2.0	0.28	450	2.22	47.08	240	26.24	22.2	4.04	7.58	71.1
2.2	0.207	495	1.64	48.72	264	30.17	26.24	3.93	7.37	69.13
2.4	0.147	540	1.16	49.88	288	33.62	30.17	3.45	6.47	60.68
2.6	0.107	585	0.85	50.73	312	37.0	33.62	3.4	6.38	59.84
2.8	0.077	630	0.61	51.34	336	39.5	37	2.5	4.69	43.99
3.0	0.055	675	0.44	51.78	360	41.63	39.5	2.13	3.99	37.43
3.2	0.040	720	0.32	52.10	384	43.50	41.63	1.87	3.51	32.92
3.4	0.029	765	0.23	52.33	408	45.0	43.5	1.5	2.8	26.26
3.6	0.021	810	0.17	52.50	432	46.3	45	1.3	2.44	22.89
3.8	0.015	855	0.12	52.62	456	47.4	46.3	1.1	2.06	19.32
4.0	0.011	900	0.09	52.71	480	48.23	47.4	0.83	1.56	14.63
4.2	0.010	945	0.08	52.79	504	49	48.23	0.77	1.44	13.51
4.4	0.007	990	0.06	52.85	528	49.6	49	0.6	1.13	10.6
4.6	0.003	1035	0.02	52.87	552	50.17	49.6	0.57	1.07	10.04
4.8	0.0015	1080	0.01	52.88	576	50.6	50.17	0.43	0.81	7.6
5.0	0	1125	0	52.88	600	51	50.6	0.4	0.75	7.04
					624	51.32	51	0.32	0.6	5.63
					648	51.6	51.32	0.3	0.56	5.25
					672	51.81	51.6	0.21	0.39	3.66
					696	52	51.81	0.19	0.36	3.38
					720	52.16	52	0.16	0.3	2.8
					744	52.3	52.16	0.14	0.26	2.44
					768	52.4	52.3	0.1	0.19	1.78
					792	52.5	52.4	0.1	0.19	1.78
					816	52.58	52.5	0.08	0.15	1.41
					840	52.64	52.58	0.06	0.11	1.03
					864	52.7	52.64	0.06	0.11	1.03
					888	52.75	52.7	0.05	0.94	0.88
					912	52.8	52.75	0.05	0.94	0.88
					936	52.84	52.80	0.04	0.08	0.75
					960	52.87	52.84	0.03	0.06	0.56
					984	52.9	52.87	0.03	0.06	0.56
					1008	52.92	52.9	0.02	0.04	0.38
					1032	52.93	52.92	0.01	0.02	0.19
					1056	52.935	52.93	0	0	0
					1080	52.94	52.935	0	0	0
					1104	52.94	52.94	0	0	0
					1128	52.94	52.94	0	0	0

Tab 16: SCS Synthetic hydrograph and Flood hydrograph values for 1989

t/tp (1)	Q/Qp (2)	t hr (3)	Q cumec (4)	S cumec (5)	t hr (6)	S cumec (7)	L24 cumec (8)	UH cumec (9)	(9)* 37/24 cumec (10)	(10)* 11.56 cumec (11)
0	0	0	0	0	0	0	0	0	0	0
0.2	0.1	37	0.97	0.97	24	0.63	0	0.63	0.97	11.21
0.4	0.31	74	3.0	3.97	48	1.86	0.63	1.23	1.90	21.96
0.6	0.66	111	6.38	10.35	72	3.81	1.86	1.95	3.01	34.8
0.8	0.93	148	8.98	19.33	96	7.76	3.81	3.95	6.09	70.4
1.0	1.0	185	9.66	28.99	120	12.53	7.76	4.77	7.35	84.97
1.2	0.93	222	8.98	37.97	144	18.36	12.53	5.83	8.99	103.92
1.4	0.78	259	7.54	45.51	168	24.55	18.36	6.19	9.54	110.28
1.6	0.56	296	5.41	50.92	192	30.69	24.55	6.14	9.47	109.47
1.8	0.39	333	3.77	54.69	216	36.51	30.69	5.82	8.97	103.69
2.0	0.28	370	2.71	57.4	240	41.64	36.51	5.13	7.91	80.69
2.2	0.287	407	2.0	59.4	264	46.24	41.64	4.6	7.09	69.59
2.4	0.147	444	1.42	60.82	288	49.75	46.24	3.51	5.41	62.54
2.6	0.107	481	1.04	61.86	312	52.55	49.75	2.8	4.32	49.94
2.8	0.077	518	0.74	62.6	336	54.91	52.55	2.36	3.64	42.08
3.0	0.055	555	0.53	63.13	360	56.67	54.91	1.76	2.71	31.33
3.2	0.04	592	0.39	63.52	384	58.16	56.67	1.49	2.30	26.59
3.4	0.029	629	0.28	63.80	408	59.44	58.16	1.28	1.97	22.77
3.6	0.021	666	0.2	64	432	60.36	59.44	0.92	1.42	16.42
3.8	0.015	703	0.15	64.15	456	61.16	60.36	0.8	1.23	14.22
4.0	0.011	740	0.11	64.26	480	61.83	61.16	0.67	1.03	11.91
4.2	0.01	777	0.1	64.36	504	62.32	61.83	0.49	0.76	8.44
4.4	0.007	814	0.07	64.43	528	62.74	62.32	0.42	0.65	7.51
4.6	0.003	851	0.03	64.46	552	63.09	62.74	0.35	0.54	6.24
4.8	0.0015	888	0.01	64.47	576	63.35	63.09	0.26	0.40	4.62
5.0	0	925	0	64.47	600	63.58	63.35	0.23	0.36	4.16
					624	63.76	63.58	0.18	0.28	3.24
					648	63.90	63.76	0.14	0.22	2.54
					672	64.02	63.9	0.12	0.19	2.20
					696	64.12	64.02	0.1	0.15	1.73
					720	64.2	64.12	0.08	0.12	1.39
					744	64.27	64.2	0.07	0.11	1.27
					768	64.34	64.27	0.07	0.11	1.27
					792	64.39	64.37	0.05	0.08	0.93
					816	64.43	64.39	0.04	0.06	0.69
					840	64.45	64.43	0.02	0.03	0.35
					864	64.46	64.45	0.01	0.02	0.23
					888	64.47	64.46	0.01	0.02	0.23
					912	64.47	64.47	0	0	0
					936	64.47	64.47	0	0	0

Tab 17: SCS Synthetic hydrograph and Flood hydrograph values for 2000

t/tp (1)	Q/Qp (2)	t hr (3)	Q cumec (4)	S cumec (5)	t hr (6)	S cumec (7)	L24 cumec (8)	UH cumec (9)	(9)* 28/24 cumec (10)	(10)* 14.11 cumec (11)
0	0	0	0	0	0	0	0	0	0	0
0.2	0.1	28	1.27	1.27	24	1.09	0	1.09	1.27	17.92
0.4	0.31	56	3.93	5.2	48	4.10	1.09	3.01	3.51	49.53
0.6	0.66	84	8.38	13.58	72	10.0	4.10	5.9	6.88	97.08
0.8	0.93	112	11.8	25.38	96	18.64	10.0	8.64	10.08	142.23
1.0	1	140	12.69	38.07	120	29.01	18.64	10.37	12.10	170.73
1.2	0.93	168	11.80	49.87	144	39.76	29.01	10.75	12.54	176.96
1.4	0.78	196	9.90	59.77	168	49.87	39.76	10.11	11.80	166.43
1.6	0.56	224	7.11	66.88	192	58.36	49.87	8.49	9.91	139.76
1.8	0.39	252	4.95	71.83	216	64.85	58.36	6.49	7.57	106.84
2.0	0.28	280	3.55	75.38	240	69.71	64.85	4.86	5.67	80.00
2.2	0.207	308	2.63	78.01	264	73.35	69.71	3.64	4.25	59.92
2.4	0.147	336	1.87	79.88	288	76.13	73.35	2.78	3.24	45.76
2.6	0.107	364	1.36	81.24	312	78.28	76.13	2.15	2.51	35.39
2.8	0.077	392	0.98	82.22	336	79.88	78.28	1.6	1.87	26.34
3.0	0.055	420	0.7	82.92	360	81.05	79.88	1.17	1.37	19.26
3.2	0.040	448	0.51	83.43	384	81.94	81.05	0.89	1.04	14.65
3.4	0.029	476	0.37	83.80	408	82.62	81.94	0.68	0.79	11.19
3.6	0.021	504	0.27	84.07	432	83.14	82.62	0.52	0.61	8.56
3.8	0.015	532	0.19	84.26	456	83.54	83.14	0.4	0.47	6.59
4.0	0.011	560	0.14	84.40	480	83.84	83.54	0.3	0.35	4.94
4.2	0.010	588	0.13	84.53	504	84.07	83.84	0.23	0.27	3.79
4.4	0.007	616	0.09	84.62	528	84.23	84.07	0.16	0.19	2.63
4.6	0.003	644	0.04	84.66	552	84.36	84.23	0.13	0.15	2.14
4.8	0.0015	672	0.02	84.68	576	84.47	84.36	0.11	0.13	1.81
5.0	0	700	0	84.68	600	84.57	84.47	0.1	0.12	1.65
					624	84.63	84.57	0.06	0.07	0.99
					648	84.66	84.63	0.03	0.04	0.49
					672	84.68	84.66	0.02	0.02	0.33
					696	84.68	84.68	0	0	0
					720	84.68	84.68	0	0	0

The above procedure was repeated for year 1989 and 2000 also and the results are given in Tab 16 and 17 respectively. The S hydrograph were prepared from column 7 & 8 of table 16 & 17 respectively for year 1989 and 2000 and are given in fig 6 and 7 respectively. The unit hydrographs of 24 hr duration and the design flood hydrographs for the effective rainfall of 11.56 and 14.11 cm for the year 1989 and 2000 are given in fig 9, and 10 respectively. From fig 8, 9 and 10 the flood hydrograph peaks were obtained as 74, 110.3, 177 cu.m/sec for year 1972, 1989 and 2000 respectively. The ISI code has prescribed certain norms on the period of desposal of this excess runoff from urban areas. Therefore, the drainage system should be designed at capacities which will be adequate to remove the excess runoff water from that area within the tolerence period to ponding.

4.0 CONCLUSION

From the present study it can be concluded that the Delhi is experiencing urbanisation at a vary rapid rate. With the urbanisation impervious area is also increasing which in tern is resulting in the higher curve number and higher runoff depth to be discharged safely to natural drains. In the study, it is found that the depth of runoff to be handled has increased from 93.79 mm in year 1972 to 115.57 mm in 1989. The peak discharges for the design rainfall of 183.6 mm have increased from 74 cu.m/sec in 1972 to 110.3 cu.m /sec in 1989 and the time to peak has reduced from 216 hr to 168 hr during the same period. With the help of certain assumptions the runoff depth, peak discharge and time to peak for the year 2000 are also found out as 141.12 mm, 177 cu.m/sec and 144 hr respectively. It is therefore recommended that urban drainage system of Delhi should be designed keeping in view the norms as laid down by ISI code. The peak discharge of 117 cu.m/sec should be modified suitably before designing the drainage system according to tolerence period of disposal from various types of land use catageries and taking appropriate safety factors.

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