CS (AR) 135

Design of Surface Drainage System for Bulandshahr area

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAWAN
ROORKEE - 247 667 U.P.
INDIA

1993-94

Preface

Surface flows that should be carried away from agriculture lands comprises precipitation excess and farm irrigation surface waste (excess). Surface runoff from agriculture land is much less than urban runoff because of the perviousness of land surface, except when the soil is containing huge amount of carbonate. Once the quantity of runoff at various points of interception is known, the surface drainage system is designed (1) as a separate system for the large land area, or (2) as a system of open drains comprising the laterals or field drains, submains, and mains. Surface drainage in simple words is the orderly removal of excess water from the surface of land through improved natural channels and when planned properly eliminate ponding, prevent prolonged saturation and accelerate flow to an outlet without siltation or soil erosion.

In order to design a surface drainage system, the peak rate of surface runoff due to a rainstorm of a specified frequency can be determined by the rational method when the command area is less than 800 ha. In this method using an appropriate value of the runoff coefficient for the agriculture area the peak discharge rate is determined. However, for agriculture drainage it may not be economical or necessary to design the drainage system for the peak discharge. The Soil Conservation Service (SCS) procedure of soil and cover conditions is perhaps more appropriate for agriculture drainage design. Surface drains are designed to handle flows from 5 to 15 year storm frequencies. A design frequency of 5 years is sufficient for design of agriculture drainage system. However, where damages can be expensive, a more conservative design frequency of 25 years should be used. The land use map for the area under consideration can be prepared using remote sensing data and the toposheets.

This report entitled 'design of drainage system for Bulandshar area' is a part of research activity of drainage division of the Institute. The purpose of this study is to determine the design discharge capacity of the drain so that the waterlogging problem existing in the study area can be abated. This report is prepared by Shri M.K.Shukla, Scientist B and Shri Hukam Singh, R.A. of drainage division of the Institute.

(S.M.Seth)

Director

CONTENTS

LIST OF FIGURES

LIST OF TABLES

Abstract

High irrigation intensities or excess precipitation may cause drainage congestion on the surface of the soil or in the root zone of crops. If the top soil of such area is less permeable than the situation becomes alarmingly worse. Such a situation is found in the Bulandshahr district of Uttar Pradesh. In this study the analysis of ground water table data for the pre and post monsoon period for last 20 years was carried out. It was observed that the water table in the entire area was fairly deep and as such there was no problem of water logging due to high water table. The daily rainfall data for the last 49 years was collected and using SCS model the surface runoff was calculated. Using remote sensing technique the land use pattern of the area was obtained and the design capacity of the drainage system for the area was calculated. The study showed that the area is suffering from the problem of surface drainage, mainly because of flat topography of the area and the presence of carbonate in the soil which reduces the hydraulic conductivity of the soil and increases runoff. The capacity of the existing drains in the area is also not adequate to handle the total runoff from the fields. The discharge taking place from the fields was calculated and the required capacity of the drains to carry that discharge for the study area was found out as 1.86 lit/sec/ha.

1.0 Introduction

A prime requirement for successful irrigated agriculture is the development and maintenance of a soil zone in which the moisture-oxygen-salt balance is favorable for plant growth. A simple but comprehensible definition of drainage is the removal of excess water, from the soil at a rate which will permit normal plant growth. Drainage can be either natural or artificial. Texture is an important parameter in drainage design because it is a soil characteristic which has a general relationship with hydraulic conductivity and water retention.

India has a total geographical area of 329 million hectare (m ha). Out of which about 140 m ha is under cultivation. India made great strides in her irrigation development during the post independent era. The irrigation potential which stood at 22.6 m ha at the beginning of first five year plan (1950-51) is estimated to have achieved the level around 77 m ha till the 7th plan (1989-90) period. As the development in irrigation potential is increasing, the problem of waterlogging and salinity is also increasing. The total water-logged area in the country is at present about 8.5 m ha. Serious problems of waterlogging have been reported from many irrigation projects like Chambal in Rajasthan & M.P., Indira Gandhi canal in Rajasthan, Nagarjun Sagar project in A.P., Tawa project in M.P., Jayakwadi project in Maharashtra, Tungabhadra project in Karnataka, Gandak & Kosi in Bihar and Sharda Sahayak in UP.

The gross area of Bulandshahr district is 4588 sq. km, comprising of 17 blocks out of this area 4250 sq.km of area falls within the UGC command (Fig 1). It lies between latitude 28^{o}N --$28^{o}45'$N and longitude $77^{o}30'$ -$78^{o}30$ E and is

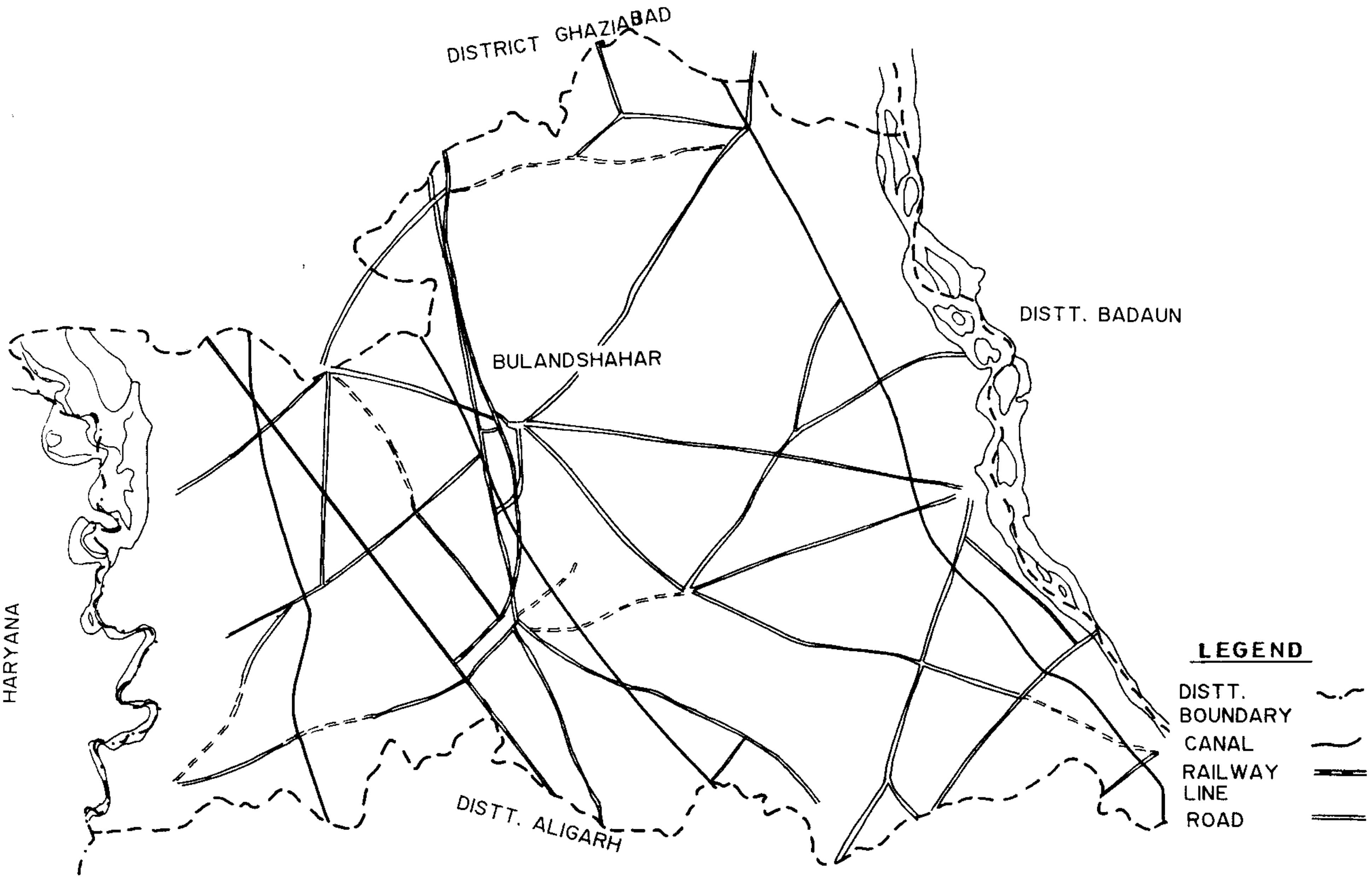

FIG. I INDEX MAP OF DISTRICT BULANDSHAHAR covered in toposheets number 53 H/10, 53H/11, 53H/12, 53H/14, 53H/15, 53H/16, 53L/2, 53L/3, 53L/4 and 53L/8. Most of the area of district is under Upper Ganga Canal (UGC) command. Bulandshahr has the boundary with district Ghaziabad, district Aligarh, river Yamuna and river Ganga. Bulandshahr district is consited of 17 blocks. They are B. B. Nagar, Siyana, Gulothi, Sikandarabad, Dankuar, Bulandshahr, Jahangirabad, Annpshahar, Unchagaon, Khurja, Sikarpur, Jewar, Arnia Khurd, Danpur, Dibai and Pahasu. The region has well integrated drainage system of river Ganga. Almost all streams follow a NW-SE course concomitant with the regional slope of the land. The slope is extremely gentle and soil erosion is less. The near parallel courses and acute angle junctions of the tributaries with master stream at most levels makes the region a pinnet drainage. River Kali, river Nim and other most of the rivers are perennial with well defined courses. These are entirely the alluvial plain rivers originating from the depressions or lakes in Bhargava tracts (Kumar S.,1991).

It has been reported that the Bulandshahr area is suffering from waterlogging problem and drainage congestion. The drainage system of the district was earlier designed at 0.5 lit/ sec/ha capacity which was recommended to be modified to 1.1 lit/sec/ha in 1985 by drainage department of Bulandshahr district. This case study deals with the determination of land use pattern of the area using Remote Sensing Technique and calculation of required capacity of the drainage system using SCS model.

2.0 Methodology

2.1 Surface Drainage System

The natural development of stream systems provides surface drainage for most sloping land . Areas that need artificial surface drainage are either nearly level or depressional. Surface drainage is the orderly removal of excess water from the surface of land through improved natural channels or constructed ditches and through shaping of the land surface. Surface drainage systems, when properly planned, eliminate ponding, prevent prolonged saturation and accelerate flow to an outlet without siltation or erosion of soil.

Surplus surface water may originate from irrigation or from precipitation. The surplus water from irrigation is generally caused by outflow from the lower ends of furrows or irrigation borders. It is found, in most cases, that the quantities of irrigation return flow are small and not critical to the design of surface drainage channel. The minimum section of the drainage channel which can be conveniently excavated will generally prove to be greater than that required by the predicted rate of irrigation return flow. On the other hand the amount of surface water derived from precipitation which must be removed by a surface drainage system during the rainy season may be considerable, and therefore, critical in the design of surface drainage channel. Whenever rainfall intensity exceeds the infiltration rate of the soil, surplus water will collect on the ground surface. If the land is flat it will cause ponding. Some of the volume of ponded water will disappear without drainage after the rain stops because of continued infiltration and surface evaporation. The critical factor, therefore, is not the volume of water to be removed but the period of time which the crops can tolerate the ponding. Generally speaking, and for most crops, shallow ponding for up to 24 hr will not cause any serious damage. If the fields are flooded from high water in a nearby river or from surface runoff at the foot of a nearby slope or hill, the problem is completely different and must be handled as a flooding rather than a drainage problem.

Surface drainage system is comparatively simple to plan, design and construct and is usually rather inexpensive. All possible excess water from all sources should be removed before it percolates to the groundwater table to create or intensify a more expensive sub surface drainage problem. The various conditions which causes surface drainage problems are:

i) Uneven land surface with pockets or ridges which prevent or retard natural runoff. Slowly permeable soils magnify the problem.

ii) Low-capacity disposal channels within the area which remove water so slowly that the high water level in the channels causes ponding on the land for damaging period.

iii) Outlet conditions which hold the water surface above ground level such as tide water elevation.

The traditional drainage system on heavy clay soils is surface drainage. Soils also need surface drains under any of the following situations:

i) A hard pan or tight layer exists in the upper zone.
ii) The sub soil within a depth of 100 cm remains dry even after an extended rainy period.
iii) In tropical and subtropical area which receives high intense

rainfall and where the soil is heavy and slow permeable.

2.2 Indian Standard Code for Surface Drainage Design

The Indian Standard (IS: 8835- 1978) was adopted by the Indian Standards Institution on 21 June 1978, after the draft finalized by the Canals and Canal Linings Sectional Committee had been approved by the Civil Engineering Division Council.

Drains are constructed with the object of relieving excess water from agricultural and other areas and disposing of surplus water not required for normal agricultural operations. The proper disposal of surplus rain water is also essential to avoid its percolation down to the water table which may otherwise lead to rise in the water table thereby aggravating or creating the problem of waterlogging. The drains may be natural or artificial. As per accepted principles, these are generally aligned along the valley lines between ridges. However, in some cases in order to reduce the length of the drain or to have proper outfall conditions, the drains are taken across the valleys. These are known as forced or diversion reaches.

The Indian Standard Codelays down broad guidelines and principles for the planning and design of surface drains for uniform application throughout the country. This standard is applicable only for surface drains in agricultural/rural areas. This does not apply to the planning and design of drains in urban areas, for which the practices are entirely different.

2.2.1 Design Frequency of Rainfall

In fixing the design capacity of the drain the following factors have to be taken into account:

a) Economics - Drains of a bigger size or catering for a rainfall of infrequent occurrence prove to be costly compared to the benefits. Drains are never designed to cater for the worst conditions. In other words, in any drainage project, occurrence of damage at periodical intervals is to be accepted.

b) Performance - The experience indicates that drains of a bigger size tend to deteriorate fast, as these are not required to carry the design discharge frequently. Consequently in carrying smaller discharge, drains end to get silted soon. On the other hand, drains of a smaller size remain in a better condition and can occasionally carry higher discharges with marginal scour of bed and sides and encroachment on free board.

c) Land Requirement - On account of small land holdings, bigger drains involve larger land acquisition resulting in a permanent loss of the cultivated land.

d) Design Frequency - Generally the drains should be designed for three day rainfall of 5 year frequency. Studies carried out indicate that 5 year frequency gives optimum benefit cost ratio. However, in specific cases requiring a higher degree of protection, the frequency of 10 or 15 year can also be adopted. Adoption of such higher frequencies will need to be justified in terms of the economics.

2.3 Surface Runoff

Runoff is that portion of the precipitation that make its ways towards stream channel, lakes or ocean as surface or subsurface flow. The term runoff usually means surface or subsurface flow. The engineer designing channels and structures to handle natural surface flow is concerned with peak rates of runoff, with runoff volume and with temporal distribution of runoff rates and volumes.

Before runoff can occur, precipitation must satisfy the demands of evaporation, interception, infiltration, surface storage and surface detention. Rainfall will occur only when the rate of precipitation exceeds the rate at which water may infiltrate to the soil. After the infiltration rate is satisfied, water begins to fill the depressions, small and large on the soil surface. As the depressions are filled overland flow begins. The depth of water builds up on the surface until it is sufficient to result in runoff in equilibrium with the rate of precipitation less infiltration and interception. As the flow moves into defined channels there is a similar build up of water in a channel detention. The water in surface storage eventually goes into infiltration or is evaporated.

Runoff coefficient depends on the type of soil, crops, general topographical conditions like land slopes, etc. In plain areas, the runoff percentage is generally of the order of 15 to 20. In semi-hilly areas the percentage may be higher. Until precise data becomes available, the following run-off coefficients for different soils are recommended for plain areas:

a)	Loam, lightly cultivated or covered	0.40
b)	Loam, largely cultivated and suburbs with gardens, lawns, macademized roads	0.30
c)	Sandy soils, light growth	0.20
d)	Parks, lawns, meadows, gardens, cultivated area	0.05-0.20
e)	Plateaus lightly covered	0.70

f)	Clayey soils stiff and bare and clayey soils lightly covered	0.55

2.4 Rational Method for runoff estimation

In the design of hydraulic structures, sometimes total volume of runoff is required and sometimes peak rate of runoff is required. This method is used for the evaluation of peak runoff and is expressed by the following equation (Michael, 1981)

$$Q = C\ i\ A/36 \qquad \text{........(1)}$$

where

g = design peak runoff rate m3/sec

C = runoff coefficient

i = rainfall intensity cm/hour for the duration equal to time of concentration found from the intensity duration curves for a design frequency

A = watershed area in hectare

and Time of Concentration, Tc given by Kirpich formulae is

$$Tc = 0.0195\ L^{0.77}\ S^{-0.385} \qquad \text{.......(2)}$$

where

Tc = time of concentration in minutes

L = maximum length of flow in meters,

S = the watershed gradient in m/m or difference in the elevation between the outlet and the most remote point divided by the length, L.

If maximum 1 hr rainfall (p0) for an area for a given frquency is available then, discharge can be calculated using Rational formula as

$$Q = \frac{C\ p0}{36} * \left(\frac{2}{1 + Tc}\right) \qquad \ldots\ldots\ldots(3)$$

Application of the rational method is normally limited to watersheds of less than 800 ha (2000 Acres). The rational method is developed from the assumptions that (i) rainfall occurs at uniform intensity for a duration at least equal to the time of concentration of the watershed, and (ii) rainfall occurs at uniform intensity over the entire area of the watershed.

Table 1 Average Runoff Coefficients For Rural Areas

Topography and Vegetation	Soil Texture		
	Open Sandy Loam	Clay and Silt Loam	Tight Clay
Woodland			
Flat	0.10	0.30	0.40
Rolling	0.25	0.35	0.50
Hilly	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated Land			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70

Hilly	0.52	0.72	0.82

TABLE 2 Average Runoff Coefficients For Urban Areas: 5-Y And 10-Y Design Frequency

Description of Area	Runoff Coefficients
Business	
Downtown areas	0.70 to 0.95
Neighbourhood areas	0.50 to 0.70
Residential	
Single-family areas	0.30 to 0.50
Multiple units, detached	0.40 to 0.60
Multiple units, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment-dwelling areas	0.50 to 0.70
Industrial	
Light areas	0.50 to 0.80
Heavy areas	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.10 to 0.25
Railroad yard areas	0.20 to 0.40
Unimproved areas	0.10 to 0.30
Character of Surface	**Runoff Coefficients**
Streets	
Asphaltic	0.70 to 0.95
Concrete	0.80 to 0.95
Brick	0.70 to 0.85
Drivers and walks	0.70 to 0.85

Roofs	0.75 to 0.85
Lawns, sandy soil	
Flat (2 percent)	0.05 to 0.10
Average (2 to 7 percent)	0.10 to 0.15
Steep (7 percent)	0.15 to 0.20
Lawns, heavy soil	
Flat (2 percent)	0.13 to 0.17
Average (2 to 7 percent)	0.18 to 0.22
Steep (7 percent)	0.25 to 0.35

2.5 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.

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 SCS developed an index, which is called the runoff curve number (CN) to represent the combined hydrologic effect of soil, land use, agricultural land treatment class, hydrologic condition and antecedent soil moisture. The curve number, CN, issued for estimation of runoff from agricultural watershed. As the soil moisture changes, the corresponding curve number changes. AMC conditions has to be identified based on the previous 5 days of rainfall. Once the AMC condition is known,based on soil type and cropped grown in that area the runoff from agricultural watershed can be estimated.

2.6 Net Storm Runoff by the SCS Approach

By studying the infiltration behavior of different types of soils, the Soil Conservation Service has developed a method of computing the direct runoff resulting from a rainfall storm (U.S. SCS, 1972). The factors affecting infiltration are: hydrologic soil group, type of land cover, hydrologic condition and antecedent (prestorm) 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.

Table 3 Hydrological Soil Group

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

(U.S. Soil Conservation Service 1986)

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 rangelands are given in Table 5. 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. 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:

Table 4 AMC classes

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 have occurred in the last 5 days

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 5 gives curve numbers (CN) for antecedent moisture condition II. Table 6 provides conversion of CN to other conditions. For an area with many different subareas, the composite CN is determined by adding the product of CN and respective area and dividing by the total area.

The SCS runoff equation is

$$Q = \frac{(P - 0.2S)^2}{(P + 0.8S)} \qquad \text{..........(4)}$$

which is subject to the restriction that $P > 0.2S$ and is represented in Fig 2.

where,

Q = accumulated runoff, in, or mm depth over the drainage area

P = accumulated rainfall depth, in, or mm

S = potential maximum retention* of water by the soil, in or mm

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

$$CN = \frac{25400}{S+254} \qquad \text{.......(5)}$$

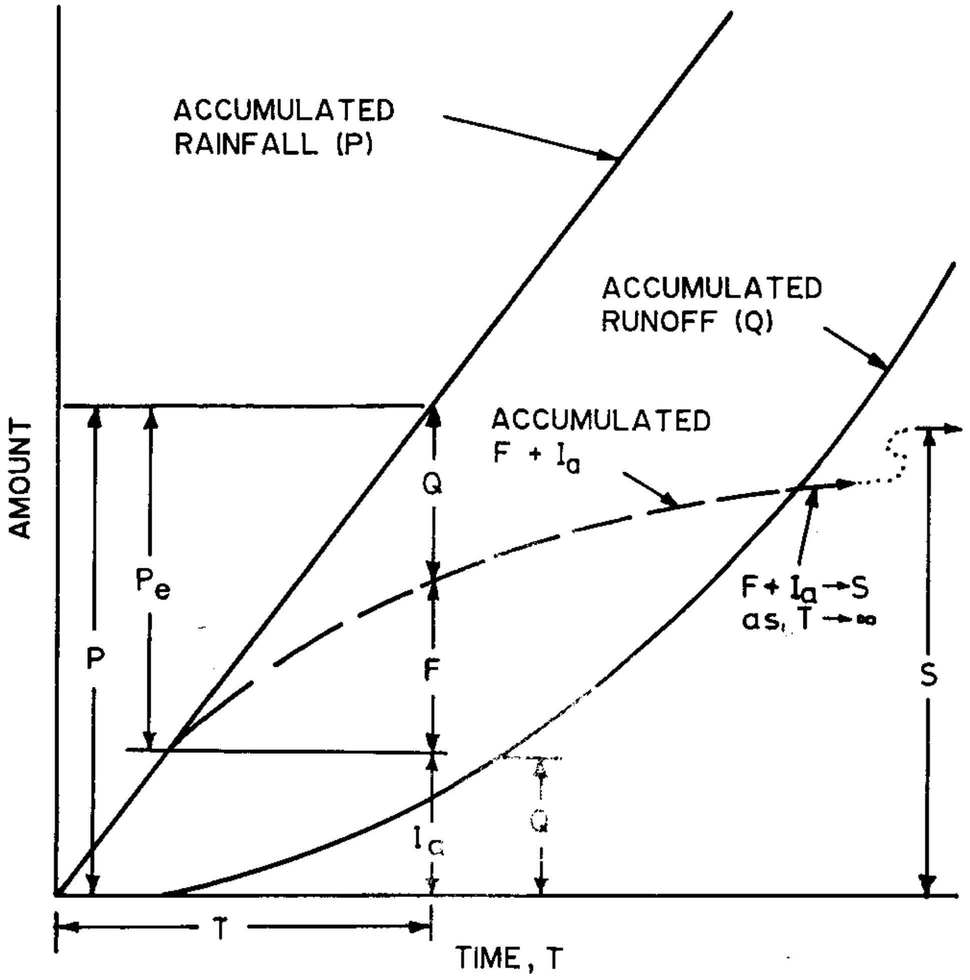

FIG. 2 SCHEMATIC CURVES OF ACCUMULATED RAINFALL (P), RUNOFF (Q), & INFILTRATION PLUS INITIAL ABSTRACTION

The design runoff (Q) in cm for the three day maximum rainfall (P) in cm can be calculated by combining equation no (4) and (5) and obtaining following relationship:

$$Q = \frac{R\,[CN(P/R + 2) - 200]}{CN[CN(P/R - 8) + 800]} \quad \ldots\ldots\ldots(6)$$

where, R = 2.54 and P > R [(200/CN) - 2] (Ponce, 1989)

Table 5 RUNOFF CURVE NUMBERS FOR CULTIVATED AGRICULTURAL LANDS

Cover Description			Curve Numbers for Hydrologic Soil Group			
Cover Type	Treatment2	Hydrologic Condition3	A	B	C	D
Fallow	Bare soil	-	77	86	91	94
	Crop residue cover	Poor	76	85	90	93
	(CR)	Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and terraced (C&T)	Poor	65	73	79	81

	C&T + CR	Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T + CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded	SR	Poor	66	77	85	89
or broadcast		Good	58	72	81	85
legumes or	C	Poor	64	75	83	85
rotation		Good	55	69	78	83
meadow	C&T	Poor	63	73	80	83
		Good	51	67	76	80

Table 6 CORRESPONDING RUNOFF CURVE NUMBERS FOR THREE AMC CONDITIONS

AMC II	AMC I	AMC III	AMC II	AMC I	AMC III
100	100	100	60	40	78
99	97	100	59	39	77
98	94	99	58	38	76
97	91	99	57	37	75
96	89	99	56	36	75

96	89	99	56	36	75
95	87	98	55	35	74
94	85	98	54	34	73
93	83	98	53	33	72
92	81	97	52	32	71
91	80	97	51	31	70
90	78	96	50	31	70
89	76	95	49	30	69
88	75	95	48	29	68
87	73	94	47	28	67
86	72	94	46	27	66
85	70	93	45	26	65
84	68	93	44	25	64
83	67	92	43	25	63
82	66	92	42	24	62
81	64	91	41	23	61
80	63	91	40	22	60
79	62	90	39	21	59
78	60	89	38	21	58
77	59	89	37	20	57
76	58	88	36	19	56
75	57	88	35	18	55
74	55	87	34	18	54
73	54	86	33	17	53
72	53	86	32	16	52
71	52	85	31	16	51
70	51	84	30	15	50
69	50	84			
68	48	83	25	12	43
67	47	82	20	9	37
66	46	82	15	6	30
65	45	81	10	4	22

64	44	80	5	2	13
63	43	79	0	0	0
62	42	78			
61	41	78			

2.7 Period of Disposal

The period of disposal of the excess rainfall is entirely dependent on the tolerance of individual crops. Crops like paddy can generally stand submersion for a period of 7 to 10 days without suffering any significant damage. Therefore, in paddy growing areas, the drainage should aim at disposing of the rain water in a period varying from 7 to 10 days. Based on experience the following periods of disposals are recommended:

Table 7 Tolerance of crop to ponding

a)	Paddy	7 to 10 days
b)	Maize, bajra and other similar crops	3 days
c)	Sugarcane and bananas	7 days
d)	Cotton	3 days
e)	Vegetables	1 day (in the case of vegetables, 24 hour rainfall will have to be drained in 24 hours)

2.8 Ground Water table analysis

The monthly ground water table data for the Bulandshahr district was provided by the ground water department UP, Roorkee Division Roorkee. The data of depth to water table from soil surface for pre monsoon and post monsoon and the reduced level of the ground surface was available. The ground water table data was analysed for the pre monsoon and post monsoon period for year 1971 to 1991 and depth to water table contours were plotted for year 1990 and 1991 post monsoon (Fig 3 and 4).

3.0 Result And Discussion

3.1 Blockwise groundwater table status

The block wise analysis of groundwater table data for pre monsoon and post monsoon period for year 1971 to 1991 is as below:

1. Anupshahar block: The groundwater table data of three wells located at Anupshahar, Ahar and Barauli is available from year 1971 to 1991. The watertable for premonsoon period of this block on an average varies between 7.15 m below ground level (bgl) to 12.92 m bgl and for post monsoon period from 5.96 m bgl to 12.78 m bgl.

2. Arniakhurd block: The groundwater table data of three wells located at Arniakhurd, Dashrakheri and Palrajhat is available. For premonsoon period the water table varried from 1.64 m bgl to 8.76 m bgl and for post monsoon from 0 m bgl to 730 m bgl. The post monsoon water level from 1975 to 1978 was below 1.5 m from groundsurface. But from 1978 onwards it is deeper than 2 m from soil surface except for year 1979 and 1983.

3. Bulandshahr block: The groundwater table data of two wells located at Bulandshahr and maman was available. The pre monsoon watertable of the block varied from 2 m bgl to 10.33 m bgl and the post monsoon water table from 0.1 m bgl to 7.98 m bgl. The groundwater table was below 1.5 m from ground surface in the well

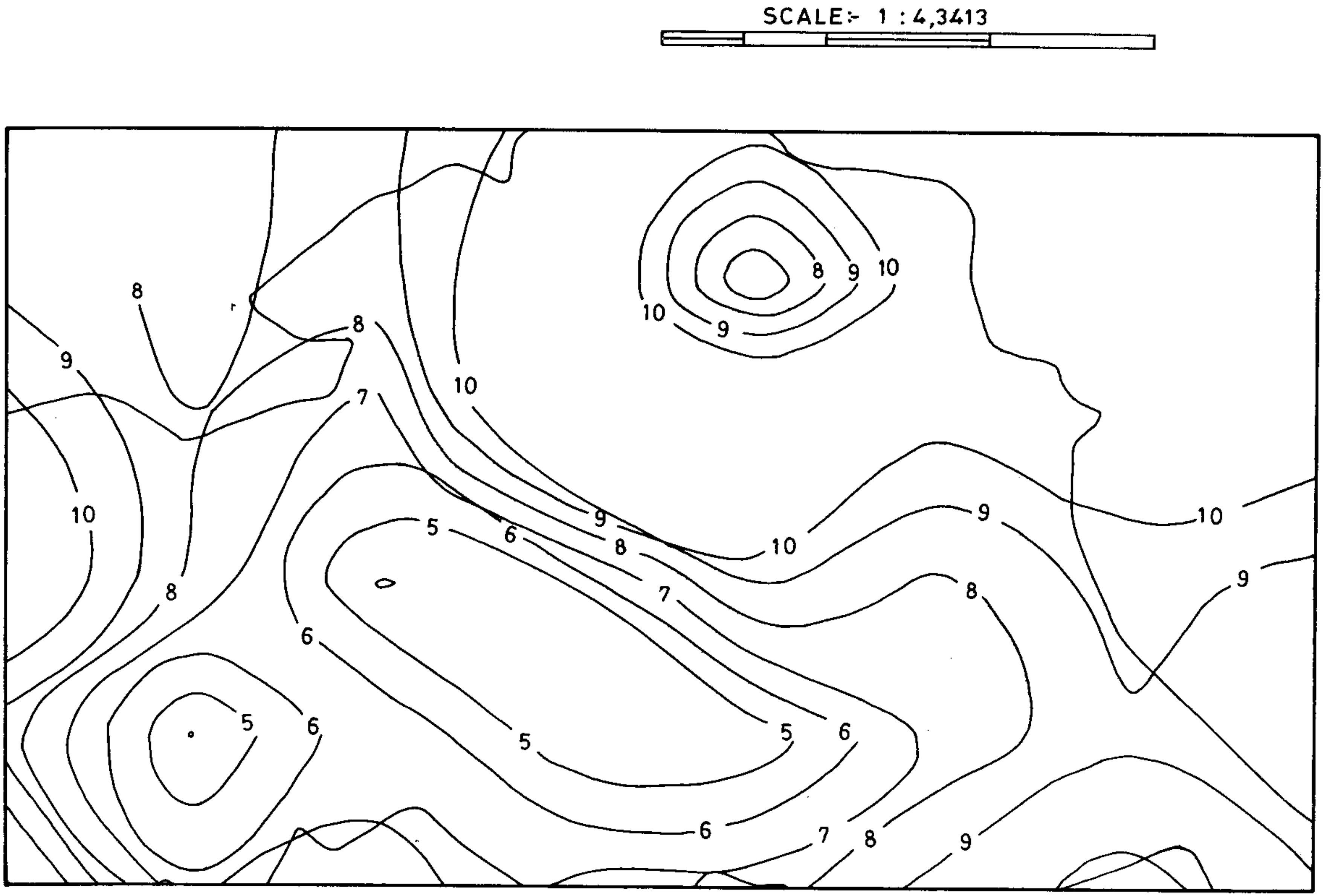

FIG. 3 DEPTH TO WATER TABLE CONTOUR MAP FOR POST-MONSOON 1990

SCALE :- 1 : 4.3413

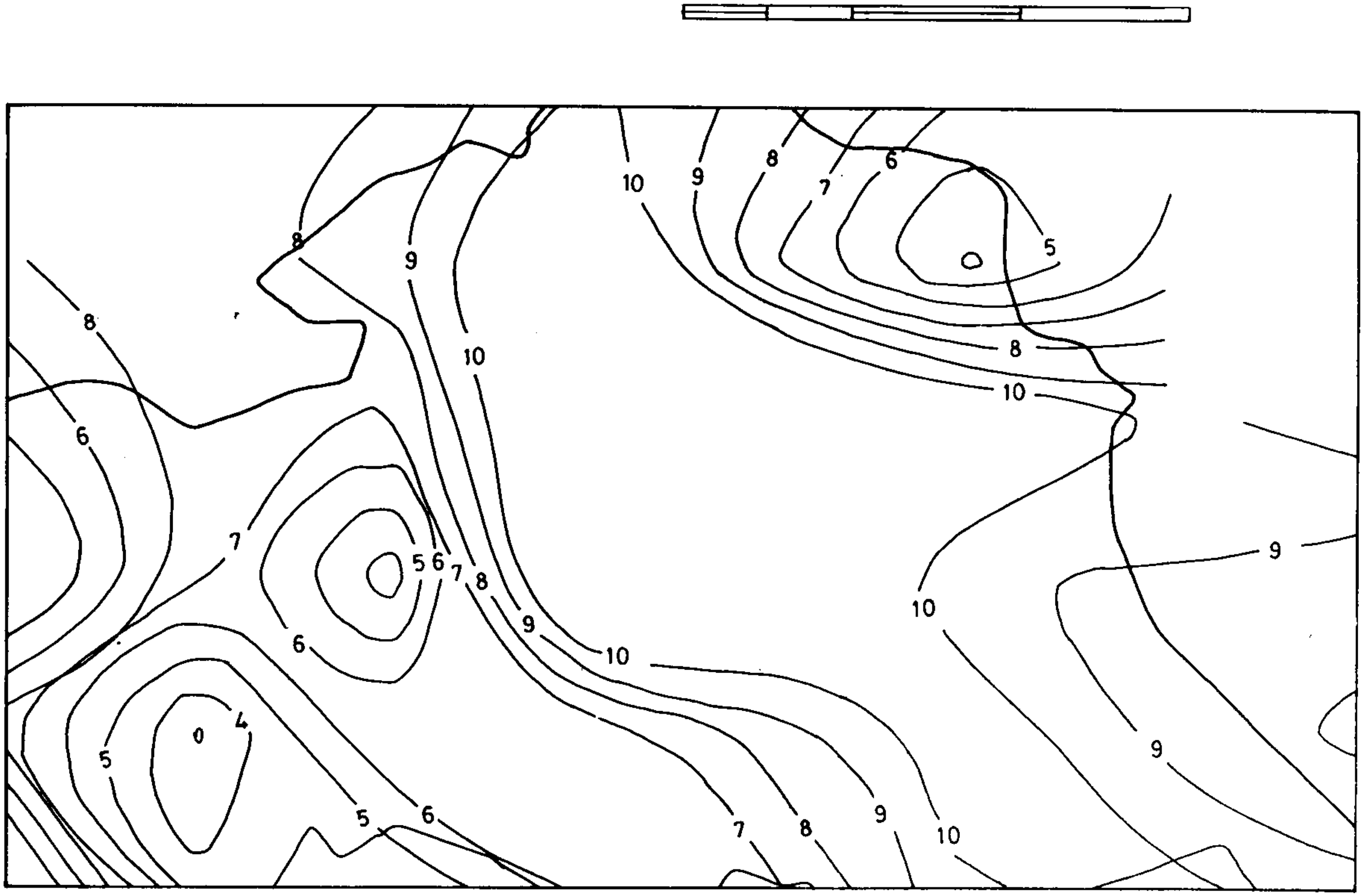

FIG. 4 DEPTH TO WATER TABLE CONTOUR MAP FOR POST-MONSOON 1991

located at maman for post monsoon period of 1976-1978 and in 1983.

4. B B Nagar: The groundwater table data for six wells located at Kucheshar, Nimchand, Sathla piyau, B B Nagar, Saielpur and Sherpur was available. The premonsoon watertable of the block varied from 5 m bgl to 15 m bgl and for post monsoon period from 2 m bgl to 14 m bgl.

5. Dibai: The groundwater table data of three wells located at Dibai, Rajghat and Ramghat was available. The water table for pre monsoon and post monsoon period varied from 6.5 m bgl to 12 m bgl and from 1.5 m bgl to 10 m bgl respectively.

6. Dankaur: The groundwater data of three wells located at Kakaud, kheri Hafizpur and Dankaur was available. The watertable for pre monsoon and post monsoon period varied from 5 m bgl to 13 m bgl and from 2 m bgl to 12 m bgl respectively.

7. Danpur: Five observation wells are located in Danpur block at Jiranli, Danpur, Nayabaskatubpur, Khudadia and Dharampur. The ground water table for premonsoon period varied from 4 m bgl to 12 m bgl and for post monsoon period from 2 m bgl to 11 m bgl.

8. Gulaothi: Ground water table observation wells are located at Gulaothi and Baral. The watertable in the block varied from 3 m bgl to 9 m bgl for pre monsoon period and for post monsoon period from 0.9 m bgl to 7.5 m bgl. Water level at Gulaothi was below 1.5 m for the year 1972, 73, 76 and 78.

9. Jahangirabad: The ground water table observation wells are located at Jadol, Jahangirabad, Palipartapur and Sakhni. The premonsoon water table varied from 3.4 m bgl to 15 m bgl and post monsoon from 1.7 m bgl to 13 m bgl.

10. Jewar: The ground water table in the block varied from 1.4 m bgl (1983) to 10 m bgl for premonsoon period and for post monsoon period from 0 m bgl to 9.5 m bgl. The observations were recorded at wells located at Jewar, Jhahangirpur, Jhajhar, Rabupura, Bankapur and Kishorepur. For the year 1977, 79 to 87 and 1988 post monsoon period the water table was below 1.5 m.

11. Khurja: In Khurja block the groundwater table observation wells are located at Khurja city and Khurja junction. The premonsoon ground water table of the block varies from 3.5 m bgl to 8 m bgl and post monsoon water table from 0.35 m bgl to 8.4 m bgl. The ground water table for the year 1976, 77, 78 indicates that watertable in the block was within 1.5 m bgl.

12. Lakhawti: Ground water table observation wells are located at Aurangabad Saiyed, Jewat, Pabsara, Lakhauti and Maharajpur Shiwali. The pre monsoon water table of the block varied from 6 m bgl to 15 m bgl and post monsoon water level from 4 m bgl to 15 m bgl.

13. Pahasu: The premonsoon watertable of the block varied from 2.5 m bgl to 12 m bgl and the post monsoon watertable from 0.2 m bgl to 11.67 m bgl. The observation wells are located at Ahamandgarh, Chhatari and Pahasu. The post monsoon waterlevel of Chhatari was below 1.5 m from ground surface for year 1976, 77, 78 and 1983.

14. Unchagaon: The ground water table observation wells are located at Unchagaon and Daulatpur. The premonsoon watertable of the block varies from 4.5 m bgl to 15 m bgl and post monsoon water level from 4 m bgl to 13 m bgl.

15. Siyana: The pre and post monsoon water level recorded at

two places namely Siyana and Shahanpur showed that water level varies from 3.5 m bgl to 10 m bgl and 1.3 m bgl to 9 m bgl respectively.

16. Sikandarabad: The observation of watertable in the block are recorded at Chandru, Chaula, Sikandarabad and Sawanta. The watertable varies from 2.92 m bgl to 9 m bgl in pre monsoon season and in post monsoon period the waterlevel varied from 0.65 m bgl to 9 m bgl. In the year 1977, 1978 the water level was below 1.5 m from ground surface.

17. Shikarpur: The premonsoon water level in the block varied from 7.3 m bgl to 13 m bgl and the post monsoon water level from 6 m bgl to 13 m bgl. The observations were recorded on wells located at Aurangabad, Khakhunda, Salempur and Sikarpur respectively.

The depth to watertable contours for post monsoon of 1990 and 1991 are given in Fig 3 and 4. From the figures it is quite clear that the water table in the district is fairly deep and there is no problem of waterlogging due to ground water table rise. This indicates that the waterlogging problem existing in the area is mainly due to surface ponding or water stagnation. This also indicates that salinity problem is not existing in the area and the white signature in the IRS imagery indicates the presence of carbonate only. In the earlier study carried out on estimation of soil hydrological properties of Bulandshahr, the soil samples were collected from various parts of the pilot area and were analysed in the laboratory. The chemical analysis of several of the samples showed that the soil of the area was containing carbonate (Shukla, 1992).

3.2 Estimation of design runoff

3.2.1 Using Rational Formula

The 1 hour maximum rainfall for a 5 year return period as given by Meteorological department of Government of India for Bulandshar area is 5.5 cm. The time of concentration for a channel of 35.5 km length and elevation difference of 20 m was calculated as 18.45 hours using equation (2). From equation (3) the peak discharge is calculated as 4.71 lit/sec/ha.

3.2.2 Using SCS method

3.2.2.1 The design rainfall

The daily rainfall data of last 49 years for Bulandshahr district was provided by the irrigation department, Madhya Ganga Division, Bulandshahr. The daily rainfall data for the last 49 years was analysed and the three day maximum rainfall for each year was obtained. This three day maximum rainfall was arranged in descending order as given in tab 8. The drainage system was designed for the return period of 5 years. Therefore from the available total number of records for the three day maximum rainfall of the area the design rainfall was calculated as below:

Tab 8 Three day maximum raifall

Years (Y)	PPT (mm)	Rank (b)	b= $\frac{\overline{Y}}{RI}$
197.5	554	1	
199.1	425	2	
1963	395	3	
1964	280	4	
1945	234	5	
1951	219	6	
1946	212.5	7	
1969	205	8	
1955	197.5	9	
1989	186	10	
1944	175	11	
1961	170	12	
1971	169	13	
1954	167.5	14	
1957			
1949	165	15	
1976	164	16	
1958	163.5	17	
1956	155	18	
1967,78 & 86	150	19	
1985 &90	132	20	

Y	PPT (mm)	b	b= $\frac{Y}{RI}$
1977	134	21	
1960	127.5	22	
1959			
1972	124	23	
1973	12.2	24	
1948	115	26	
1953	114.5	27	
1952	114	28	
1968	111	29	
1965	108.5	30	
1984	108	31	
1979	106	32	
1947 & 80	105	33	
1966	100	34	
1983	99	35	
1950	92.5	36	
1970	91	37	
1962	90	38	
1981	83	39	
1992	75	40	
1982	61	41	
1987	36	42	
1974	22	43	

Total number of records of three
day maximum rainfall of area (Y) ....= 43
The return period (RI) ....= 5

Therefore,

design rainfall = Y/RI =43/5 = 8.6 = 8th severest storm

from table 7 the eighth severe most storm for the three day maximum rainfall is 205 mm. Hence the design rainfall for the area is 205 mm or 20.5 cm.

3.2.2.2 Antecedent Moisture Condition

The three day maximum rainfall selected as design rainfall was 205 mm. This rainfall has occurred in the month of August 1969 on 6th, 7th and 8th. Therefore total five day antecedent moisture condition of the area is that 28 mm of rainfall has fallen in the last 5 days i.e. from 1st to 5th april 1969. The table 8 given below indicates that if total 5 day antecedent rainfall is more than 0.5 inches or 1.27 mm and less than 1.1 inches or 27.5 mm than AMC II condition prevails in the area. Therefore, in the study area AMC II condition is prevailing.

Table 8 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

3.2.2.3 Determination of Curve Number for the area

Bulandshahr is an ungauged catchment and has only nonrecording type rain gauges. The daily rainfall data of last 49 years was collected. Based upon the 5 year return period the design rainfall was selected. The land use pattern of the area was determined from the FCC of IRS Liss II path and row 28 and 48 A1 B1 dated 7 may 1989 of Bulandshahr district. The white signature on the FCC was selected to represent the carbonate affected area (Fig 5), the blackish blue signature was selected to represent urban area or city or village, the red signature was selected to represent the cropped area and the blue signature was selected to represent the water bodies. The residential area and the area having grass cover and forest was also varified using toposheets representing the Bulandshaha district. Based upon the analysis of FCC following land use and the corresponding CN for AMC class II was obtained (Ponce,1989).

Table 10 CN and land use pattern of study area

S No.	Type of land use	Area in sq. km	Hydrologic soil group	CN
1.	Agriculture	3808.0	A	67
2.	Carbonate in field	182.0	D	94
3.	Tree grass forest	60.0	A	39
4.	Urban Residential	200.0	A	77

Table 11 Composite curve number for the area

S No.	Type of land use	Area in sq. km	CN	Weighted CN
1.	Agriculture	3808.0	67	
2.	Carbonate in field	182.0	94	
3.	Tree, grass			69

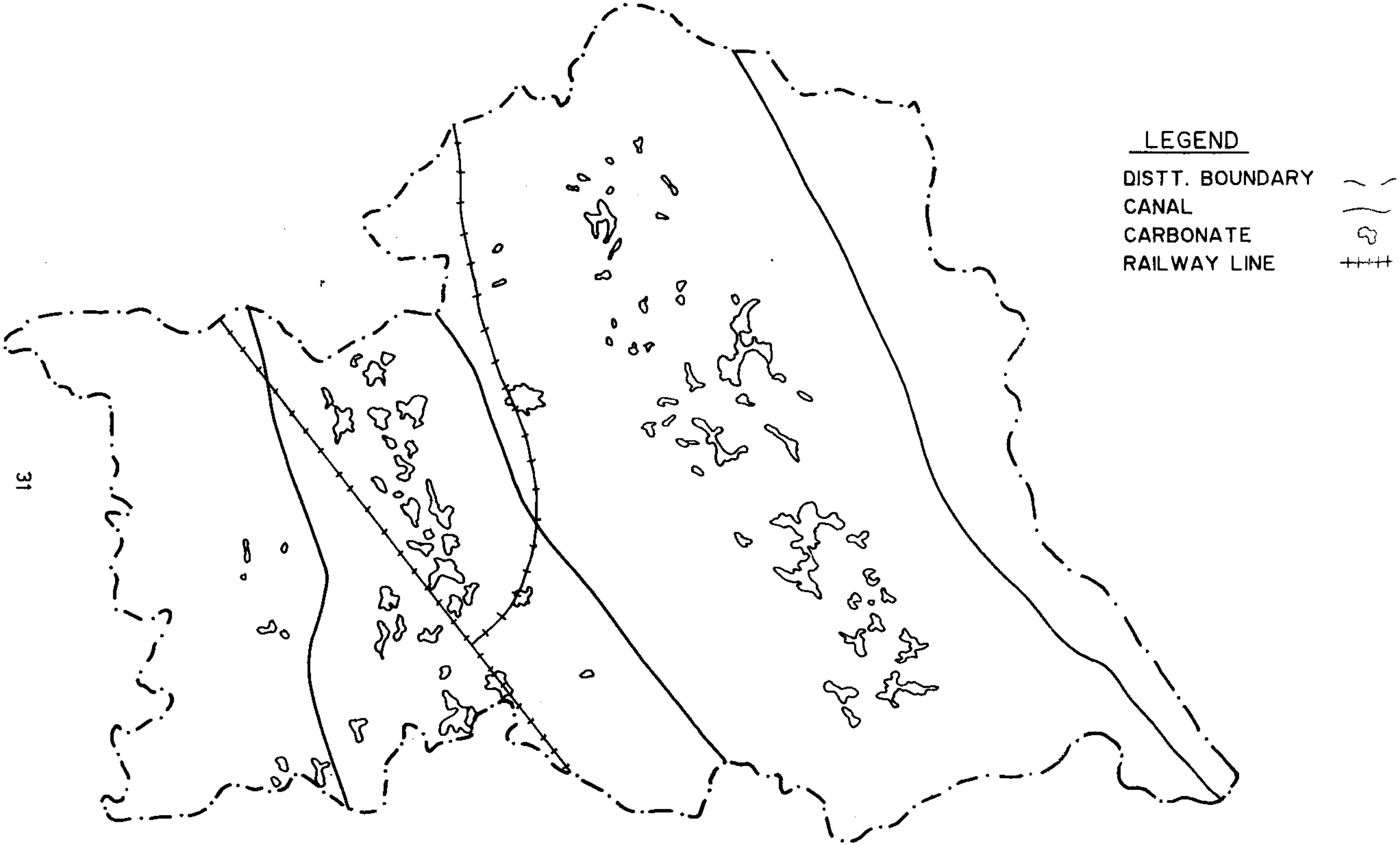

FIG. 5 MAP SHOWING THE LOCATION OF CARBONATE AFFECTED SOIL

	Forest	60.0	39
4.	Urban		
	Residential	200.0	77

$$\text{The weighted CN} = \frac{3808*67 + 182*91 + 60*39 + 200*77}{4250}$$

= 68 [illegible] 69

Since AMC II soil moisture condition was prevailing in the area. The corresponding curve number was 69 as calculated above. Using equation no (5) the potential maximum retention (s) was calculated as 114 mm. From equation no. (6) the total depth of runoff resulting from a three day maximum design raifall of 205 mm and potential maximum retention of 114 mm was calculated as 112.1 mm or 11.2 cm.

3.2.2.4 Cropping pattern and tolerance of crops to ponding

The cropping pattern of the district is such that Sugarcane and wheat is grown extensively. Out of these two Sugarcane is perhaps the main crop in Kharif. The tolerance of sugarcane to ponding in the field is seven days and the tolerece of wheat to ponding is of 3 days (Tab 7)(Drainage manual).

3.2.2.5 The design discharge

The total runoff depth resulting from the design rainfall of 205 mm for the study area was calculated as 11.2 cm. If kharif season is selected for the design of drainage system than tolerence to ponding of kharif crop i.e. sugarcane is 7 days. Therefore, in order to remove 11.2 cm depth of runoff that is resulting from an area of 4250 sq. km in seven days or 1.6 cm of runoff per day resulting from the same area, the discharge capacity at the outlet of the drain should be equal to 1.86 lit/sec/ha.

If we consider the wheat crop that is grown in Rabi season. The tolerance to ponding of wheat crop is of three days. Hence, from an area of 4250 sq. km the runoff depth of 3.7 cm should be removed daily. Hence, the design capacity of the drain at the outlet should be 4.28 lit/sec/ha.

The analysis of last 49 years of daily rainfall data of the Bulandshahr district indicated that most of the severe rainstorms in Bulandshahr occurred in the monsoon months. Therefore, it will be adequate to design the drainage system for the kharif crop i.e. the sugarcane. Hence, an outlet discharge capacity of 1.86 lit/sec/ha will be sufficient as well as economically viable to carry the discharge resulting from the design raifall within the safe limit of disposal of the crops.

4.0 Conclusions

Study area Bulandshahr is suffering from the problem of surface waterlogging or water stagnation. It is mainly due to the flat topography of the area. The carbonate present in the soil at certain locations is acting as a cementing material by way of reducing the ground water recharge and accelerating the runoff. Moreover, the existing drains in the area are not adequately designed (0.5 lit/sec/ha), as a result water gets stagnated in the fields causing severe damage to crops. The peak discharge rate calculated by rational formula is 4.71 lit/sec/ha . As has been reported by various researchers that it is not necessary and even undesired to design the agriculture draiange system for the peak discharges. Therefore, the existing surface drainage system should be redesigned for a discharge capacity of 1.86 lit/sec/ha as been obtained by SCS procedure.

References

Drainage manual (1992). National Institute of Hydrology Roorkee.

Garg S.K. (1987). Hydrology and Water Resources Engineering Publication, Delhi

Gupta R.S. (1989). Hydrology and hydraulic systems, Prentice Hall, Englewood Cliffs, New Jersey.

Indian Standard Code (1978). Guidelines for planning and design of surface drains (IS:8835-1978).

Kumar S. (1991). A Holocene Soil Chronoassociation and neotectonics in the Western Gangetic Plains, India, unpublished Ph.D. Thesis Department of Earth science, Univ. of Roorkee, 1991.

Michael A.M. and T.P. Ojha (1981). Principles of Agricultural Engineering.

Ponce V. M. (1989). Engineering Hydrology principle and practices. Prentice Hall, Englewood, New Jersey, p155.

Seth, S.M. (1990). Laboratory analysis of soil samples from Kolar sub basin of river Narmada.. TR-82, National Institute of Hydrology.

Shukla M.K. et.al.(1993). Estimation of soil hydrological properties for design of drainage system for Bulandshahr area - A case study. A National Institute of Hydrology Publication (CS-94).

Shukla M.K. et.al.(1993). Estimation of soil hydrological properties for design of drainage system for Bulandshahr area - A case study. A National Institute of Hydrology Publication (CS-94).

STUDY GROUP

Director	**S. M. Seth**
Technical Coordinator and Head	**G. C. Mishra**
Scientific Staff	**M. K. Shukla** **Hukam Singh**
Documentation Staff	**Kiran Ahuja**